Training Manual for

Certified Livestock Advisor on Poultry

28 Dec 2021 -11 Jan, 2022

ICAR-Directorate of Poultry Research

Rajendranagar, Hyderabad-500030, Telangana, India
ISO 9001: 2015
http://pdonpoultry.org/pdpnew/

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(An autonomous organization of ministry of Agriculture & Farmers Welfare, Govt. Of India), Rajendranagar, Hyderabad-50030, Telangana, India
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Editors: Dr. Shyam Sundar Paul, Dr. S Jayakumar and Dr. N Balasubramani

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R.N. Chatterjee, U. Rajkmaur and S .V. Rama Rao

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INTORDUCTION

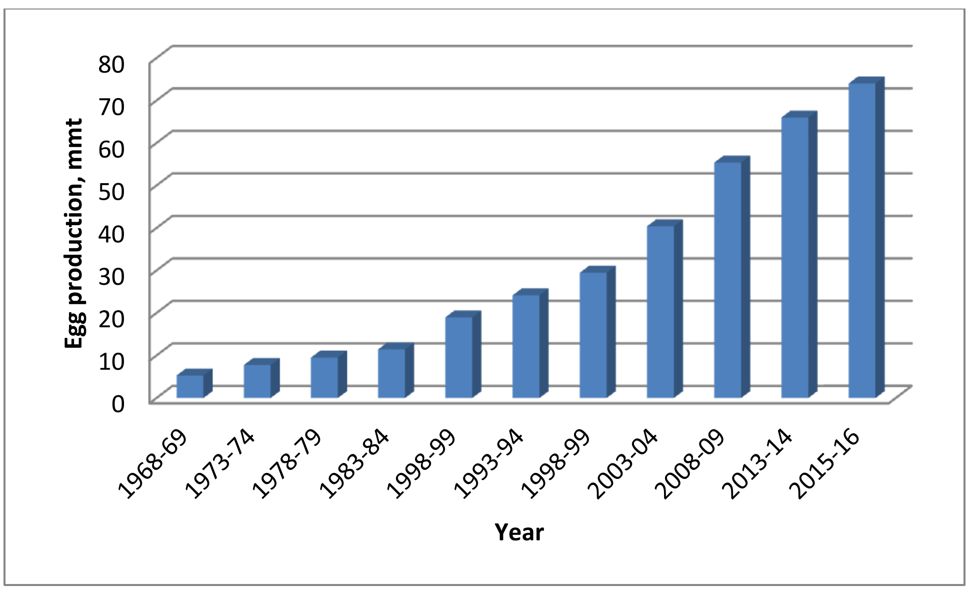
Poultry is one of the fastest growing segments of the agricultural sector in India with around eight percent growth rate per annum. The poultry sector in India has undergone a paradigm shift in structure and operation which has been its transformation from a mere backyard activity into a major commercial agri based industry over a period of four decades. The constant efforts in upgradation, modification and application of new technologies paved the way for the multifold and multifaceted growth in poultry and allied sectors. The development is not only in size but also in productivity, sophistication and quality. Development of high yielding layer (310-340 eggs) and broiler (2.4-2.6 kg at 6 wks) varieties together with standardized package of practices on nutrition, housing, management and disease control have contributed to spectacular growth rates in egg (4-6% per annum) and broiler production (8-10% per annum) in India during the last 40 years. The annual per capita availability also increased to 60 eggs and 2.5 Kg of meat, consistently with increase in productivity. However, it is far below the recommended level of consumption of 180 eggs and 10.8 kg poultry meat per person per annum by Indian Council Medical Research. This transformation has involved sizeable expansions and investments in breeding, hatching, rearing and processing. India is one of the few countries in the world that has put into place a sustained Specific Pathogen Free (SPF) egg production project.

The growth of the poultry sector in India is also marked by an increase in the size of the poultry farm. In earlier years broiler farms had produced on average a few hundred birds (200-500 chicks) per cycle. Today units with fewer than 5,000 birds are becoming rare, and units with 5,000 to 50,000 birds per week cycle are common. Similarly, in layer farms, units with a flock size of 10,000 to 50,000 birds have become common. Small units are probably finding themselves at a disadvantage because of high feed and transport costs, expensive vaccines, and veterinary care services and the non-availability of credit. Some small units are reported to be shifting from layer to broiler production because output in broiler units can be realized in six weeks.

The structure of India's poultry industry varies from region to region. While independent and relatively small-scale producers account for the bulk of production, integrated large-scale producers account for a growing share of output in some regions. Integrators include large regional firms that incorporate all aspects of production, including the raising of grandparent and parent flocks, rearing DOCs, contracting production, compounding feed, providing veterinary services, and wholesaling. The southern region account for about 57 percent of the country's egg production, the eastern and central regions of India account for about 17 percent, The northern and western regions contribute 26 percent of egg production

Current Scenario

India ranks 3rd in egg production and 7th in chicken meat production in the world (Watt Executive Guide, 2015). About 3.4 million tons (74 billion) of eggs are produced from 260 million layers and 3.8 million tons of poultry meat is produced from 3000 million broilers per annum in India. The Poultry Industry is contributing about Rs. 70,000/- crores to the national GDP and providing employment to more than 3 million people either directly or indirectly. About 2-2.5 million tons of poultry litter, a valuable organic fertilizer, is produced as a by-product every year. The poultry industry is concentrated in certain pockets of the country. The State of Andhra Pradesh and Telanagana leads the country followed by West Bengal, Maharashtra, Tamil Nadu and Punjab.



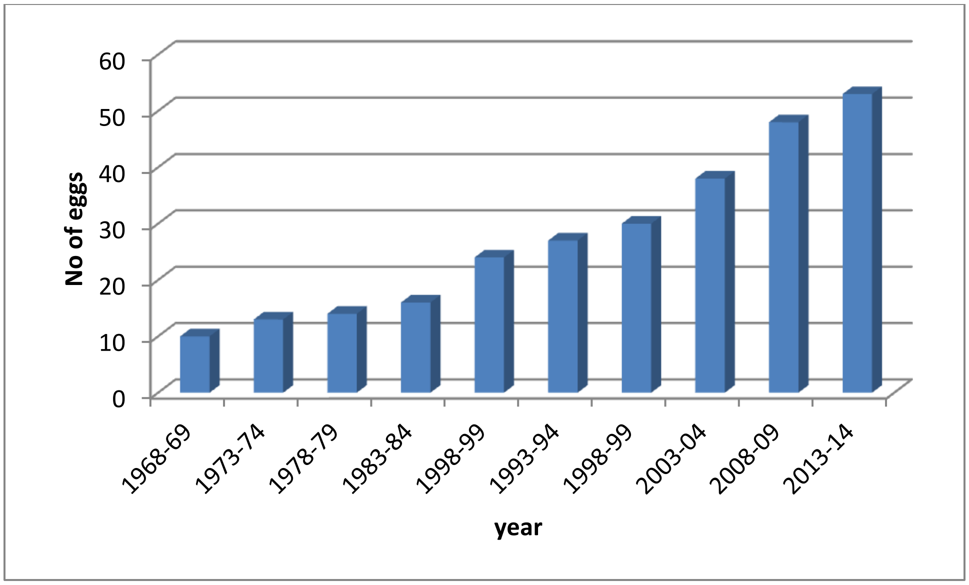
(Source: DAHD, 2014)

Fig 1 . Trends in egg production over last 6 decades

The popularity of poultry meat is on the rise during the last two decades. It is presently accounting for about 45% of the total meat consumed and is the most popular meat from any single livestock species.

Chicken dominates the poultry production in India with nearly 95% of the total egg production and the rest is contributed by ducks and others. Majority of ducks are found in certain states on the eastern and southern coast like West Bengal, Assam, Kerala, Andhra Pradesh, Tamil Nadu etc. Other species like turkeys, guinea fowls, ostriches, emus etc. are reared only in small numbers in areas having specific market demand. India is the home for many breeds of native chicken like Aseel, Kadak Nath, Miri, Nicobari, Kalahasthi etc., which are still popular among the rural and tribal areas for back yard/ free range farming. For the commercial farming, high yielding crosses developed and supplied by the private sector like Babcock, Bovans (egg type) and Cobb, Ross, Hubbard (meat type) are being used. The crosses developed under the public sector like Krishilayer, Krishibro (multicolored broiler etc.) are popular in certain areas.

Availability of eggs is highly non-uniform in different parts of the country primarily due to wide variation in the production levels. Much of the eggs produced are consumed by the urban population while the rural and tribal areas have little access to the eggs and meat produced from the industrial sources and the availability is very low. In spite of rapid growth, the poultry industry suffered many setbacks in recent times due to rising cost of feed, emergence of new or reemerging of existing diseases, fluctuating market price of egg and broilers, etc. which need to be addressed to make the poultry sector as a sustainable enterprise.



(Source: DAHD, 2014)

Fig. 2. Per capita availability of eggs in India

Poultry production systems

The rapid expansion of poultry production has been associated with technological change and increasing scale of production units. More specifically, the development has involved a switch in emphasis from traditional small-scale production using dual-purpose indigenous breeds to intensive commercial production systems using hybrid birds specially bred either for meat or for egg production. The introduction of improved, exotic, genetic material is an important first step in the growth and development of the commercial poultry sector. Generally, the new strains are less hardy and less resistant to endemic diseases than indigenous birds. The greater productive potential cannot be attained without complementary inputs of specially compounded concentrate feeds, and improved housing, management, and veterinary care. Nonetheless, the introduction of new genetic material is the foundation on which other technological improvements are added.

FAO classified poultry production systems in to four categories based on the volume of operation and level of biosecurity. The four categories are better described as “sectors” than as “systems”, as increasing commercialization is associated with increased segmentation of different stages in the value chain from input supply through to retail delivery of the product

(Upton, 2007). Although formal biosecurity may be higher in industrial/commercial systems, the greater bird population density may increase the probability of infection and the scale of disease outbreaks that occur in these concentrated production systems (FAO, 2007). Increasing concentration of production is also associated with problems of waste disposal and soil, air and water pollution (FAO, 2006). Within each sector there is a great deal of variation between individual types of production system and value chains, so further discussion is needed.

Village or backyard production

The most basic and simple backyard production system involving a few hens and a cockerel is essentially a closed system. Home-produced fertile eggs are hatched to provide replacements, birds feed by scavenging or are provided with household scraps and crop by-products; there are virtually no veterinary inputs and the remaining eggs and meat produced are consumed within the household. Such very simple subsistence poultry production systems are probably quite rare. Producers with even slightly larger flocks, generate cash income from the sale of eggs and birds within the local community. Transactions may take place directly between producers and consumers, but traders and other market intermediaries may be involved, selling on to other sectors of the poultry industry. Village or backyard production systems are widely distributed and exist in both rural and urban areas. In most countries, the majority of producers fall into this category, but with development of the industry a growing proportion of both meat and egg production is derived from the commercial sectors. It is estimated that today in India, only 15 percent of total poultry output is derived from "backyard" production (Landes *et al.*, 2004). In areas that are less densely populated by poultry, "backyard" systems are likely to contribute a larger proportion of total poultry production. In the village or backyard sector, production is generally based on traditional local, native breeds, producing both eggs and birds for meat. None the less, village or backyard production can make a useful contribution to dietary protein intake and incomes of resource poor households (Acamovic *et al.*, 2005, Rajkumar et al., 2010). Furthermore, given the lower opportunity costs5 of resources and the higher market prices offered for local poultry, backyard systems are likely to yield a positive economic return, despite increasing competition from the commercial sectors.

Commercial poultry production with low biosecurity

This sector is based on commercial production, but it retains some characteristics of the traditional, backyard systems, particularly in selling live birds in wet markets or directly to retail shops. Production units are generally intermediate in scale between backyard systems of up to 200 birds and commercial systems of over 10000 birds. Levels of biosecurity are low, in that birds are often not permanently housed, mixed flocks of chickens and waterfowl may be kept, birds are generally marketed live, and a range of different markets, un-monitored for health risks, are used for produce sales and input supplies (Upton 2007). The flocks are generally reared either for broiler meat production or for egg production. Feed is generally purchased either as premixed rations or as raw materials for home milling and mixing.

In India, the smaller independent commercial producers are of regional importance in the north and east of the country, where integrated contract production has not become established. Market limitations arise in countries, like India, where there is a marked consumer preference for live birds, rather than dressed, chilled or frozen carcasses. In India, it is suggested that relatively small-scale producers are at a disadvantage in facing high feed and transport costs, limited access to vaccines and veterinary services, and shortage of credit (Upton, 2007)

Large-scale commercial with high biosecurity

This sector consists of the generally larger-scale (over 10000 bird) commercial flocks of broilers, layers or breeding birds. Only relatively wealthy individuals or commercial joint-stock companies have the necessary investment funds or can raise sufficient credit for these larger-scale investments. Biosecurity levels are defined as high, as birds are continuously housed, strictly preventing contact with other flocks or with wildlife. Despite this, many outbreaks of HPAI appear to have started in large-scale commercial flocks. Inputs are generally supplied and products marketed through formal market agencies. The production and marketing process is clearly segmented and separate value chains for broilers and layers can be clearly identified. Production of day-old chicks, broiler growing, processing and retail distribution of the final product is the responsibility of separate commercial enterprises. They are all “stakeholders” in the value chain, adding value to the product at each stage.

The scale and intensity of production is substantially higher in the commercial and industrial sectors than in backyard systems. Advantages are derived from economies of scale, providing scope for specialization and division of labour between the different stages in the production process, leading to automation of operations and labour-cost savings. These advantages add to those derived from the use of highly productive commercial hybrid chicks and improved technologies such as the evaporative cooling or air-conditioning of poultry houses. The need for vertical coordination of all stages in the production chain, particularly in the regular supply of chicks and the transfer of birds to slaughter or markets when ready, leads to concentration of commercial poultry production in particular areas of the country. The four southern states, where poultry densities and flock sizes are high, together contribute 57 percent of the nation's egg production (FAO, 2007).

Industrial and integrated production

This sector consists of the largest and most industrialized enterprises in the poultry industry. The various stages in the value chain are vertically integrated into a single industrial company. The broiler or layer components are either fully integrated as part of the parent company, or are separate production units operating under contract to the parent company, it has been assumed that although the whole process, from chick breeding and hatching through to distribution and retailing is integrated in a single organization, feed milling remains as a separate business enterprise. In many instances, the feed and poultry production activities are integrated, together with "horizontal" links to other sectors. In other cases, vertical integration is partial – from breeder down to broiler grower, or from market distributor up to broiler producer. Vertical integration yields financial benefits by reducing the operational costs at different stages of the value chain. In non-integrated poultry systems, transaction costs are likely to be high because of: first, the frequency and regularity of transactions resulting from the cyclical nature of poultry production; second, the risks of disease and market price fluctuations; and third, the investment in very specific types of assets, or "asset specificity", involved in poultry production, processing and marketing (Williamson and Masten, 1995; Dorward *et al.*, 1998). In these circumstances, the vertical integration of the different stages of the breeding, production, processing and marketing of poultry produce is a rational economic response, which should increase efficiency and reduce unit costs. In India, substantial numbers of integrated poultry production companies have been established, particularly in the four southern states and in western India around Mumbai (Landes *et al.*, 2004).

The introduction of improved, exotic, genetic material is an important first step in the growth and development of the commercial poultry sector. Generally, the new strains are less hardy and less resistant to endemic diseases than indigenous birds. The greater productive potential cannot be attained without complementary inputs of specially compounded concentrate feeds, and improved housing, management, and veterinary care. Nonetheless, the introduction of new genetic material is the foundation on which other technological improvements are added. The dynamic changes and trends in poultry are presented in Table 1 and 2 (Kotaiah, 2016)

Table 1. Trends in layer industry

Sl No	Parameter	1990	2015
1	Layers (crores)	10	24
2	Average layer farm size		
3	Eggs per hen	260	310
4	Separate brooding (%)	10	80
5	Feed automation (%)	10	80
6	Feed Price (Rs) per Kg	12	22
7	Egg price (Rs)	1.5	2.9
8	Eggs cleaning and packing	No	Important

(Source: Poultry Fortune, 2016)

Table 2. Trends in broiler industry (Source: Poultry Fortune)

Sl No	Parameter	1990	2015
1	Broiler parents housed (crores)	0.7	3.5
2	Broilers placements per month	5	25
3	FCR	2.2	1.6
4	Feed Price per Kg (Rs)	20	30
5	Body weight (kg) 42 days	1.5	2.5
6	Broiler Price / Kg live(Rs)	25	65
7	Broiler integration	0	60

8	Slaughter age	48	38
9	Processing (%)	1	7
10	Antibiotics	Nil	50

(Source: Poultry Fortune, 2016)

Feed Resources

Success on poultry production rests primarily on the quality of the bird employed, comforting environment and provision for good feed, the last being most expensive of all other inputs, deserves befitting attention. Feed accounts for 65-70% of broiler and 75-80% of layer production cost. Maize is the popular cereal used in combination with protein meal like soybean meal which generally determines the cost of compounded feed. Production of maize increased from 9.65 million tons in 1989-90 to only 24.4 million tons in 2015. Similarly, soybean meal production increased to 11.35 million ton in 2015 from 3.52 million tons in 1999-2000. Average increase in maize availability has been 3.8% per annum which is far below the growth rate of egg or meat production. Thus, there is a need to increase the production of maize and soybean or explores the usefulness of other alternate energy and protein rich feedstuffs to maize and soybean meal, respectively, in poultry diets.

In view of the large gap between the demand and availability of feedstuffs for poultry production, a holistic approach is needed to meet the demand of ever growing poultry industry. Some of the approaches in these respects are

- **Identification of newer feed resources-** Since the production of cereals and oil seeds may not increase significantly, the availability of grain and oil seed meal to feed industry is expected to decrease. This would lead to escalation in the cost of feed ingredients and consequently the cost of eggs and meat. To some extent such a situation can be corrected by developing strains that need less feed input. However, alternate feed ingredients that are not related to human consumption and available in plenty should be identified and their suitability should be tested.
- **Utilization of structural carbohydrates and phytate phosphorus-** With the advancement of technology, the reduction in dependency of poultry on the storage plant carbohydrate, protein or other nutrient and to allow them to make greater use of structural carbohydrates and other nutrients to meet the requirement of highly genetic potential stocks. Hence the dimension from research should change from as such providing feed

than technologies that utilize feed better. There are many components of feed such as B-glucans, pentosans, mannans, cellulose,lignin and phytic acid which can not be digested by poultry. These non digestible feed ingredients frequently generate digestive stress in poultry with a consequent reduction in nutrient utilization and wet litter problems. These problems could be largely alleviated by use of feed enzymes.

- **Overcoming limitations of Agro-industrial byproducts and unconventional feed stuff-** The influence of agro-industrial byproducts and unconventional feed ingredients on the performance of industrial commercial layers and broilers needs to be established before they are incorporated into feeds on regular basis. It is also essential to identify suitable easily adoptable and economically viable methodology to inactivate anti-nutritional factors and enhance the nutrient availability. The nutritive value of a variety of maize and soybean meal replacers has been examined and despite their potential, the utilization in practical formulations is negligible due to constraints imposed by several anti-nutritional, technical and socio-economic factors. These constraints need to be resolved by the feed industry utilizing the services of scientists, planners and policy makers.
- **Processing of feeds and their impact on nutritional improvement-**Commercial poultry diets normally involve the admixture of a number of different feed ingredients. Processing is related to the treatment of materials during or immediately following and mixture with the purpose of providing a balanced diet suitable for consumption of poultry. Many incriminating factors of feed are also destroyed due to processing. The loss of nutrient through excreta and the cost of production can be minimized through processing of feed. This process generally involves some degree of grindings of the material which improves uniformity of admixture provides particles of a size perceived to be suited to the target group and may make nutrients more available for digestion in the birds. Subsequently the feed may be subjected to heat treatment or pelleting. The production of crumbles and pellet feeds, especially for broilers are in increasing trend. Steam pelleting and extrusion is much more effective to reduce microbial contamination in feedstuffs.

Disease management

Management of diseases in poultry plays an important role for the progress of the industry. Birds in the commercial farms are reared in open sided houses and maintained under optimum management conditions. Birds are reared under veterinary supervision. Vaccination is regularly practiced to protect the bird against diseases. In spite of all the measures, the poultry industry in India suffered a major setback last year due to the outbreak of Avian Influenza. The industry suffered serious trade losses following downfall in consumption of poultry meat and eggs for about 6 months.

To minimize the occurrence of disease in poultry the three most important components of disease control are Bio-security, Vaccination and Medication. Bio-security refers to all measures taken to secure prevention of all types of pathogens in poultry farms. Effective bio-security and implementation of successful hygienic procedures are increasingly dependent on Hazard Analysis Critical Control Point approach (HACCP). The principles of HACCP such as hazard analysis, critical control points, critical limits, correction, recording and verification should be strictly followed for analyzing risk assessment and risk management. Vaccination should be practiced regularly following the regulatory procedures.

Priorities for effective disease management in making the poultry industry a sustainable enterprise are

- Trans-boundary disease – Many of the diseases which are not endemic to India (Avian influenza, VVMD) may enter through germplasm and biologicals. This need strict quarantine measures.
- Establishing and strengthening surveillance and monitoring system – The surveillance and monitoring system should be carried out in established laboratories. There is need to establish a National Avian Disease Laboratory with all modern facilities for surveillance and monitoring of infectious disease in poultry.
- Diagnoses through genomic approach – Efforts may be made to develop new diagnostics and biological using genomic approaches for rapid and accurate diagnosis and effective control of poultry disease.

Food safety

There is a worldwide concern to minimize the use of antibiotics in poultry because of disease resistance and antibiotics residues in food chain. In such case suitable alternatives need to be explored, which could be beneficial and cost effective. Many products of such nature like Probiotics, Gut acidifiers, immunomodulators, etc. are available in the market, but need further research. Ensuring safe food is paramount for the protection of human health and for enhancement of the quality of life. Safe food plays an important role, whether domestically produced and consumed, imported or exported. In addition, the production of safe food represents an opportunity for income generation and market access. Over the last decades, the food chain approach has been recognized as an important step forward to ensure food safety from production up to consumption. This approach requires the commitment of all players in the food chain, involving producers, traders, processors, distributors, competent authorities as well as consumers.

The role of animal feed in the production of safe food is also recognized worldwide, and several events have underlined its impacts on public health, feed and food trade, and food security. Concerns prompted by the outbreak of bovine spongiform encephalopathy (BSE), and other more common food problems associated with Salmonella, enterohaemorrhagic Escherichia coli and other contaminants, have encouraged professionals and the feed industry to scrutinize more closely the causes of these diseases and methods for their control. Measures may require limiting the use of some ingredients or radically changing the way in which they are prepared (processed) or sourced. In some cases the locations where animals are grazed need to be restricted. FAO therefore provides current knowledge on animal feed and its impact on food safety, and orientation and advice on this matter.

Marketing

Though, commercial production of eggs and chicken meat on scientific principles has been well standardized, marketing of eggs and broiler meat are not fully organized except few in urban sectors. Eggs are still transported in open condition and in un-refrigerated vehicles. Eggs are sold as commodity in India and purchased by consumers mostly from shop next door for daily needs. Eggs are channeled through wholesale dealers, sub-dealers, retailers etc. in two to three stages, which raises the cost of eggs by 10-15% over the actual sale price at producer’s place. Broilers are sold live or slaughtered at the place of sale. Sometimes the birds are dressed and displayed for sale in the open air without any concern for hygiene. Similarly eggs are sold in open without consideration for preservation of their quality. Seasonal variations in consumption and demand of eggs and meat pose greatest challenge to the stabilization of prices. The fluctuations at times go to the extent of up to 30-40% in a short period of 3-4 weeks. Thus, there is a need to strengthen the marketing system. Some of the approaches in this direction are

- Development of reliable and stable market chain round the year for marketing of poultry products.
- Facilities for hygienic slaughter and preservation of eggs should be made available at market places in both urban and rural areas.
- Formation of producer co-operatives/ Associations and Rural market yards will help in proper marketing.
- National Egg Coordination Committee, a farmers' cooperative agency has been contributing to the improvement in marketing of eggs. However, more systematized marketing strategy and the State's involvement in minimizing the channels are required for making poultry farming remunerative and cost effective in the years to come.
- Because of the location of farms in urban and peri -urban areas that too concentrated in few states, availability of eggs and chicken meat are high in these areas only, but in rural areas and rest of the country the availability is low. Thus, there is a vast scope to tap the rural markets and remote areas of the country where availability is low.

Processing and exports

Trading of chicken in India is primarily done in number and not by weight at the wholesale level. Live and fresh dressed broilers account for the bulk of sales and sale of processed meat is limited (below 5%). However, acceptance of processed chicken is on the rise, particularly in the urban markets. Due to pollution and environmental concerns, slaughtering of birds under unhygienic conditions at open places is being discouraged. Thus, the sale of slaughtered chicken is expected to increase. Hence, there is a need to develop processing facilities. Hence, there is an urgent need of many chicken processing plants in the near future and sale of processed chicken to increase both to cater domestic as well as export markets.

A few plants for processing eggs have been installed using state of the art machinery in some states with an average daily turnover capacity of 0.7-0.8 million eggs. Whole egg powder, yolk powder, egg weight powder, lysozyme etc. are being produced under high standards of operation. Egg powder from India is well accepted in EU, Japan and Far-east. However, to tap the international market there is a need to establish many more egg processing plants. It has been told that India is geographically ideally located to cater to the middle East and far eastern countries for shell eggs. Therefore vast scope exists to increase the export of shell eggs from India to these countries.

Exports of poultry produce are very low, about 700 crores per annum and the trade is very small in global market (Shukla and Nayak, 2015). At present mainly table eggs (UAE, Kuwait and Oman), hatching eggs (UAE, Oman and Kuwait) and egg powder (Japan, Poland, Belgium and UAE) are exported from India. Our major markets Middle East and Asia. Egg powder is exported to Japan and EU. India has infra structure to export eggs including all primary packaging mechanism and cold chain to deliver top quality produce to customers.

Poultry Production in rural areas

India has nearly 70% of its population living in rural areas. However, in the present scenario most of the commercial poultry production is concentrated in urban and peri - urban areas. Just 25% population living in urban areas consumes about 75-80 % of eggs and poultry meat. Non-availability of poultry products and low purchasing power of the rural people devoid them of access to the highly nutritious products like egg and meat, thereby, resulting in malnutrition. Free range and small scale semi-commercial back-yard poultry production can be advantageously promoted in rural areas, as the large commercial poultry production continues to be concentrated in urban and peri - urban locations. It can be used as a powerful tool for alleviation of rural poverty, eradication of malnutrition and creation of gainful employment in vast rural areas (Sharma and Chatterjee, 2009; Rajkumar *et al.*, 2010).

Adopting small scale poultry farming in backyards of rural households will enhance the nutritional and economic conditions of these people. A new avenue for poultry exports is also opening up as a result of the growing worldwide trend towards the consumption of eggs and meat from birds reared under free-range conditions. The enormous contributions from the public sectors resulted in development of many chicken varieties suitable for backyard/ rural poultry farming. Directorate of Poultry Research, Hyderabad under the aegis of Indian Council of Agricultural Research has developed promising crosses namely Vanaraja, Gramapriya, Srinidhi etc. Vanaraja and Srinidhi are dual purpose birds, while Gramapriya is having good egg production potential. Apart from this agricultural/veterinary universities also developed rural chicken varieties such as Giriraja, Rajasri, Gramalaxmi, Krishna J, etc. for backyard poultry. Some private firms also developed promising varieties like Kruoiler and Rainbrow roster for rural poultry and are being propagated extensively eastern parts of India The attractive multicolor feather pattern, adaptability under diversified conditions and production potential in backyards made these birds quite popular in almost all parts of this country.

Organic poultry production

Consumer awareness is growing in terms of organic food products in recent years as almost all the food ingredients are grown under intense production systems which utilize lot of chemicals and pesticides to control the pests and diseases. Organic farming can be defined as an approach to agriculture where the aim is to create integrated, humane, environmentally and economically sustainable agricultural production systems producing acceptable levels of crop, livestock and human nutrition, protection from pests and diseases, and an appropriate return to the human and other resources employed (Lampkin, 1997). Maximum reliance is placed on locally or farm-derived, renewable resources and the management of self-regulating ecological and biological processes and interactions. The usage of chemical and other external inputs are reduced as far as possible. Organic agriculture is known as ecological agriculture, reflecting this reliance on ecosystem management rather than external inputs. In India free range farming is considered to be organic if birds are reared without any medication and other feed compounds. Some of the important aspects of organic poultry are as follows

- Management of livestock as land-based systems (i.e. excluding feedlots and intensively-housed pig and poultry units) so that stock numbers are related to the carrying capacity of the land and not inflated by reliance on 'purchased' hectares from outside the farm system, thus avoiding the potential for nutrient concentration, excess manure production and pollution;
- Reliance on farm- or locally-derived renewable resources, such as biologically fixed atmospheric nitrogen and home grown livestock feeds, thereby reducing the need for non-renewable resources as direct inputs or for transport.
- Maintenance of health through preventive management and good husbandry in preference to preventive treatment, thereby reducing the potential for the development of resistance to therapeutic medicines as well as contamination of workers, food products and the environment.
- Housing systems which allow natural behaviour patterns to be used and give high priority to animal welfare considerations, with the emphasis on free-range systems for poultry.

Value addition in Poultry

Value addition in poultry plays in important role in increasing the profits. The value addition may be through nutritional manipulations, processing and transgenesis. Omega enriched eggs and meats are available in the market for premium price developed by nutritional approaches. Feeding the chicks with rich sources of omega fatty acids will aid in increasing the levels of omega 3 fatty acids in eggs and meat of the birds. The second one is through biotecnologcal approaches where in the gene responsible for specific trait will be transgressed leading to transgenesis. However, this approach is still in primitive stage where in research is being carried out. The commonly utilized method for value addition is processing of the poultry products. By value addition low valued meats and by products can processed in to a highly nutritious finished products adding to the returns.

Welfare concerns in Poultry

Welfare of poultry has become an important issue in recent days since EU banned cage rearing of birds. Animal welfare activists increasingly argue that rearing of these high producing and rapid growing birds in intensive system of rearing resulted in some of the welfare and health issues which were not apparent in slow growing extensively reared birds. Animal welfare activists allege that the welfare of birds reared particularly in conventional cages (CC) is compromised. The space provided in CC is not sufficient for birds to do normal activities such as to stand, lie down, and turn around without touching each other and sides of the enclosure (Chatterjee and Haunshi, 2015). The birds kept in CC do not have sufficient space to express their natural or highly motivated and comfort behaviours. Highly motivated or internally driven and comfort behaviours in laying hens are nesting behaviour, preening, dust bathing, wing flapping, wing stretching, foraging, pecking, etc. Wing flapping is often referred to as "comfort" (stretching) behaviour, Wing flapping requires more space than wing stretching (one wing stretched downward) and wing raising(slight elevation of both wings). All these behaviours are not seen in birds kept in CC cages.

Broilers are reared mostly on floor in open sided houses for a short period of time i.e. up to 6 weeks of age. Hence, welfare issues in broiler production are entirely different. Genetic selection for higher body weight over the last 50 years resulted in increase in growth rate by over 300% from 25 g per day to 100 g per day (Nicol 2013). This phenomenal increase in growth rate of broilers resulted in emergence of metabolic disorders such as ascites and sudden death syndrome (Bessei, 2006). Other welfare problems are leg disorders and lameness in the fast growing broilers and hunger in the broiler breeders (Weeks and Butterworth, 2004). Extreme hunger in broiler breeders due to feed restriction to prevent accumulation of fat and in-turn affecting the egg production is considered to be one of the welfare concerns in broiler breeders. Incidence of contact dermatitis (Pododermititis) that includes hock burns, breast blisters and foot pad lesions is considered to be another welfare issue.

Policy makers should consider both positive and negative aspects of the problem before making a decision on the issue related to cages. A layer bird producing 330 eggs in a conventional cage and a broiler growing at rapid rate (2.5 kg in 42 days) is itself is very good example that the birds quite comfortable. One cannot imaging a spectacular productivity from birds if the birds are under stress or uncomfortable.

Constraints

Issues relating to animal welfare and environmental pollution by poultry units have been of increasing concern in developed countries such as the U.S. and the European Union (E.U.). Considering globalization and the international trade in poultry products, however, these issues may assume significance in a few years because of pressures from importing countries such as those in the E.U.

- A major constraint affecting the growth of the poultry industry in India is the lack of basic infrastructure such as storage and transportation, including cold chain. As a result, there are wild price fluctuations in the prices of poultry products, i.e., eggs and broilers.
- An inefficient marketing system. The presence of so many market intermediaries harms both the producer and the consumer.
- The price and availability of feed resources. Maize or corn plays a major role in broiler production, as it constitutes 50 to 55 percent of broiler feed. As the broiler industry is growing at the rate of 15 percent per annum, the demand for maize is thus likely to increase. Presently India grows only 11 million tonnes of maize and only 5 million tonnes are available for poultry, which is not sufficient if the current growth rate of the industry is to be maintained.
- Emerging and re-emerging diseases of poultry. Mutations in viral genomes leading to new variants in viruses and developing resistance to vaccines and antibiotics. Avian Influenza outbreaks occurring in parts of India is a very good example.

The policy measures that are required to improve the poultry industry must involve: (a) improving infrastructure facilities, which will help not only to stabilize the price of poultry products in the domestic market, but will also make them available in remote areas; (b) creating an efficient marketing channel that will help provide remunerative prices to producers (in other words, India's marketing set-up should also grow along professional lines); and (c) increasing maize production, which will involve using GM (genetically modified) seed varieties or, alternatively, will necessitate finding other sources of feed ingredients that can replace maize.

Conclusions

The poultry production in India continues to exhibit spectacular growth inspite of several challenges encountered over the years. With increasing demand for chicken egg and meat, the poultry production in India foresees further expansion and industrialization. Adoption of small scale poultry farming in backyards of rural households will enhance the nutritional and economic status of the rural people. With the advent of knowledge in different fields of poultry, the future challenges will not be a hindrance and thus sees a bright future for poultry production in this country.

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Feeds and feeding of layer and broiler chickens and least cost diet computations

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Proper feeding of poultry is very critical for realizing the full genetic potential of birds and making the farming successful. Several nutrients are critical for development of the chick into a well performing broiler or layer. Nutrition and feeding of birds during all the phases of life, therefore is of great significance. Further, feed accounts for a greater proportion (over 65-70%) of the total cost of production making it imperative to understand the role of nutrients present in feed and the tips of feeding management.

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Nutrients in feed

Energy and protein (amino acids) are two major nutrient components of poultry feed. Energy is required to maintain all biological activities (movement, walking, heartbeat, respiration, panting, etc.), vital processes (consumption, digestion, absorption, transportation, etc.) and chemical reactions occurring in the body for synthesis of proteins, fats, glycogen, eggs, organic molecules, etc (Mandal *et al.*, 2004). Energy concentration in the diet or its requirement is expressed either as calorie (cal) or joule. One kilocalorie (kcal) is equivalent to 4.184 kilojoules (kj), alternatively one kj is equivalent to 0.239 kcal. Energy requirements are expressed in terms of Metabolizable Energy.

The other important nutrient is protein, which plays an important role in body structural functions, muscle contraction, transportation of nutrients and oxygen, regulating acid-base balance, catalyst in chemical reactions (enzymes), immuno-competence (antibodies), chemical regulation (hormones), blood clotting, dim light vision, growth and production. Poultry birds require all the 20 amino acids for protein synthesis and other biological functions. Essential amino acids are those that are not synthesized in the animal body at a rate required for normal growth and other production functions, hence must be supplied through diet. These are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tyrosine and valine. In addition, glycine and proline are also essential for broilers. The limiting amino acids are those essential amino acids which are usually deficient in diet. Methionine is the first limiting AA in broilers on conventional corn-soya-based diets. Threonine is the third limiting AA for broilers and first limiting AA in starting egg-type pullets. Formulating diets based on digestible amino acid values is also used, which permits higher dietary inclusion of cheaper, alternative protein sources and decrease nitrogen excretion by the bird.

Minerals are dietary essential for their vital functions like structural components of body, maintain acid-base balance, catalysts in enzyme and hormone functions, immunomodulators etc. Vitamins are organic compounds normally required in minute quantities and are essential for their role in metabolism. Each of these vitamins has a definite role in the chicken bio-system, some of which are vision, reproduction, cell integrity, immunity, bone and egg calcification, hatchability, anti-oxidant effect, blood clotting etc.

Feed ingredients

The available feed resources, natural or synthetic, are classified as energy supplements, protein supplements, mineral supplements and vitamin supplements. Energy feedstuffs, constituting about 60-70% of the poultry feed, play an important role in cost effective feed formulation and providing bulk. They are divided into high energy and low energy supplements. Maize, wheat, broken rice, sorghum, fats and oils are high energy supplements. Pearl millet, finger millet and other small millets, rice polish or bran, de-oiled rice bran, wheat bran, molasses, tapioca flour, etc. are low energy supplements. Maize is the commonly used energy feedstuff in poultry feed but other ingredients, if available at cheaper rate, can be used to replace it partially or even completely.

Protein supplements are divided into vegetable and animal protein supplements. The former group includes cakes and meals of different seeds like groundnut, soybean, rapeseed, mustard, cottonseed, sunflower, safflower, sesame and cluster bean. Roasted full-fat soybean meal is also very good source of protein and fat, especially for broilers. Maize gluten, rice gluten, dried distillery grains with soluble (DDGS) etc. are also very good sources of protein. Animal protein supplements include fish meal, meat-cum-bone meal, meat meal, blood meal and poultry byproduct meal. These supplements, especially meat-cum-bone meal, meat meal and fish meal provide better quality protein than the blood meal. But caution is needed to procure good quality protein meals and utilizing them following their safe inclusion level. Synthetic amino acid supplements (L-lysine hydrochloride, DL-methionine, L-threonine, L-tryptophan) are also available in the market.

Minerals are supplemented either through a ready-made mineral mixture or through specific mineral supplements. Mineral mixture is available commercially or can be compounded. Specific mineral supplements are also added. In this case, calcium carbonate/oyster shell/ cheap marble are used as sources of calcium, and dicalcium phosphate or monocalcium phosphate as source of calcium and available phosphorus. Common salt is added as source of sodium and chlorine. Trace minerals (Cu, Zn, Fe, Mn, Se, I and sometimes Cr) are added in the form of premix (trace mineral premix). Organic sources of trace minerals are available commercially, which may have better bioavailability.

Vitamins are supplemented either through premixes or through individual vitamins. Two types of vitamin premixes are available in the market. One premix supplies vitamins A, D_3, and K and riboflavin (B_2). The inclusion rate is 5.0 to 15 g /q depending upon concentration. The other premix supplies water-soluble vitamins including members of B-complex, vitamin E and sometimes vitamin C. The rate of inclusion is 7.5-25 g/q of feed depending upon concentration of different vitamins. In addition, choline chloride (100, 60 or 50% premix) is also available in the market.

Feed Additives

Besides nutrients, present day's poultry are also fed several other compounds aimed at preventing/minimizing the infectious agents' loads, preventing mycotoxins, augmenting nutrient digestibility etc. Probiotics (live bacterial and yeast strains) and certain non-digestive feed components (prebiotics) like galacto-oligo-saccharides, fructo-oligo-saccharides, and mannanoligo-saccharides are used to combat colonization of pathogens (*Salmonella* spp., *Escherichia coli, Vibrio cholera, S. typhimurium, S. enteridis* etc.). Enzymes for improving nutrient utilization have become very popular in the nutrition of monogastrics like chickens. Non-starch polysaccharidases such as cellulases, pectinases, hemicellulases, arabinoxylanases and beta glucanases are used for releasing nutrients trapped in high fibrous diets. Supplementation of diet with microbial phytase increases availability of phytate-bound phosphorus, calcium, zinc, copper, crude protein and amino acids.

Addition of suitable coccidiostat in diets protects growing poultry birds (below 12 weeks of age) from coccidiosis. Similarly, use of different toxin binders or adsorbents (activated charcoal, bentonites, zeolites, diatomaceous earth, mannanoligo-saccharides, live yeast, etc.) reduce the adverse effects of mycotoxins. Oflate other compounds viz., essential oils, antioxidants, liver tonics, immunostimulants etc. have also become a regular component of poultry feed.

Nutrient Requirements

The requirements of chickens have been optimized and published (NRC, 1994, BIS 1992 etc.). Use of NRC standards under Indian conditions may not be appropriate as the requirements differ due to several factors such as management practices, genetic makeup, environmental temperature, metabolic and behavioral characteristics, feedstuff qualities and dietary variables. The available requirements are very old and present day’s poultry are fed mostly based on company’s recommendations. Very recently ICAR has come out with the latest nutrient requirements for poultry (ICAR, 2013).

Daily requirements for different nutrients during pre-starter (0-10/14d), starter (11/15-21/28d) and finisher (22/29-42d) periods of broiler as a function of metabolic body size and daily body weight gain are given in different equations. The requirement of other amino acids can be calculated as proportion of Lys requirement, i.e. for Arg 110-114, Ile 73, Leu 109, Val 82, Phe 65, His 32 and Trp 18%. Requirement of digestible amino acid is calculated based on the digestibility coefficients, i.e. for Lys 0.90, Met 0.90, Thr 0.84, Arg 00.92, Ile 0.88 Leu 0.93, Val

0.87, Phe 0.89, His 0.88 and Trp 0.91%. The regression values and practical experiences in commercial practice are the basis for prescribing the nutrient requirements during pre-starter phase.

Layer type replacement pullets are generally reared in three phases viz. starter (0-8 weeks of age), grower (8-20 weeks of age) and layer (20 weeks or above). For meeting the nutrient requirement, particularly that of calcium at onset of lay, pre-lay phase (17/18 – 20 weeks) is recommended. Similarly, the laying phase is often divided into phase I (20-40 weeks) and phase II (>40 weeks).

On an average one laying hen showing 90% egg production requires 16-18g of protein and 285 to 290 kcal ME per day. Meeting calcium requirement is important during overall growth (0.9 to 0.7%), but most crucial during laying phase. Just prior to initiation of egg production, huge amount of calcium is stored in bones, which is sufficient for 6 to 30 eggs. Therefore, calcium concentration is increased to about 2% of diet a week before onset of egg production. White Leghorn hens producing 90% eggs require daily about 3.8 to 4.2 g of calcium.

Feed Formulation

Feed formulation is a mathematical calculation to prepare a balanced ration. Though it is an art, but use of skill and scientific knowledge on nutrition principles, dietary variables, nutrient and dietary interactions, etc. make the formulation effective to exploit maximum performance. Birds are maintained at a low cost without exerting much stress. The important points considered during feed formulation are requirement of nutrients for poultry or composition of a formula in terms of nutrients, analytical nutrient composition of various feed ingredients, maximum effective/ safe levels of inclusion of feed ingredients, availability, wholesomeness and cost of feed ingredients.

Requirement of nutrients: Based on the nutritional research studies, the essential nutrients (energy, protein, amino acids, minerals and vitamins) required for different classes of birds have been given. Though a big list of nutrients is available, the attributes that need consideration are metabolizable energy, protein and amino acids (lysine, methionine, methionine + cysteine, threonine, arginine, phenylalanine), calcium, available P, electrolyte balance (sodium, potassium, chlorine), zinc, manganese, iron, copper, selenium, vitamin A, vitamin D3, vitamin E, riboflavin and other water soluble vitamins.

Feed composition values: The most efficient way to furnish nutrients to the birds is to analyze the feed ingredients for various nutrients. However, under practical conditions it becomes difficult to analyze all the ingredients for desirable nutrients, though it is a must to ensure feed quality. The average nutrient content of the feed ingredients based on the analyses done previously is available in the form of published feed composition tables. These can be used very cautiously using knowledge on nutrition.

Maximum level of inclusion of feed ingredients: There is a need to utilize locally available feed ingredients in the least cost efficient feed mix. However, most of the feedstuffs in their native state harbour one or more of the anti-nutritive substance(s). Inclusion of an ingredient beyond its maximum level may induce imbalance of nutrients, and reduce the palatability of the diet and performance of the birds. Birds are rendered ill due to the presence of anti-nutritional factors beyond tolerance level.

Availability and cost of feed ingredients: The knowledge on the availability and cost of feed ingredients in the local market is a prerequisite for formulating feed. The quality and cost of feed ingredients vary widely, and need consideration. The cost of ingredients based on nutrient density (energy and protein) should get priority over mere cost of ingredients when choosing the ingredients for formulation.

Methods of feed formulation

Algebric equation : is used commonly when two mixtures are to be combined for arriving at required nutrient concentration. Popular example is with the cereal and protein concentrates.

Pearson square : A simple procedure originally devised to blend milk products to a known fat percentage, and can be used for diet formulation too.

Hit and trial method : This has been the traditional way of feed formulation and still widely used by professionals. The amount of feed ingredients is changed so as to arrive at required nutrient levels in the feed. For this, the ingredients are arbitrarily altered and the nutrient concentration is calculated, which is continued till the desired nutrient level is achieved. The computer applications like MS Excel can be effectively used for quickly formulating the feeds using this method.

Least cost formulation : Is a feed formula that is both nutritionally-complete (within limits) and with a minimum ingredient cost (within limits). It is now-a-days developed and completed through the use of computers using linear-programming software. There are numerous computer software developed on the linear programming for formulating least cost rations, which are widely used by most feed mills/manufacturers. Some of the popular software include Ecomix, Winfeed, Myfeed, FeedMu, Feedsoft, Autofeed, Optimix etc.

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Unconventional feed resources for chicken

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Introduction

Feed constitute 70-75% of production cost in organized poultry farming. High growth rate of egg (5-7% per annum) and broiler (8-10%) production in India is contributing to increase in price of traditional feed ingredients like maize, soyabean meal, meat meal, fish meal, DCP, etc. due to burgeoning demand supply gap. Therefore, lots of research efforts have been made in identifying alternate feed resources during last two decades. Most of the alternate feed resources contain some anti-nutritional factor or are low in available nutrients causing reduction in nutrient density in diet or may induce imbalance in level of certain nutrients in ration if used beyond a level and hence their safe level of inclusion including their processing need, if any, are being assessed by nutrition researchers. A wide range of alternative feedstuffs are available for feeding in all three poultry production systems. The scope for efficiently utilizing these feedstuffs will be more in traditional family poultry systems (scavenging and backyard) and the semi-commercial system. . In low-input family poultry systems, locally available, alternative feedstuffs can be used to supplement the scavenging feed base. In the semi-commercial system, only part of the feed requirement is purchased from commercial compounders, so on-farm mixing or dilution of purchased feeds with locally available, alternative feedstuffs are easily achievable. Growth or production performance of commercial chicken are higher as compared to village type or non commercial birds, and hence, they are likely to be more sensitive to low nutrient density or anti-nutritional factor present in ration. Alternative feedstuffs are often referred as “non-traditional feedstuffs” because they have not traditionally been used in animal feeding or are not normally used in commercial animal diets. Feedstuffs that may be classified as non-traditional in some regions, may actually be traditional and based on many years of usage in others. Some feedstuffs earlier considered as non-traditional, are now being used increasingly in commercial diets. In this report attempts have been made to compile available information on various alternate feed resources, factors limiting their extensive use in poultry feed, and their safe level of inclusion in different types of chicken.

Energy sources

Maize is the energy source of choice in poultry diet because of better digestibility, high palatability, less fibre content, high energy content, high content of pigments like xanthophylls, leutine, etc. which supports attractive colour of egg yolk and meat. Several feed resources have been explored as alternate to maize and they include jowar, millets, bajra, ragi, korra, various fat/oil sources, etc. The following section will present salient and useful information about these newer alternative energy sources.

Jowar (Sorghum vulgaris)

About 6.44 million tons of jowar grain is produced annually in India which is ranked 3rd among cereal crops produced in India. Jowar contains slightly higher protein content (13 vs 10% CP) than that of maize and its ME content is variable (2617 to 3886 Kcal/kg) depending on tannin content. It may contain as high as 2% tannin which has performance depressing effects in poultry. Supplementation of the diet with methionine and choline are known to ameliorate performance depressing effect of jowar. Dark variety can be included at the rate of 10-20% whereas white variety can be used at 25-40%. It has been shown that sorghum having less that 1% tannin can be used in broiler diet and tannin free sorghum can replace upto 74% of maize in ration of layer.

Millets

Foxtail millet (korra or Italian millet or German millet), finger millet (ragi or African millet or Indian millet) and pearl millet (bajra) are now available for feeding poultry in good quantity. Millets contain slightly more crude protein than maize and are equal to slightly lower in ME content than that of maize. In a study conducted at DPR has shown that maize can be completely replaced by bajra in broilers. Ragi has higher fibre content than maize (4.4% vs 2.4% CF) and high level of replacement of maize (>25%) with ragi tend to reduce FCR . Korra millet contains higher level of crude protein, ether extract, sugar, crude fibre, lysine and methionine but slightly lower ME as compared to maize. One study indicated that on replacement of maize (upto 62%) with korra on isonitrogen and isocalorie basis korra supported comparable weight gain in broiler chicken. Similarly, total substitution of maize (61%) with korra improved weight gain and feed intake in white leghorn chicks aompared to those fed maize based diet.

Wheat

Wheat contain similar net energy content as maize but may contain higher protein (10-17%). Normaly not available for feeding to poultry but can be used when available at cost competitive rate. The major problem in feeding wheat to poultry is its high NSP content which causes increase in viscosity of digesta and wet droppings. Wheat can be used without restriction when exogenous NSP degrading carbohydrase is added otherwisw maximum 40-50% can be included.

Spent Brewers' dried grains (BDGs)

Generally barley is used as input for fermentation and production of beer residues after fermentation is dried and sold as BDG. According to NRC (1994) BDG contains 25.3% crude protein (CP), 6.3% crude fat and around 2080 Kcal/Kg metabolisable energy and is also a good source of B vitamins. BDG can be a potential substitute for a part of maize and soya bean meal in chick's diet. BDG in broiler diet compared to ground corn caused an improvement in body weight gain and increased profit margin. Maize/Sorghum based BDG (MSBDG) could replace up to 50% maize in poultry diets without affecting performance. It has been shown that inclusion of 20% BDG replacing maize, soybeanmeal, rice bran in vanaraja chicken had no adverse effect (Swain et al., 2012). Barley based brewers dried gran may contain high fibre (16%) and hence cannt be used more than 15%.

Protein sources

Fish meal, meat meal and soybean meal are traditional protein sources. But these are expensive and fish and meat meals show wide variation in nutrient composition. Different alternative to tradition protein sources have been evaluated which have been summarized below.

Decorticated Cotton seed meal

Cotton seed meal has about 26% protein and 1556 KCal/kg ME. It contains 12.5% fibre against 6% fibre in soybean meal. Cotton seed meal is deficient in lysine, methionine and leucine and also contain gossypol. Free gossypol will cause yolk discoloration on storage and cyclopreopene ring in fatty acids of cottonseed oil causes pink discoloration of egg white. Processing of cotton seed meal causes most of the gossypol to be bound. Addition of low levels of iron salt to diet can also counter some toxic effects of gossypol. Cotton seed meal must have a low residual oil content to minimize discolouration of egg white . Decorticated cotton seed meal can be used to the extent of 15% in diet of broilers and layer chicks and upto 10% in growers and layers.

Decorticated Safflower meal

Decorticated safflower meal contains 42% CP and 8.5% fibre. The use of decorticated *safflower* is possible in *poultry* diets if the energy level is adjusted, with a special care to lysine, methionine and isoleucine supplementation. Recommended inclusion levels are lower for young birds (5-8%) than for older broilers and hens (10-15%).

Sunflower meal

Sunflower meal contains 2230 Kcal/kg ME, 37% protein and 11.6 % fibre, Moderate source of methionine. Limitation is due to high fibre. Can be used upto 20-30% in poultry diet. Can b e added as sole protein source when energy and limiting amino acids are balanced.

Guar meal

A large quantity of guar is processed in the world for gum extraction and residue left over from processing is converted into guar meal. It has a good amino acid profile with crude protein contents of about 33-45%. However, anti-nutritional components like guar gum (β-mannan), saponins and trypsin inhibitors limit the use of guar meal in broiler diets.

These anti-nutritional factors have been reported to depress growth in birds but at lower levels some of these (β-mannan and saponins) have positive effects on bird health and performance. β-mannan is considered a major anti-nutritional factor when higher levels of guar meal are used in poultry. To improve the utilisation of such feeds, β-mannanases are used. Roasted guar meal can be safely used upto 10% in diet of chicken.

Karanj cake

Karanj cake contain toxins like karanjin. Solvent extracted karanj cake (CP 26%, ME , 1900 Kcal/kg) could be incorporated after alkali (1.5% NaOH, w/w) processing at an enhanced level of 6.43%, replacing 12.5% of soybean meal nitrogen, in the broiler diets up to 4 weeks of age, beyond which the observed growth depression on this diet could be alleviated by 0.2% methionine supplementation (Panda et al., 2005).

Rape seed cake/mustard cake

Mustard cake contains 35.1% CP and 2373 kcal/kg ME. Toxic principles like erucic acid, tannin, glucosinolates and argimone contamination limits their use. Can be used upto 5% only. However, double zero variety can be used upto 30% in broiler or layer diet.

Til cake/sesame meal

Til/sesame cake contains 39.1% CP and 1900 Kcal/kg ME and good source of methionine but high in phytate and oxalates. Can be used upto 10% in broilers and layer chicks and upto 20% in growers and layers.

Copra meal

Copra meal contains 23%CP and 1200 Kcal/kg ME but high in fibre (12.5%). It can be used at maximum of 5% level in chicken diet.

Distillers dried grain with soluble (DDGS)

In the biofuel industry, starch of cereals are subjected to fermentation to produce bioethanol, and DDGS is a coproduct. Distillers' grain (DG) raw materials used for distillation include maize, wheat, rice, tapioca, and sweet potato. The nutritional characteristics depend on the raw materials used. Distillers' grain has a relatively high CP content. DDGS contains 27–35% protein, but low energy content and is used in livestock and poultryfeeds. It is cheaper than maize and SBM. Amino acid content of DDGS is highly variable. Conservatively, DDGS can be added at 5–8% of starter diets for broilers and turkeys and 12–15% of diets for layers and growing-finishing diets for broilers, ducks, and turkeys when diets are not formulated on a digestible AA basis. The DDGS diet achieves excellent performance and egg and meat quality. Recent research studies have shown that DDGS can be added to poultry diets at 25% for layers and broilers to achieve excellent performance, and egg and meat quality provided that accurate nutrient profiles specific to the DDGS source are used, and diets are formulated on a digestible AA basis.

Rubber seed meal

Rubber seed contain about 18% CP and contain 48% oil. Although rubber seed cake contain 35% protein and 1900Kcal ME/kg but are poisonous as contain HCN. Heat treatment (boiling following soaking)and storage can reduce toxic effect. Detoxified cake can be used upto 5-10% level in chicken diet.

Azolla

Azolla is a water fern and contain 22% protein, rich in carotenoids, minerals, vitamins and antioxidants but high in NDF. However, there is wide variation in nutrient composition in different species of azolla. High fibre content limits its use . Generally 5% inclusion in diet of chicken is considered as safe.

Alternate animal protein sources

Dried fish silage

Fish silage is a liquid product produced from the whole fish or parts of it, to which acids, enzymes or, lactic acid producing bacteria are added, with the liquefaction of the mass provoked by the action of enzymes from the fish. After collection and processing of fish wastes, fermented fish silage (FFS) is prepared by adding jaggery to the paste. The decrease in pH below 4.5 during fermentation is responsible for preservation of the product. The dry matter, crude protein, crude fat and total ash percentage of fermented fish silage estimated are 40.55±0.52%, 15.56±0.53%, 33±2.26%, 4±0.34% respectively. Dried fish silage can completely replace fishmeal in poultry diet but the limitation is it need to be dried.

Blood meal

Blood meal contain very high level of protein (73%) but is extremely deficient in some of the amino acids like isoleucine. Its palatability is also poor. It can be used only upto 5% level in poultry diet.

Poultry by product meal

High in protein content (56%). Feeding value similar to meat meal and recommended level of inclusion is 5%.

Hydrolyzed Poultry feather meal

Very high protein content (94%) but deficient in several amino acids and availability of most of the amino acids are low. Can be included only upto 5% in poultry ration.

silkworm pupae/snail meal

Good source of protein can replace 50% of fish meal but no commercial system of harvesting. Can be included in diet of family poultry safely.

Insect larvae meal

Insects contain 39-64% protein with good balance of essential amino acids and is emerging as a very good alternative protein source. Insects which can be included in poultry feed includes Grasshoppers, house flies, mealworm (larvae of black beetle) and black soldier fly larvae. Black soldier fly larvae is commonly found in manure and contain DM, 17-20%; CP, 40-60%, Ash, 0.8%, fat 2-15-30%, Met 2.64%, Lys 2.86%, ME 700 Kcal/kg Ca, 5-8%, P 0.6-1.5% of DM. Experimental feeding trials indicated that total or partial replacement of fish meal and total replacement of SBM resulted in similar body weight gain, less feed intake and better FCR. Feeding larvae on cow manure with fish offals was shown to enrich PUFA, EPA, etc.

Factors limiting use of alternate feed ingredients in poultry

Various factors limiting use of alternate feed ingredients include lack of consistency in nutrient quality, limited information on the availability of nutrients, need for supplementation of some nutrients to compensate imbalanced or deficient nutrients, need for detoxification of antinutritional factors, need for processing, limited info on inclusion levels, poor price made available to producers compared to conventional feedstuffs.

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Broiler Breeder Grower Management

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Management of Growers

Growing is the one of the most important phase in the life of breeders and influence to a large extent the performance during laying period. The main objective of the grower management is to achieve target body weight and flock uniformity. Growing stage starts at 7 weeks and ends at 20 weeks.

Body weight control during rearing

The main objective of growing period is control of body weight. The growth rate is comparatively slow during growing period. The flock should have uniform body weight and skeletal frame. Both average body weight and deviation in body weight determine the extent of effectiveness growing period. The weight of broiler parents at 6 weeks is 1500-1600g and the target weight at 20weeks of age is 2200 to 2300g. During growing period weigh a representative sample of 50-100 birds to get average body weight. During first 4 weeks, a group of 5 birds can be weighed at time and after that weigh birds individually. To calculate uniformity record individual body weights, calculate the average weight and the + and – 10% weight range, and then calculate the percentage of birds that fall within this range. It is extremely important to regularly review the recorded body weights and make necessary adjustments in the amount of feed when weights differ from target weight.

Importance of proper mature body weight of breeder females

Controlling the growth rate of males and females helps in reaching sexual maturity without excess body fat. This helps in

a. More uniformity of body weight
b. Delay in onset of sexual maturity and production
c. Better early egg size
d. Inmproved egg production
e. Increased number of hatching eggs
f. Reduced layer house mortality
g. Reduced feed cost during growing
h. Increased fertility and hatchability

Table-1 Guidelines for body weight and feed intake of growing pullet

Weeks of age	Body weight(g/bird)	Feed intake (g/bird)	Feed type
1	120	25	Starter
2	230	27	
3	330	29	
4	420	31	Grower
5	510	34	
6	610	36	
7	680	40	
8	760	43	
9	860	46	
10	960	49	
11	1050	53	
12	1150	58	
13	1250	62	
14	1350	66	
15	1450	70	
16	1550	75	
17	1670	80	
18	1790	85	
19	1900	92	
20	2040	97	
21	2200	103	
22	2320	110	Breeder

Feed restriction during growing period

During growing period feed restriction is followed to obtain target weight. The level of feed restriction is as low as 40% of ad libitum feeding. So, small feed increment of 2-4 g/week is sufficient to attain the target weight. During the restricted feeding programme sufficient feeder space should be provided so that all the birds can eat at a time. A general rule is that a restricted flock should finish their feed within 45 minutes. Feeding space recommendation for different systems of raring at various stages of development is given in Table 1.

Table 5. Requirement of linear feeder space (inches) for broiler breeders

Age, weeks	Females			Males		
	Deep litter	Slat	Cage	Deep litter	Slat	Cage
1 - 6	4	4	4	4	4	4
7 – 16	6	6	6	6	6	9
17 - culling	8	8	8.25	8	8	12

Growing is the one of the most important phase in the life of breeders and influence to a large extent the performance during laying period. The main objective of the grower management is to achieve target body weight and flock uniformity. Growing stage starts at 7 weeks and ends at 20 weeks.

Housing.

Two types of housing is practiced

a. Brood grow system of rearing: in this system, generally breeding stock remains in the same building during brooding and growing. About one third of the house is used during brooding perion after that chicks will given acess to etire building up to 20 weeks
b. Brood- grow-lay system: in this system same house is used for brooding, growing and laying. The chicks are placed at day old and remain in the same housetill end of laying period.

In both types of housing two types of floors are used.

a. All litter floor: A floor space of 3 sq ft per bird is provided.
b. Combination of litter and slats: A floor space of 2.6 sq ft per bird is provided

Feeder space

During growing period as feed restriction is followed, sufficient feeder space should be provided so that all the birds can eat at a time. A feeding space of 8 inches incase of trough feeders and 8-10 birds per feeder in case of round feeders.

Rearing programme

Males should be separated from females during growing period. Separation will reduce the stress. Though there are three growing programmes, Growing males separate from the females during the complete rearing period is ideal. The advantage of this programme gives better control of body weight development. For males the reproductive performance is increased and help reduce problems associated with early male.

Water Restriction

During feed restriction, birds tend to consume more water, which results in wet litter condition. To prevent wet litter, water is turned on one hour prior to feeding and kept available at least up to two hours after all the feed is consumed. The rest of the day water is provided for one hour each in the after noon and evening. Water restriction is not advisable when the temperature goes above 30^0C.

Beak trimming

The second time beak trimming is done between 12 – 14 weeks of age. The precautions as stated earlier should be adopted during beak trimming at this age.

Points to remember during growing phase

- Feed increments should be 2 – 4 g / week during this phase
- Body weight is the target and modulation of feed allowances is the key to achieve the target
- Correct fleshing and uniform skeletal frame from 12^{th} week onwards are necessary for better productivity

Emerging and Re-emerging Diseases of Poultry

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A phenomenal growth in poultry production in past few decades was observed in India with egg production ranking 3rd and chicken meat production at 5th position in the world. Strategies aiming at improved breeding, economic feed formulations, better health coverage and management in an organised way has contributed to the phenomenal growth of poultry sector.

The term "disease" refers to conditions that impair normal tissue function. Microorganisms that are capable of causing disease are called pathogens. Disease can be caused by a single factor or combination of different factors.

Robert Koch has defined a single cause of disease by the use of the following postulates:

A pathogen is causal if

- It is present in all the cases of diseases;
- It does not occur in another disease as a fortuitous and non-paathogenic parasite and
- It is isolated in pure culture from an animal, is repeatedly passaged and induces the same disease in other animals.

Examples of disease that are caused by single infectious or non-infectious factors are infectious bronchitis, newcastle disease, laryngotracheitis, gumboro disease, mareck's disease, coccidiosis etc. which can be reproduced by inoculating a chicken with single agent.

A disease complex can by defined as a condition with which several known and unknown factors operates sequentially and successfully to precipitate the pathogens (virus, bacteria, or parasite) viably in the vicinity to cause greater havoc in the flock at any age of the bird's life. Among these respiratory disease complex (RDC) and enteric disease complex are having significant economic importance in poultry production. Literature says that multifactorial diseases can be categorised as a) Diseases caused by combination of well-known causes (Necrotic enteritis caused by both *Clostridium perfringens* and coccidiosis); b) Diseases caused by different combinations of partly unknown causes (Infectious stunting syndrome) and PEMS (Poult enteritis and mortality syndrome); c)Diseases such as RDC caused by several strains of infectious bronchitis virus, avian pneumo virus, low-pathogenic avian influenza, new castle disease virus, mycoplasmas, immunosuppressive agents, unfavourable environmental conditions, respiratory reactions induced by routine vaccination programs and diseases of multifactorial enteritis complex with complex etiology involving combination and interaction between different viruses, bacteria and other non-infectious agents..

What are emerging diseases?

According to World Health Organization (WHO) definition of an emerging disease is: Ä disease that has appeared in a population for the first time, or that may have existed previously but is rapidly increasing in incidence or geographic range".

Emerging diseases include new, previously undefined diseases as well as old diseases with new features. These new features may include the introduction of a disease to a new location or a new population, new clinical features, including resistance to available treatments, or a rapid increase in the incidence and spread of the disease. Avian Influenza is of public health concern among emerging diseases due to its genetic nature and the emergence of novel strains is inevitable.

What are re-emerging diseases?

Diseases that reappear after a period of absence can be considered as re-emerging. Some examples are certain food borne pathogens *viz.*, salmonellosis which has major public health importance.

Emergence of new diseases and re-emergence of recognized diseases is a familiar event in poultry medicine. Reappearance of a disease which was once endemic but had since been eradicated or controlled, would classify it as a re-emerging infectious disease. Emergence may also be due to a new recognition of an infectious agent in the population or the realization that an established condition has an infectious origin[1]. There is a possibility of the sporadic and endemic diseases to emerge or re-emerge as an epidemic or pandemic with the introduction of something new or unusual in the poultry population. Global activities involved in poultry production involving movement of live birds, eggs and poultry products across political borders, makes it difficult to contain an emerging or re-emerging disease to a country or continent.

Certain factors contributing towards disease emergence or re-emergence involve:

- The genetic changes in the microorganism or in the host.
- Changes in the environmental or management practices can influence the conditions favourable for microbes to express pathogenic properties. In commercial poultry

environment, viruses and bacteria, including some that have the potential of causing disease are common.

- Commensal microbes of respiratory and gastro-intestinal tract can become pathogenic following an insult, although it may be mild to the host. Example of this is *Escherichia coli* which are regarded as a universal secondary infection in poultry.
- Live virus vaccines which are mild pathogens may also be present. Immunocompromised flocks due to infectious or non-infectious agents can result in unusual disease syndromes, increased susceptibility to disease or lack of responsiveness to vaccination.
- The combination of etiologies of diseases could result in additive or synergistic effects.
- Multi-drug resistance developed by microorganisms following medication with same antibacterial or anticoccidial drugs over time, sub therapeutic doses intending increased growth promotion can lead to emergence of resistance to those antimicrobial or anticoccidial drugs.

Mechanism involved in emergence of poultry pathogens[2]:

- Genetic changes in the microorganisms could have rendered them more virulent or pathogenic. Genetic changes in the birds could have altered its susceptibility and resistance to disease. Genetic changes in microorganisms through accumulation of point mutations in the genome or even recombination and assortment of gene sequences sometimes result in an altered pathogen with the ability to multiply more effectively in the host. Initially these changes may not be recognized, but as the mutant strain of the pathogen multiplies, becomes better adapted to the host, and spreads within flocks and among production sites, disease problems can become apparent – emerge – against the background of normal expected levels of losses during production activities. Virus evolution is also a way of producing an emerging disease. Best example is emergence of novel genotypes of infectious bronchitis virus.
- The co-evolution of viral pathogens with their vaccines and medications as do any other organisms, poultry pathogens tend to change and evolve. Antigenic change results from genetic control, and can be accelerated under immune pressure. Immune responses are geared to controlling pathogens, and include antibody production and t-cell activation against pathogen-specific protein structures, which are those most likely to change over time. Medication with antibacterial or anticoccidial drugs exerts similar effects over time.

Way forward

To address the emergence and re-emergence of poultry diseases, studying the history of the emergence provides useful insights about the detection, characterization, and control of emerging pathogens. Understanding the ecology of the poultry diseases especially complex disease involving multifactorial aetiology is essential. New and improved molecular diagnostic tools, especially next generation sequencing technologies can be utilised for identifying the disease complex as well as investigating the pathogenic mechanisms of emerging disease complex/disease syndrome of respiratory and gastrointestinal system. For the diseases of public health importance or zoonotic importance guidelines described by the OIE can be followed for the control and prevention programme. To ensure food safety and combat drug resistance measures for safe withdrawal of antibiotics and coccdiostats and alternate to antibiotics are to be considered. A comprehensive national strategy addressing the challenges of emerging and re-emerging infections in poultry should include surveillance tools, advanced diagnostic tests, vaccines and therapeutics through basic, translational and applied research. National commitment and comprehensive efforts are necessary to meet the threat of emerging and re-emerging diseases. Joint collaborations of avian health and human health professionals are required to address the emerging zoonotic pathogens.

Over all, emerging pathogens that have the potential to emerge in poultry in the future can be a new previously unknown pathogens, evolving strains of established pathogens, known pathogens with a stronger transmission component through poultry meat, foodborne pathogens affecting susceptible subgroups of the population, previously unknown pathogens with suspected, but not yet established, transmission through poultry meat, eggs or live birds and pathogens common in other parts of the world that may present a future emergence threat.

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Basic concepts in chicken reproduction

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Female reproductive system

The avian female reproductive system has two gonads and oviducts developing in the early stages of embryo but the right side regresses and the left side only continues to develop and become functional. The left ovary is situated at the cephalic end of the left kidney and is attached to the body wall through meso-ovarian ligament. Ovary contains many thousands of oocytes that develop sequentially into follicles. These grow very slowly up to about 2 mm diameter and then through unknown mechanism one follicle is selected daily for rapid growth that reaches full size of 40 mm in about 8 days and is ready for ovulation. Together with six or seven large follicles of different sizes gives the ovary the appearance of bunch of grapes.

The oviduct can be divided into five portions namely infundibulum, magnum, isthmus, uterus and vagina. The ovum immediately after release from Graafian follicle is engulfed by the infundibulum and remains for about 18 minutes before moving to the magnum. The ovum remains in the magnum for about 3 h and albumen is secreted and forms a thick coating of egg white around the ovum. It then passes through the isthmus, where egg membranes are formed. These semi-permeable membranes are made of protein fibres that allow only water and ions to pass but not albumen. The inner and outer membranes separate at broader end of egg to form air cell. The ovum stays in the isthmus for about 1 h and 14 min and then moves into the shell gland (uterus) where it stays for 20 h and 40 min. Here water is first transferred across the membranes, plumping of albumen and calcium carbonates are then deposited to form the egg shell. The vagina is the terminal portion of the oviduct and measures about 12 cm in adults. There is a muscular sphincter at the utero-vaginal junction. Once oviposition begins the sphincter relaxes, the shell gland contracts, abdominal pressure increases and the egg is laid by passing through the vagina, cloaca and vent. The post-ovulatory follicle is a source of oestrogen and progesterone, which control the onset of pre-laying and nesting behaviour 24 h later, just prior to the laying of the egg.

Factors like age, breed, nutrition, lighting, housing, stress, environmental temperature and disease condition affect the number and quality of the egg laid by the hen. The hen has special spermatic crypts at the junction of uterus and vagina called as sperm storage tubules. After natural mating or artificial insemination the sperm move up and get stored for upto three weeks in these structures and are released periodically which then move up and fertilize the ovum.

Lighting is an important factor in the onset and persistence of lay. In commercial conditions light is decreased throughout the growing period and is increased at sexual maturity. However, it is difficult to control lighting in backyard chicken rearing. Adequate nesting area should be provided considering the number of hens for proper egg laying.

Male reproductive system

The male reproductive system consists of paired testes, epididymis and vas deferens. There are no accessory sex glands. The epididymis is smaller in birds compared to mammals. IN contrast to mammals the semen production occurs in testis located inside the abdomen and at body temperature of 41°C. The testis is located in the dorso-central part of the body cavity close to the kidneys, which increases ten-fold in weight at sexual maturity. Testes have dual function namely spermatogenic and endocrine. The sperm is produced over a 14-day period in the seminiferous tubules from diploid spermatogonia, with successive reduction divisions producing haploid spermatocytes, spermatids and finally spermatozoa. Sertoli cells through nutrient rich secretions govern the differentiation and formation of spermatozoa. Suspended in the seminal fluid the sperm are swept into rete testis, lined by ciliated cells, which move them on into the epididymis. The sperm are temporarily held in epididymis where they mature and acquire fertilizing capacity. The vas deferens conducts semen from the epididymis to the cloaca and provides a reservoir for semen prior to ejaculation. When presented with a receptive female, the male mounts her and ejaculates through engorged phallic folds, which protrude from the cloaca.

The endocrine function of the testis is performed by Leydig cells which secrete several androgens, the major being testosterone. At sexual maturity leutinizing hormone (LH) released from anterior pituitary stimulate the output of testosterone.

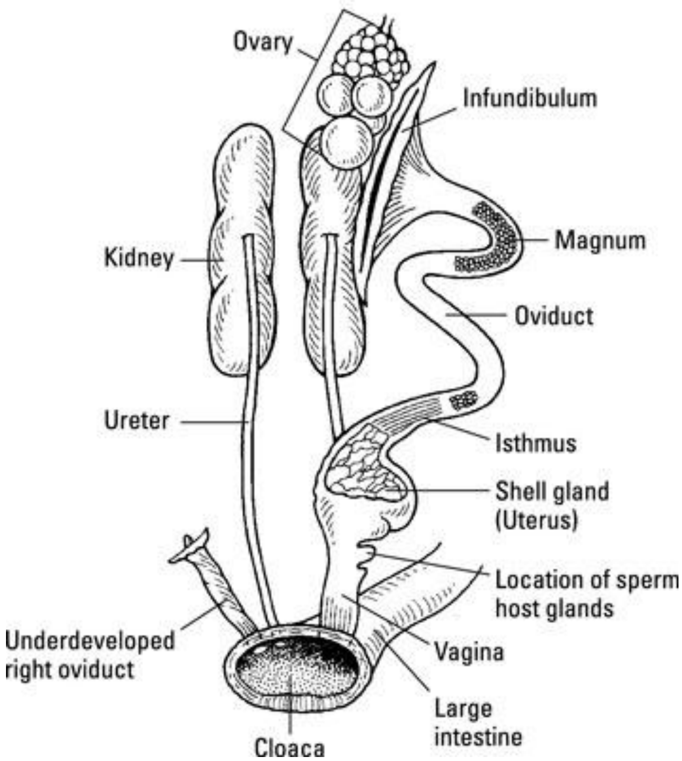

Figure 2 **Female reproductive system.**

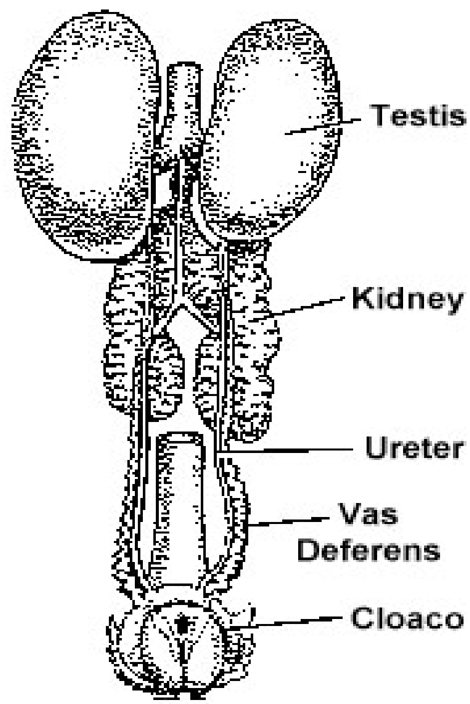

Figure 1 **Male reproductive system**

Semen or seminal fluid is a biological fluid that contains spermatozoa. The semen consists of sperm and seminal plasma. The volume of semen and concentration of sperm varies with the type of chicken. Broiler breeders produce 0.1-0.9 ml of semen with sperm concentration of 3-8 billion sperm/ml, whereas egg layer birds produce 0.15-0.3 ml of semen with sperm concentration of 3.5-6 billion sperm/ml. Indigenous breeds like Aseel and Kadaknath produce 0.1-0.4 ml of semen with sperm concentration of 5-8 billion sperm/ml. Different physical semen parameters are also affected by the line/strain, age, climate, frequency of collection, feed, lighting, health and other stress factors.

The spermatozoon is composed of an acrosome, head, mid piece and tail. The acrosome is attached to the head only at its most rostral point. The head is long and slender and the tail is long and moves in an undulating manner.

Artificial Insemination

Artificial Insemination (AI) is the process by which semen from male bird is collected and introduced in to female reproductive tract for the purpose of fertilizing eggs. The objectives of artificial insemination in poultry are a). To place the required dose of semen into the oviduct of the female so that it is deposited near the sperm storage glands and b). To carry out the AI process with due regard to the best health and welfare of the breeder females thereby achieving the highest fertility levels possible.

Biologically**,** after deposition of semen in the oviduct the sperm will enter the sperm storage tubule (SST) situated at the junction of the vagina and the shell gland/uterus and from here the sperm will make their way up the oviduct to a second storage site situated at the junction of the magnum and infundibulum. The passage of an ovum into the infundibulum stimulates sperm activity and fertilization of the ovum by one sperm takes place.

Artificial insemination technique is needed for increased mating ratio, use of older males with outstanding performance and for successful cross breeding. It is widely used in the commercial meat-type poultry production because of lower fertility resulting from natural mating. The semen can be diluted using diluents (BPSE (Beltsville Poultry Semen Extender) or high temperature diluents) or if inseminated soon after collection normal saline can also be used for dilution. This diluted semen can be used to inseminate higher number of hens.

Semen Collection

Two persons are needed for this process - one for handling the rooster and vent opening, and other for collection of semen. The first person holds the male between his arm and body. The collector stimulates the male by stroking the birds back from the middle towards the tail, while at the same time the person holding the bird strokes the abdomen towards the vent. The collector after several stoking actions with the help of thumb and the index finger massage the pubic bones lightly. This causes the male to extrude the phallus and, if the bird is producing semen, results in ejaculation, which is then collected in a sterile glass funnel.

The semen samples collected should be evaluated for concentration and motility that give a rough idea about the quality of semen. There are other biochemical and enzyme reduction assays that can be carried at laboratory conditions for thorough screening of birds giving good quality semen. Samples with low concentration and poor sperm motility should not be used for insemination. Under practical conditions gross visual evaluation of semen gives rough idea about the quality of semen. Thick creamy semen that is viscous indicates sample containing high sperm concentration. Any other colour indicates contamination of semen. Green colour indicates fecal contamination, reddish/pink colouration indicates contamination with blood and brown colour indicates dust/dirt contamination. Watery semen indicates low concentration of sperm in the sample. Semen mass activity or sperm individual motility can be observed with the help of microscope. Samples with high progressively motile sperm are preferred for insemination.

Insemination

- During insemination, pressure is applied to the left side of abdomen of the hen around the vent. This causes the cloaca to evert so that a syringe or plastic straw can be inserted into the vagina to a depth of an inch and the appropriate amount of semen delivered.
- As the inseminator expels the semen, pressure around the vent is released simultaneously, which assists the hen in retaining sperm in the vagina or the oviduct.
- Usually in commercial operations 0.1 ml of undiluted semen is deposited in the vagina of hen that yields optimal fertility.
- Inseminations should be carried out continuously once in every 3-5 days when fertile eggs are required.

- Should be done during afternoon. During the morning, most hens have an egg in the oviduct, thus obstructing the free passage of semen to the ovary and due to reverse peristalsis sperm may not be able to reach the sperm storage tubules.
- Fertile eggs are obtained from second day after insemination.
- In order to increase the number of hens that can be inseminated from the semen of single rooster, the semen may be diluted with a normal saline if immediately inseminated or with diluents such as modified Ringer's solution or BPSE (Beltsville Poultry Semen Extender) or high temperature diluent. When diluted semen is used for insemination the number of males kept for semen collection may be reduced in number.

Understanding the reproductive physiology and the factors that influence the normal physiological functions will enable to improve the productive performance of poultry.

Health Chick Production through Scientific Hatchery Management

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Receiving and cleaning of hatching eggs

Eggs start deteriorating from the moment it is laid. The first change which takes place in the egg after it is laid is loss of weight due to evaporation of moisture and loss at small quantity of gases. The other change which develops during storage can be identified by candling of eggs. The egg when laid comes immediately in contact with litter, excreta, feed, water, etc., and it is usually dirty and its surface harbors bacteria and viruses.

1. **Never wash an egg with water:** Do not wash eggs unless necessary because a bacterium has a greater chance of entering through the pores. An egg's shell has a natural protective coating (cuticle) that resists the entrance of bacteria and retains moisture inside. Washing eggs with water removes this protection.
2. **Floor Eggs:** Floor eggs are a costly expense and generally not recommended for hatching purpose. Eggs laid in litter or on slats are usually dirty or cracked.
3. **Collection of eggs:** Collect the hatching eggs as frequently as possible. The fresh eggs should be cooled to temperature below the physiological zero level as quickly as possible.
4. **Cleanliness of the shel**l: Clean eggs hatch better than the soiled eggs. Dry cleaning of soiled eggs with rough cloth or sand paper may be done before setting in incubator.
5. **Precautions by the hatchery staff**: The hatchery staff should wear clean clothes and protective gloves to avoid any contamination from their side.
6. **Sanitation**: It is a very important factor while collecting eggs it is also recommended to adequately sanitize the plastic /pulp egg trays.

Selection of hatching eggs

The following points should be considered while selecting eggs for hatching purposes.

1. **Size of eggs:** The medium size (50-55 gm) should be preferred over too small or too large eggs as they create hindrance in setting in incubation trays and also do not hatch as good.
2. **Shape of eggs:** The shape of hatching eggs should be oval. Duck and turkey eggs may be less oval than chicken eggs.
3. **Shell quality:** Eggs with sound shell should be selected. Shell should be clean and thick.
4. **Interior quality of eggs:** hatching eggs should have good albumen and yolk quality and free from blood and meat spot or any other defect.

Grading of eggs

Grading is the sorting out of eggs in to different categories according to the interior quality and the individual weight of an egg. Grading for internal quality is done by candling while for noting the weight of an individual egg there are various types of automatic devices in the market. Some standards for grading of eggs are as under.

Table 1 Indian standards for quality of shell eggs

Quality factor	Grade A	Grade B
Shell	Clean, sound, unbroken and normal shape	Clean to moderately stained, sound but slightly abnormal.
Air cell	4.0 mm. or less in depth, practically regular.	8.0 mm. or loss in depth and slightly bubbly
White	Clear, reasonably firm.	Clear, may be slightly weak
Yolk	Fairly well centred practically free from defects Out line indistinct	May be slightly off centre. Outline slightly visible.

Fumigation and storage of hatching eggs before incubation

We carefully attend to the incubation process but disregard the care of the eggs before they are placed in the incubator. Even before incubation starts the embryo is developing and needs proper care. Produce quality fertile eggs from a well-managed, healthy flock which are fed properly balanced diets. Listed below are tips to maintain hatching egg quality.

1. **Fumigation:** Pre incubation fumigation of hatching eggs should not adversely affect hatchability, if the proper gas concentration is used for not more than 20 minutes. Eggs should be properly ventilated before setting.
2. **Transportation of hatching eggs**: Eggs which have been shaken or jarred in transit should be allowed to settle for24 hours or so before setting in incubator.
3. **Storage of hatching eggs**: Ideal storage conditions include a 14 -15 ^{o}C temperature with 75% relative humidity. Never store eggs at temperatures about 75°F and at humidity lower than 40%. These conditions can decrease hatchability dramatically in a very short period of time. Maintaining a constant environment for hatching eggs prior to incubation is critical to achieve optimum hatchability. Household refrigerators are too cold for storing fertile eggs.
4. **Storing position:** Store the eggs with the small end down. Turn the eggs to a new position once daily until placing in the incubator, if not incubating within 7 days.
5. **Storing Period:** Don't store eggs more than 7 days. Hatchability holds reasonably well up to 7 days, but declines rapidly afterwards. Eggs stored more than 7 days will benefit from daily turning. Plan ahead and have a regular hatching schedule to avoid storage problems. Do not store eggs for more than 10-14 days. After 14 days of storage, hatchability begins to decline significantly. After 3 weeks of storage, hatchability drops to almost zero.

Methods of incubation:

There are two methods of incubation, natural and artificial.

1. Natural method of incubation: In this method eggs are incubated with the help of broody hens. A broody hens used for incubating eggs should be healthy, quiet, a good sitter and have good body size. The broody hens should also be treated for internal and external parasites before allowing her to sit on eggs. Depending up on the size of hen 10-15 eggs can be placed under one bird. The broody hen should be taken out at least twice a day for about 30 minutes to be fed and watered. Candling may be done on 7th day to remove the infertile eggs. This method is still popular with small poultry keepers in remote rural areas. Although this method is disappearing and being replaced by artificial method of incubation.

2. Artificial method of incubation: In this method eggs are incubated in "egg incubators". This method of incubation of eggs is known to man for more than 2000 years. Various size's hatchery are used for this purpose. The modern hatchery is an impressive example of engineering solution of biological requirements of developing embryos and production of viable and healthy chicks. There is perfect control of temperature, humidity, ventilation and turning of eggs under hygienic condition to produce over 1 million chicks a week with relative ease from incubators equipped with sophisticated controls to maintain optimum hatchability.

Sanitation and disinfections of incubators

The microbial contamination can be prevented and controlled using proper hatchery management practices and modern health care products. Thoroughly clean and disinfect the incubator before and after you use it. It is just as important that the incubation room and egg storage area are kept equally clean. The lack of sanitation will decrease hatchability. Microorganisms are everywhere! Some are relatively harmless while others are highly pathogenic. Some pose a lethal threat to one species of animal while remaining harmless to another species. Some organisms are easily destroyed while others are very difficult to eliminate.Three terms commonly used but often misunderstood are

Sterilization: The destruction of all infective and reproductive forms of all microorganisms (bacteria, fungi, virus, etc.).

Disinfection: The destruction of all vegetative forms of microorganisms. Spores are not destroyed.

Sanitation: The reduction of pathogenic organism numbers to a level at which they do not pose a disease threat to their host.

Select the right disinfectant: Proper cleaning of facilities removes the vast majority of all organisms and must be used before application of disinfectants. This applies to all areas within the hatchery including floors, walls, setters, hatchers, trays, chick processing equipment, air and personnel.

1. The type of surface being treated
2. The cleanliness of the surface
3. The type of organisms being treated
4. The durability of the equipment/surface material
5. Time limitations on treatment duration
6. Residual activity requirements

Preparing the Incubator: Before you incubate the eggs make sure that incubatoris working properly and that you know how to operate it. Check the thermometer (at least 24 hours before you set the eggs & be sure it will stay at the correct temperature and humidity).

1. Run your incubator without any eggs for 12 to 24 hours, regulating and checking the internal temperature, humidity and turning at hourly interval.
2. Check the thermometer's accuracy and calibrate properly.
3. Thermometer with a split or gapped mercury will not give an accurate reading.
4. Do not load the eggs until the temperature and humidity are correct.
5. During incubation, eggs found to be leaking, cracked, or mouldy should be removed and disposed off. Such eggs may explode because of high microbial contamination.

Fumigation of Incubators

1. Excessive and improper fumigation may result in higher mortality in developing embryos.
2. The killing of bacterial organisms by formaldehyde is based on the concentrations of the gas, exposure time, temperature, and humidity of the incubator.
3. The disinfectant potassium permanganate and formalin (40% formaldehyde gas) have proven to be the most effective method of destroying bacterial organisms in the hatchery.
4. Fumigation of loaded setters for 30 minutes with 20 grams Potassium permanganate and 40 ml of 40% of Formalin solution for 100 cubic feet of incubator area.

Warming of hatching eggs before setting

Hatching egg removed from the cold room should not be placed directly in the setters. Rather they should be warmed slowly to room temperature first before placing in the incubator.

1. Abrupt warming from 14 degrees to 36.7 degrees Celsius causes moisture condensation on the eggshell that leads to disease and reduced hatches**.**
2. When the egg cools, embryonic development stops. Embryonic development starts again when the temperature is increased.

Incubator operation

Incubators have been designed to operate in rooms that are comfortable for people. If a room is too hot or cold, an incubator may not be able to hold the proper temperature. If the incubator is in a room where temperatures are decreased to 55 ^{0}F over the weekend, hatchability will be affected. If several people are involved in the incubation process, keep a written record.

Incubating the eggs: Successful incubation depends on maintain favourable conditions for hatching of fertile eggs. Four factors of major importance are temperature, humidity, ventilation, and turning. Commercial incubators are automated to control all of these factors.

I. Temperature (during incubation)

The required level of heat in the incubator can vary from 99.5 ^{o}F (36.7 ^{o}C) to 101 ^{o}F.

1. Using two thermometers is a good idea to ensure an accurate reading
2. The acceptable range of temperature is 98° to 101°F. Mortality is seen if the temperature drops below 97°F or rises above 102°F for a number of hours.
3. Before putting eggs into an incubator, plug it and make sure the temp is holding at 99.5-101 °F.
4. Temperature is the most important single factor influencing the development of the embryo.
5. Higher temperature will advance the hatch and a lower temperature will delay hatch.
6. Incubator overheating can quickly kill the developing embryo.
7. Never cool eggs again after starting incubation.
8. Overheating the embryo is much more damaging than is under heating.
9. Once the eggs are in the incubator, do notadjust the temperature or humidity for a few hours unless the temperature exceeds 102^{o}F.
10. Do not adjust the temperature upward during the first 48 hours after eggs are set.

II. Humidity (during incubation)

The amount of moisture in the incubation air is the relative humidity. It is usually measured by a wet bulb thermometer. Function depends on the cooling caused by evaporating water. A thermometer is covered by a cloth sleeve that extends into a container of water. If the humidity is low, much evaporation occurs, resulting in a lowering of wet bulb temperature; therefore, the wet bulb temperature is much lower than the dry bulb temperature. Humidity must be regulated. Commercial incubation maintains a wet bulb temperature of about 85^{o}F for the first 18 days for chicken eggs and 91 ^{o}F for the last 3 days. Humidity should be set so that an egg loses 13 percent of its initial weight by the last 2 days before hatching. Too much or too little humidity in the incubator will cause hatching problems and the death of embryos.

1. During hatching period, the humidity in the incubator may be increased by using an atomizer to spray a small amount of water into the ventilating holes.
2. Whenever you add water to an incubator, it should be about the same temperature as the incubator so you do not stress the eggs or the incubator.
3. Water drum meant for water air cool system should be kept full at all times.
4. The wet bulb should remain wet in water at all the time.
5. Incubation maintains a wet bulb reading of about 85 ^{o}F for the first 18 days for chicken eggs and 91 ^{o}F for the last 3 days.
6. Low humidity can cause, the shell membrane becomes dry and embryo stick to the shell, which also causes embryo mortality.
7. Humidity inside the Incubators should be controlled by slightly adjusting the rotavents and manual top ventilator.
8. If more humidity is needed adjustment can also be made by increasing or decreasing ventilation.
9. During the hatching period, using an atomizer to spray a small amount of water into the ventilating holes may increase the humidity in the incubator.
10. Relative humidity should be balanced with temperature; different temperatures require different relative humidity.

III.Turning

The act of changing the position of eggs, this keeps the embryo cantered in the egg during incubation to prevent the embryos from sticking to the shell membranes.

1. Eggs must be turned hourly during the first 18 day of incubation.
2. Turning the egg prevents adhesion of the embryonic membranes and helps in the movement of the embryo into the normal hatching position.
3. Turning stimulates the growth of the membranes, and increases the heart rate.
4. The increased heart rate and membrane growth facilitate absorption of the nutrients from the yolk, albumen.
5. Turning is not requiredduring the last three days before hatching.
6. Do not open the incubator until the hatch is completed to insure that a desirable hatching humidity is maintained.

IV.Ventilation

The embryo is living tissue and as such needs to exchange oxygen and carbon dioxide throughout the growth process.

1. The best hatching results are obtained with normal atmospheric air, which usually contains 20-21 percent oxygen and produces optimum hatching results.
2. While the embryo is developing, oxygen enters the egg through the shell and carbon dioxide escapes in the same manner.
3. As embryos grow, the air vent openings are gradually opened to satisfy increased embryonic oxygen demand.
4. The air vents should be almost fully open during the latter stages of hatching.
5. Do not open the incubator unless necessary during the last 3 days of incubation.

Testing of Incubated eggs through candling

Candling should be performed in a dark room. A fresh egg appears clear with only a small air cell. Egg candling will detect infertile and early dead germs. After 10 days of incubation, an infertile egg has an enlarged air cell, and the yolk causes an obvious dark area in the egg. After 10 days of incubation, a fertile egg has visible blood vessels and a dark spot that is the embryo.Eggs with white shells are easier to candle and can be tested earlier than dark shelled eggs. Two classes of eggs can be removed on the basis of this early test, "infertile" and "dead germs." "Infertile" refers to an unfertilized egg or an egg that started developing but died before growth could be detected. "Dead germs" refers to embryos that died after growing to be seen when candled.Eggs can be out of the incubators for half an hour without any harm for candling.

Bad eggs: The egg shows a ring at 6 days. This ring is formed by concentrated bacteria which has invaded the eggs membrane.

Good Eggs: A live embryo is spider-like in appearance, with the embryo representing a spider's body and the large blood vessels spreading out much like a spider's legs. A "dead germ" can be distinguished by the presence of a blood ring around the embryo.

1. Fertility is rarely 100%.
2. When the flock is of good producing age and the right proportion of males to hens are place together, it can be assumed that a fair amount of eggs will be fertile
3. Fertility may vary from 65% to 95% with season, condition and type of birds.
4. Fertility of eggs cannot be determined before incubating them.
5. Candling chicken eggs on the 7th and 18th day of incubation is the ideal.
6. Eggs that appear clear at 18th days in incubation should be removed from the incubator. They are infertile or early dead embryos.
7. Candling will not influence embryo development if you handle the eggs gently.
8. Fertile egg shows a black spot at the top of the yolk shadow along with few blood vessels.
9. Transfer the eggs quickly to avoid cooling down of the eggs.

Hatchery Hygiene

The hatchery must always be regarded as the greatest potential source from where disease can spread. There are two classes of diseases which originate from the hatchery. The 1st includes those diseases which are definitely egg transmittable. The 2nd includes diseases those are transmitted by contact with disease producing microorganism introduced from sources other than eggs after chicks are hatched.

Ways by which infection enters in the hatchery:

The surface of eggs, egg boxes & fittings can convey infection from the poultry farms.

1. Vermins can act as carrier.
2. Flies, cockroaches etc. can bring infection from the exposed debris.
3. Clothing and hands of hatchery staff, particularly of sexers.
4. Dead or ailing birds brought to hatchery for diagnosis and advice.

To avoid the spread of diseases from hatchery following precautions may be exercised:-

1. Only nest clean eggs should be collected for hatching in clean filler flats and boxes.
2. Hatchery should not be located near poultry farms, Poultry processing plants or other hatcheries.
3. Incubators should be located in a separate room with "No Admittance" sign at door.
4. Each year before the season starts the hatchery building and all the equipments should be thoroughly cleaned and fumigated.
5. All eggs entering in incubators must be fumigated.
6. The ventilating system in the hatchery should be designed to bring fresh and filtered air in all areas. Ideally no air should be re-circulated in the hatchery.
7. The wall, ceilings and floors should be constructed of water repellent material so that they can be washed easily.
8. Keep fans, air conditioner, ventilator etc. free from chick down and dust.
9. Hatcher, chick tray etc. should be kept clean.

Using protecting

1. The hatching process releases much fluffy debris inside the incubator.
2. Care should be taken not to open the incubator.
3. Wearing gloves and a facemask may help to provide better hygiene while doing this cleanup.

Common disinfectants and uses

a) Phenol derivatives. One part of phenols with 4 parts of water, 1 gallon used a spray in 400 sq floor area is very effective for routine purpose.

b) **Iodine Preparations**: - Iodine preparations were containing 1.75 % iodine as is used @ 30 ml/2 gallon of water for cleaning the floor and equipment.

c) **Chlorine Preparation**: - Chlorinated lime or bleaching powder is a well-known disinfectant. It is prepared by saturating lime with chlorine gas & should contain 30-35 % of available chlorine used as disinfectant of hatchery floor.

d) **Quaternary Ammonium Compounds**: - These compounds are cleaning agent and used to scrub and disinfectant premises.

e) **Coal Tar**: - These are cresol products which form milky emulsions when mixed with water. 5% is effective for disinfecting purpose of floor space.

f) **Dettol:** - Dettol & similar products are expensive but quite effective antiseptics and disinfectants.

g) **Caustic Soda**:- It generally used as cleaning agent but 2 % solution is used as disinfectant for most microorganism

h) **Lime**:- It is used as white wash

i) **Ultraviolet Rays**:-Ultraviolet ray kill bacteria and are used for incubators and other hatchery equipments.

j) **Dry heat and steam cleaning**:- Few instruments particularly Incubator trays & metal parts are subjected to pressure steam at boiling point

k) **Formaldehydes**: - Under ideal condition formaldehyde is very effective for killing bacteria, fungus and viruses. Formaldehyde is notorious for being a poor penetrator and only works on the surface of the material.

l) **Ethylene oxide**: -It has many advantages over formaldehyde as it is effective against many poultry pathogens. Its penetrating properties are excellent so it is valuable for sterilizing the hatchery equipment. Precaution should be taken while using as it is highly inflammable and dangerous.

Entrepreneurial Opportunities in Poultry Sector

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Outline:

Scope of poultry sectors

Entrepreneurial opportunities in poultry sector

Government & Institutional support

The Indian poultry sector contribute about 17 billion USD to India's Gross Domestic Product (GDP) and is one of the major agriculture sectors providing employment and livelihoods to about 6.5 million people. Poultry industry produce about 250 million eggs and 13 million broiler chicken per day. Majority of the poultry produce comes from commercial poultry sector. However, according to the Indian government's National Action Plan for Egg & Poultry-2022 (NAPEP), backyard poultry accounts for 20% of India's poultry sector. The size of broiler market was around ₹850 billion and eggs market was around ₹ 450 billion. Across the country, around 30 million farmers are engaged in backyard poultry (Estimates the 19th Livestock Census of India). Poultry farming is one of the fastest growing Agri-sector in our country with an annual cumulative growth rate of about 9.6% in broiler meat and 6-7% in egg production. The government has made significant expenditures on processing, breeding, rearing, and hatching operations to further enhance the growth of the industry.

As per the recommendation of Indian Council of Medical Research (ICMR) every person should consume 180 eggs/year and chicken meat 11kg/year. Presently, per capita egg and chicken consumption is 86and about 4.1 kg, respectively. According to a report by McKinsey and company, the per capita chicken consumption is set to grow to 9.1 Kg by 2030, on account of rapidly changing consumption behavior of individuals. Share of poultry and other meat in household food consumption is expected to grow from 12 to 24per cent by 2030, if so, the poultry sector should grow many folds to meet the projected requirements. Demand of poultry produce is increasing every day. Growth in per capita income, a growing urban population, health consciousness about red meat, availability and affordability are the major contributing that attracts poultry products. A growing rural market and awareness among rural people also create demand of poultry products in rural India.

Poultry farming (Chicken, Duck, Quail, etc), chicken meat processing, medicines, feed additives, health products, equipment, management, other technical services and transportation are the major fields where opportunities are more. Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Maharashtra in the west, Haryana, Punjab in the north and West Bengal are key regions in the country where poultry production potential are much more compared to other parts.

Foreign Direct Investment (FDI) is important component to flourish business idea and there are several opportunities for foreign direct investment (FDI) in the poultry sector in areas like breeding, medication, feedstock, vertical integration, and processing. Currently, 100% Foreign Direct Investment (FDI) is permitted in the food processing sector.

Entrepreneurial Opportunists

1. Poultry farming with modern technology
    - Commercial broiler farming
    - Commercial layer farming
    - Production of parent stock and supply of backyard birds among stakeholders
    - Duck farming (with or without water)
    - Swan farming
    - Duck and Fish farming
    - Quail farming
    - Turkey farming
    - Pigeon farming etc

2. Organic poultry production
3. Poultry Farming Equipment
    - Local production of poultry equipment
    - Supply of equipment
4. Modern Hatchery: to supply chicks among stakeholders

5. Supply of poultry health care products (Vaccine, Medicines and other instruments & products)
6. Poultry feed manufacturing and supply
   - Feed processing, packaging and supply
   - Feed supply
   - Feed ingredients procurement and supply
   - Feed additives manufacturing and supply
7. Supply chain management (Transportation of birds and other poultry related products)
8. Waste management of poultry industry
9. Capacity development of Human Recourses required in poultry sector
10. Advisory Services- Technical, Establishment, Financial and others
11. Modern Slaughter house
12. Value added Products: Poultry Produce processing unit and supply- Egg processing/ Chicken processing
13. Export of Poultry produces

Institutional and Government support:

The Right Support and direction at Right time- Helps Agri-Entrepreneurs Thrive and flourish. These are some governmental schemes which support the entrepreneurs in the poultry sector:

- Agri-clinics & Agribusiness Centers
- MUDRA Loan
- NLM Scheme- Poultry Venture Capital Funds
- Heath support from Veterinary Department
- Improved birds from PSP Centers/ KVK
- Capacity Building from KVK/ SAU/ SVU/ICAR etc
- State specific programmes
- 100% FDI in feed processing

In India, poultry farming is a booming industry due to its demand and investment by different stakeholders. Entrepreneur must assess the advantages and cons of it before investing, taking a loan, and putting time & efforts. The poultry business is only lucrative if done with proper planning and taking consideration of need and dynamics of market.

Post-Mortem Examination of Poultry

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Post-mortem examination of poultry is essential to identify the cause of death. It is one of the tools to identify any disease outbreaks in the farm and helps in early and effective control. However, a good knowledge on the flock history and proper observations are essential for making any diagnosis.

Post mortem procedure

- The post-mortem examination should be carried out at the earliest because once putrefaction sets in, then it becomes very difficult to observe the tissue changes due to disease.
- Protection must be taken by the persons carrying out the examination by wearing face masks, hand gloves, aprons etc., to avoid infections and allergies.
- The dead bird is identified by its wing band number; the details like strain, age should be entered in the post-mortem recording sheets.
- The carcass is placed on its back and examined for any physical deformity, external parasites, discharges from nostrils and eyes, colour of comb and wattles, dehydration and emaciation etc.
- The angle of jaw is cut through inside the oesophagus and inside the crop for examination; the trachea is cut down its length from the larynx for examination.
- Both legs are drawn outside away from the body and the skin is cut between the leg and abdomen. Each leg is then held firmly in the area of the femur and pulled and twisted so that head of femur is broken free from the hip joint.
- Then the skin from the vent to back is cut. The cut edge is forcibly reflected forward until the entire vertical aspect of the body is exposed. Haemorrhages in the muscles can be observed at this stage.
- To expose and observe the abdominal organs, cut open the abdominal walls transversely midway between keel and vent and then through the breast muscle on each side. Bone

scissors are used to cut the rib cage and then the coracoid and clavicle bones on both sides. The sternum and attached structures can now be removed from the body and placed on the other side. The visceral organs can be examined now. Lungs, air sacs, liver and heart can be examined for any lesions. Air sacs should be examined for cloudiness, caseous material etc. Observe pericardial sac and cut open to examine for any fluid accumulation. Lungs may be examined for congestion, fibrinous or cheesy material accumulation. Observe the liver surface for any fibrin deposits/necrotic foci/ granulomas.

- The intestines are freed by cutting through the oesophagus just anterior to proventriculus and liver. The intestines can be removed by gentle traction which breaks the mesenteric and airsac attachments.After removal of the intestine, ovary, oviduct and kidneys should be observed. Cut open the proventriculus and examine its surface for any haemorrhage or enlargement. Observe the proventriculus and gizzard junction.
- All the lobules of kidney filling the abdominal cavity must be examined. The sciatic plexus beneath the kidney should be examined after removal of the kidney tissues. The bronchial plexus should be examined on either side near the thoracic inlet.
- The softness or hardness of the ribs should be noted. The nasal cavites and sinuses should be examined for the presence of exudates and discharges.
- To examine the brain, separate the head and reflect the skin over the skull. The skull may then carefully cut in the midline with sharp, firm scalpel and transeversely likewise. The four quarters may be reflected outwards from the middle by firmly holding it with forceps. The whole brain surface may be examined for any haemorrhages or necrosis etc.
- Tentative diagnosis can be made based on the history and lesions observed. Appropriate samples must be collected for laboratory examination for confirmatory diagnosis.
- After examining the carcass and collecting suitable materials for laboratory examination, it should be properly disposed.

Typical Post mortem findings in various diseases of Poultry

Sl.No	**Diseases**	**Typical Lesions**
I. Viral diseases		
1.	Ranikhet disease	Pinpoint haemorrhages on the tips of glands in proventriculus, haemorrhagiccaecal tonsils, haemorrhagic changes in the

		intestinal walls.
2.	Gumboro disease/ Infectious Bursal disease (IBD)	Enlarged/swollen bursa, Haemorrhages on its inner surface, haemorrhages in the thigh and breast muscles.
3.	Infectious bronchitis (IB)	Haemorrhagic bronchitis, caseous plug in the trachea, congested lungs, Kidneys enlarged and show gout symptoms
4.	Infectious Laryngotracheitis (ILT)	Caseous plugs and haemorrhages found in trachea and bronchi. Mucosa haemorrhgic.
5.	Fowl Pox	Skin form: Pox lesions on the comb, wattles and eye lid Diptheritic form: small white nodules or cheesy plaques in larynx and trachea.
6.	Avian Influenza	Bluish discolouration of the comb, wattles and shanks, head swollen, eye discharge, haemorrhages on heart and muscles, congested trachea and lungs, severe haemorrhages throughout the body.
7.	Marek's disease	Thickening of peripheral nerves mainly sciatic nerve and brachial plexus with disappearance of cross striations and glistening diffuse enlargement or nodular lesions found in liver, spleen, kidney, ovary, lungs, heart and proventriculus, etc.,
8.	Lymphoid leukosis	Diffuse enlargement or nodular lesions in liver, spleen, kidney, intestine etc.,
9.	Egg drop syndrome (EDS_{76})	Inactive regressed ovaries and decrease in size of the oviducts.
10.	Inclusion body hepatitis (IBH)	Liver pale, swollen and haemorrhagic.
11.	Chicken Infectious Anaemia	Anaemia, atrophy of lymphoid organs, haemorrhages and thymic atrophy, yellow or pale bone marrow
12.	Avian nephritis	Visceral gout

13.	Adeno virus infection (Leechi disease)	Hydropericardium giving peeled leechi fruit appearance

II. Bacterial diseases

1.	Colibacillosis/ colisepticaemia	Fibrinous exudate covering the liver and heart. Egg peritonitis, omphalitis, salphingitis and synovitis of hock joint
2.	Infectious coryza	Swelling of the face, Mucus or pus with fibrin in nasal passage and infraorbital sinus.
3.	Fowl Typhoid	Enlarged and congested/ coppery bronze colour liver.
4.	Fowl Cholera	Necrotic foci in liver, enlarged and haemorrhagic liver
5.	Tuberculosis	Granulomas in visceral organs, in liver, spleen, bone marrow and gut.
6.	Salmonellosis	Lungs, liver, spleen and kidneys enlarged, congested. Unabsorbed yolk. Necrotic foci in lungs, liver and heart.
7.	Avian Mycoplasmosis/ Chronic respiratory disease (CRD)	Cheese-like material in the air sacs and pneumonia Accumulation of fluid and thickening of the synovial membrane.

III. Others diseases

1.	Coccidiosis	Caeca enlarged and distended with clotted blood Ballooning of middle portion of intestine and filled with blood.
2.	Gout	Urate deposition in kidney, heart, proventriculus and lungs, White chalky deposits in the joints.
3.	Aspergillosis	Yellowish white plaques or nodules in the lungs and air sacs.
4.	Aflatoxicosis	Enlarged liver, kidney and spleen are enlarged, friable and haemorrhagic.
5.	Rickets	Soft and rubbery bones, keel bone curved and beaded ribs.
6.	Fatty liver syndrome	Liver enlarged, pale and fatty

7.	Heat stress	Breast muscles are pale and present cooked meat appearance
8.	Bumble foot	Abscess in the foot pad
9.	Egg Peritonitis	Thickened yolk, cheesy semi-solid yolky material in the abdominal cavity.
10.	Ascites	Large amount of fluid in the abdominal cavity. Enlarged heart. Accumulation of fluid in the pericardium. Liver swollen and congested. Lungs congested.
11.	Necrotic enteritis	Small intestine thickened, yellowish or greenish material inside the intestine.

Post-mortem examination only gives tentative diagnosis based on the lesions found; however, laboratory examination is essential to make confirmatory diagnosis.

Sample collection for laboratory examination

- **Tissues for histo-pathological examination**

Tissue sections of 3-5mm or pieces placed in 10% formal-saline in a ratio of tissue to fixative of 1:15 can be preserved in room temperature for histo-pathological examination.

- Impression smears
- Swabs for bacterial culture and examination
- Tissues for virus isolation

Poultry Housing and Management

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Four major ingredients essential to success in the poultry business are good birds, good feeding, good management and good record keeping (Ensminger, 1993). The term management refers to ideal combination of elements of an enterprise to optimize the output and returns. Hence poultry management in broader sense includes rearing, feeding, disease control, marketing and other aspects (Sreenivasaiah, 1998). However, it literally means the art of rearing birds or art of caring for, handling or controlling.

POULTRY HOUSING

Housing of birds is essential to protect them from sun, wind, rain, extreme variation in temperature and predators. Proper housing is a prerequisite for profitable poultry production. There are different housing systems depending on type of rearing of birds.

Housing Systems

1. **Free-range:** In free-range system of rearing birds are set free to roam for scavenging without provision for night shelter. Stocking density of birds under this type of rearing is about 250-birds/ hectare of land.
2. **Semi Intensive:** Under this system birds are reared halfway in houses and half way on range and stocking density is usually 750 birds per hectare of land.
3. **Intensive System:** In this system birds are confined entirely to houses, this system is most efficient, convenient and economical as compared to other systems. Again in Intensive system there are different types houses depending upon the system of rearing.
    - **Deep litter:** Here birds are reared on floor with litter materials spread on the floor. By and large broilers and broiler breeders are reared on deep litter system.
    - **Cage rearing:** In cage rearing birds are reared in metallic cages and stocking density in cage rearing will be high as compared to the deep litter system of rearing. Cage system of rearing is more popular in our country and layers and layer and broiler breeders are reared in cage system of housing.

- **Slat and litter house:** In this type of house the floor is partly covered with slats and partly with litter material. These types of house have advantages of deep litter system of house and all slat houses. This system is used for meat-type breeders.
- **All slat house:** Under this type of house the floor is entirely of slat type and fecal material is accumulated beneath the slat.

Types of Houses

I. **Controlled environment houses (Non-conventional-closed):** In this system houses are entirely closed; optimum requirements of birds like temperature, humidity and air movements are controlled by artificial means. Artificial light is provided to illuminate the interior. On most occasions animal heat is used and additional heat is used mainly during brooding period. This system is mostly followed in developed country as financial involvement is very high for construction of controlled environmental houses.

II. **Open sided houses (Conventional):** In this system side walls of poultry house are partially or completely opened and fitted with wire mesh for free movement of air. In India this type of housing is followed most commonly.

Sub types of open sided houses:

a. Brooder house-cage/deep litter
b. Grower house-cage operation
c. Layer house-cage operation
d. Breeder house with pens- deep litter
e. Broiler house- deep litter rearing
f. Hatchery building

Site Selection: *The site for construction of poultry houses should be selected in such a way that the low lying areas with a potential to flooding should be avoided. Preferably elevated areas with good drainage facility must be selected. Availability of the basic infrastructure facilities such as water (low salt content), electricity and access to all weather roads must be taken into consideration before selecting the site for construction of poultry houses.*

Orientation: *Orientation of the houses is usually in east-west direction to avoid direct sun light, draft and rainfall into the building***.** *Prevailing wind direction through out the year at the site of poultry houses must also be taken in to consideration in order to benefit from natural ventilation.*

Construction of Houses

Houses are preferably constructed on elevated areas with a plinth of 0.6 - 0.9 m to keep the floor above the ground level in order to avoid seepage of moisture from surrounding of the houses. The floor of poultry houses must be pucca, durable and easy to clean and disinfect and it should be termite and rat proof. The height of the poultry house at sidewall should be 2.1 to 2.4 m and 3.0 to 3.3 m at the centre to provide slope on either side. The roofing materials like tins, asbestos sheets, tiles or thatches may be used for construction. The overhang of roof should be sufficient (1 to 1.5 m) to offer full protection from sun and rain. For low cost housing locally, available construction materials like bamboo, wooden planks, thatch, grass, etc. may be used.

A brooder house where young chicks are grown up to 4 - 6 weeks of age should be constructed with $2/3^{rd}$ portion of the side wall made of solid material from floor level and remaining $1/3^{rd}$ portion may be fitted with chicken mesh (wire-netting) for open air ventilation. For adult birds and broilers reared on deep litter system, half of sidewall of the houses should be constructed with bricks and another half with wire netting. For growers, layers and breeders reared in cages sidewall should be of wire netting type. The width of poultry house may not exceed 9 m to have effective cross ventilation and length of the house may be as per the requirement. There should be sufficient space between poultry houses to prevent the spread of poultry diseases. Footbaths in front of the doors of poultry houses to keep disinfectants should be constructed to prevent the transmission of poultry diseases.

BROODING MANAGEMENT

The management with due care of baby chicks till 4 - 6 weeks of age is known as brooding. This is the most critical period in the rearing of chicken so proper brooding management is crucial in achieving efficient growth and preventing undue mortality of chicks. There are two types of brooding.

I. Artificial Brooding

Artificial source of heat is used to provide extra heat to chicks to maintain their body temperature as baby chicks lack well developed body feathers to conserve body heat. Temperature at brooder required during first week of brooding period is 35 ^{o}C which has to be reduced @ 2.8 ^{0}C per week till the end of 4th week / up to 21 ^{o}C. The source of artificial heat used may be electricity, wood, gas, sawdust, kerosene, and infrared light depending on type of brooder used. “Bukharies’ with burning of wood, charcoal or sawdust are useful in remote areas where availability of electricity, gas or kerosene is limited and it is very much useful for smaller farms.

Preparation of Brooder House

Brooder house should be thoroughly cleaned, disinfected, and fumigated. The equipments like brooders, waterers, feeders, etc. should also be cleaned and disinfected well in advance. Overnight fumigation of house must be done 24 hours before housing chicks and should be ventilated it at least for 3 - 4 hours to remove traces of poisonous gas. Spread litter material such as dried sawdust, rice husk or wood shavings on floor with 5–10 cm thickness.

For the first 7 to 10 days old news papers/any papers have to be spread over the litter material in order to prevent chicks from eating litter material and subsequent choking. Feed or maize grit has to be sprinkled on papers for feeding of chicks in initial stages. Remove the top layer of paper daily to clean, turn it upside down after 4 or 5 days and remove it altogether after 8 or 10 days. About 50 – 66 cm^2 space per chick under brooder is recommended. Arrange waterers, feeders, etc. in wheel-spoke pattern around brooder for easy accessibility of feeder and waterers to baby chicks and run empty brooders for 4-5 hours before arrival of chicks to confirm maintenance of temperature.

Brooder Guard: Also known as chick guard is a barrier provided around brooder to avoid straying away of baby chicks from source of heat, feed and water and to prevent floor drafts. A cardboard or metal sheet of 0.45 m height placed in circular manner at a distance of 0.85 to 0.90 m from the edge of brooder acts as brooder guard.

A) Floor Brooding: Under this system chicks are reared on deep litter and there are two types of floor brooding.

- **Incandescent bulbs brooding:** Under this method Incandescent bulbs of 40 to 100 watts are used and canopy is required to preserve the heat in brooding area.
- **Infrared bulb brooding:** Infra-red-red and white bulbs of 150 or 250 Watts for 75 to 90, and 125 to 150 chicks respectively are used. Usually there is no need for canopy to preserve the heat since the materials or chicks get heated which directly come in contact with the infrared rays.

B) Battery Brooding: Here brooding is carried out in brooder cages. In this method birds are reared in a battery brooder which consists of 4 to 5 tiered batteries each of which has the heating space comprising one thirds of the total area and the remaining portion as the 'run space'. The heating unit consists of an electric heater with a thermostatic control; the heating space is also converted with the false roofing made of GI to trap the hot air. Paper is spread on the mesh flooring and after 10 days it is removed so that the droppings fall directly into the fecal trays.

II. Natural Brooding

In this method body of broody hen, which incubates and hatches out chicks, is used for brooding. A broody hen can comfortably take care of hatching and brooding of 12-15 chicks. The broody hen and day old chick must be provided brooding nest and protection in the night. Scratch feeding of grains or home waste may be practiced for faster growth of chicks. The broody hen must be allowed to take out newly hatched chicks in daytime for foraging of food. This system is commonly practiced in backyard poultry farming.

LIGHTING MANAGEMENT

Artificial light in the poultry house must be provided to encourage feed consumption, optimum growth and to prevent birds from piling or stampeding when scared.

Lighting in layers: To start with 48 hours of continuous light should be provided followed by dim light during all dark hours except for 1 hour at night during brooding period. At floor level, the light intensity should be 0.5 foot candle, which can be supplied by one 150-watt bulb for each 1000 sq ft of floor space. In growing period (8 -18 weeks) light duration should not exceed 10 – 12 hours. During laying period (after 18 weeks) birds need light for 15 to 16 hours duration. Extra light required during laying period might be given either in the evening (6 pm to 10 pm) or early morning (2 am to 6 am) or both in evening and morning (6 pm to 8pm and 4 am to 6 am).

Lighting in broilers: Lighting in broilers should be started with 23 hours of continuous light with light intensity of 2.0 foot candle (20 lux) with one hour of darkness in first 24 hours duration. Subsequently, dim light with intensity of 0.5 foot candle (5 lux) during all dark hours except for 1.0 hour must be given. Alternatively below mentioned (Table 2) lighting schedule may be followed in commercial broilers.

Table 2. Light schedule in commercial broiler production

Age of broiler (days)	**Light Intensity (lux)**	**Photoperiod**
0.-7	20	23.0 h light : 1.0 h dark
8-35	5, increase light 2 h / week	17.0 h light : 6.0 h dark
36-49	5	23.0 h light : 1.0 h dark

Stocking Density: It is essential that birds should have adequate floor, feeder and waterer space irrespective of whether they are housed in small groups on village farms or in larger semi-commercial or commercial sheds. Lack of space can lead to leg problems, injuries and increased mortality. Below mentioned (Table 3) floor, feeder and waterer space are normally followed in commercial layer and broiler production

Table 3 Optimum floor, feeder and water space per bird at various stages of growth in deep litter system of rearing for layers and broilers

S. No.	**Particulars**	**Floor-space** (cm^2)	**Feeder space** (cm)	**Water-space** (cm)
1	Brooding period (0-8 weeks)	450	2 - 7	0.5 - 1.5
2	Growing period (8-18 weeks)	900-1900	7 - 10	1.5 - 2.5
3	Laying period (above18 weeks)	1800-2200	12 - 15	2.5
4	Broiler Starter (0-3 weeks)	450 (0.5’)	2-7	0.5 to 1.5
5	Broiler Finisher (4-6/7 weeks)	750-850 (0.95’)	7-10	1.5 to 2.5
	EC houses (Broilers)	0.5-0.75’		

LITTER MANAGEMENT:

Litter management is very important in most poultry production systems. Floors in poultry houses are normally of concrete type and saw dust, paddy husk are used as litters to cover the floor. Litter dilutes manure, provides cushioning and insulation for the birds and captures nutrients that are used subsequently to fertilize the field. Litter is also a medium for birds to scratch and is important for welfare. Birds are also raised on slat floors through which the droppings fall into a pit below and are later removed. Droppings are required to be kept dry to reduce odors and flies.

Common litter materials include, saw dust, paddy husk, or soft wood shavings, other materials may be suitable include sand, recycled newspapers, ground nut hulls, etc., Litter material should be high in carbon to prevent loss of nitrogen and should compost well. Birds have a concentrated form of waste called uric acid, which makes it possible to keep a lot of birds on litter, but moisture can build up. If litter feels damp to the back of the hand, it is probably at least 30 percent moisture. The house should be ventilated well to remove moisture in the air and water leaks or sources of moisture such as condensation from un-insulated metal roofs should be avoided.

High moisture in litter is very problematic, resulting in cake or a nonabsorbent crust. Caking especially occurs under waterers or other high impact areas. Wet litter causes breast blisters and sores on the birds' foot pads and hocks, and pathogens and parasites such as coccidian proliferate. In wet litter, uric acid is converted by bacteria to ammonia. Ammonia is a toxic gas that can damage the respiratory system of the birds and make them more susceptible to infections. Ammonia levels should not exceed 25 parts per million (ppm) in the house. Fly larvae also grow in wet litter and can be a nuisance.

Litter moisture guideline

When a handful of litter is squeezed, the ball should begin to break up when released. When the litter is too wet, it remains balled up. When litter is too dry, it will not ball up.

FEEDING MANAGEMENT

Since feed alone accounts for 70% of the total expenditure of poultry production process it is imperative to efficiently utilize the feed by incorporating better feeding practices. If feeder space is insufficient, growth rates will be reduced and uniformity will be compromised. Feed distribution and the proximity of the feeder to the birds are essential for achieving optimum feed consumption rates. In tropical developing countries, the main factor reducing feed consumption is high micro-environmental temperatures. Feed should be withheld at the hottest time of the day, to prevent heat stress and the resultant mortality. Pan feeders are better than trough feeders, as they allow unrestricted bird movement around the feeder and there is lower incidence of feed spillage and improved feed conversion.

In most commercial operations, automated pan or trough and chain feeders are used, providing 2.5 cm of feeder space per bird. To reduce feed spillage, the lip of the feeder should be at the level with the bird's back. Feed should be kept in rodent proof storage area for keeping at least for five days of feed consumption. Farmers must store the feed in strong watertight bins, to reduce the risk of rodent attack and of mould and bacterial growth on the feed.

General Principles of Feeding

1. The poultry feed should be well balanced with respect to energy, protein, minerals, vitamins, fiber and moisture (water).
2. Feed should be free from microbial contamination.
3. Feed should not be stored more than 1.5 months.
4. Feed in feeders should be stirred twice daily.
5. Minimum of two feeding norm i.e. feeding in the morning and evening should be followed for optimum consumption of feed.
6. Feeders should not be filled more than 2/3rd of their capacity to avoid wastage.
7. Overfeeding or underfeeding of birds must be avoided.

GENERAL MANAGEMENT

In addition to providing the proper temperature, ventilation, lighting, and litter conditions for the birds, feeding, watering, and health are important parts of management. Birds and equipment should be inspected at least twice per day to monitor health and identify any problems. Caretakers should be trained in bird management and welfare. They should treat the birds calmly with no rough handling.

Beak Trimming: It is also known as debeaking. The main objective of beak trimming is to prevent vices like cannibalism, vent pecking, feather pecking, toe pecking and body injury while fighting of birds. Beak trimming should create as little stress as possible and at the same time it should ensure that beaks do not grow again. Beak trimming is practiced at different ages like day old beak trimming, early precision beak trimming (5-10 days), beak trimming at 4-6, 6-8, 8-16 weeks or just before the start of egg laying.

Dubbing: Removal of comb is referred to as dubbing. It is mostly practiced in White Leghorn layers/breeders to prevent the injury to the comb and obstruction to the vision while feeding by the birds. It is best done at day old or at least within the first few weeks of life to minimize hemorrhage. Dubbing is usually carried out using a pair of manicuring scissors facing concave side of scissors towards upper side and running from front to back.

Toe Clipping: The inside and back toes of all breeding males are clipped to prevent tearing of backs of the females during mating. It is best done at the hatchery/ 6-8 days of age at the time of beak trimming.

Pest Management: Pest cause more nuisance and transmit diseases to the poultry, if allowed to multiply they completely run over the farms and creates unhygienic situation. Integrated pest management (IPM) approach has to be adopted to control the pests like flies. Natural factors such as climate (temperature), litter moisture and predators play important role in control of flies and it is observed that about 95 % of flies are controlled by these factors and IPM has to deal only with 5 per cent of flies. Some important steps in IPM include prevention of leakage of water through nipples and drinkers to maintain the moisture below 60 % in the litter. When manure is to be removed in a build-up system, a 10-15 cm pad is left to allow 'seed' of beneficial insects to survive. Spraying of insecticides on manure must be avoided. Ventilating pans can help dry the manure. Raking or stirring of litter is a very efficient management practice to keep litter dry, powdery and resilent without affecting natural habitat. In cage layer houses, high-rised heaps or cones of droppings are indicative of proper drying of manure.

Rodent Control

Rodent control is a very important management practice in poultry production; rats kill chicks, eat feed, and spread disease. Common species of rodents that cause problem in poultry farming are Norway rat (*Rattus norvegicus*), the roof rat (*Rattus rattus*), and the house mouse (*Mus musculus*). Rodent control is a system based approach of prevention and exclusion including the following.

Habitat Reduction: Vegetation should be kept short around houses, spilled feed cleaned up, hide-outs dismantled, including scrap piles. Rodents should be exposed so they are vulnerable to predation.

Exclusion: Concrete or gravel floors help keep rodents from tunneling into a house. In a small portable house with a raised floor, the space between the ground and the floor provides attractive, darkened nesting sites, unless the floor is high enough above the ground that rodents do not feel protected. Poultry feed should be stored in rodent-proof containers. Traps such as snap traps, sticky traps, or mechanical 'tin cat' traps can be used to control rodents.

Predators. Cats and dogs can help control rodents; rat terriers are especially helpful. Barn owls eat rodents but also eat chicks unless the chicks are in predator-proof houses at night.

Bait. Rodenticides can be incorporated into attractive food as baits to control rats. **Anticoagulants.** Since these rodenticides prevent blood clotting, the rodent dies through internal bleeding. The well-known Warfarin© was the first type developed. Multiple dose anticoagulants are the safest type to use, since a rodent has to nibble the bait several times to be affected. Single-dose anti-coagulatants are more lethal and work faster but are less safe around children and pets.

Norway rats live underground in burrows, where bulk pellets should be placed. Roof rats and mice can be controlled with blocks that are nailed or tied down to prevent them from dragging blocks away to store. Putting bait in a bait station will keep random animals from eating the bait. Baits are usually rotated to prevent rodents from becoming accustomed to them. Sulfur dioxides, or smoke bombs, are permitted as an underground rodent control.

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Poultry Farm Management for Better Production and Productivity

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Poultry production in India from 1960 to till to-day is a great affair. From scratch it has come to a viable Industry representing our country in the global level of 3rd. place in egg production and 5th in chicken meat production. The enormous efforts put, in managing this Industry by the Scientists, Managers and other workmen involved in the field are countless. The management of the chicken from day-old to the production level in terms of egg and meat are manifold. Effective and strict management techniques are required for the birds to exhibit their production potential. So to start with, we will go-through the different management procedures involved in raising poultry.

Overall Farm Operations include

A. Chick Management/Brooding Management
B. Grower Management
C. Breeder Management

A. Brooding Management: It is the management of chicks or nursery rearing

Isolation of the brooder House

Chicks should be brooded in a house that is not located near other poultry due to danger of disease transmission. At least 300 ft. should be allowed between such houses. But a greater distance is preferable. Air moment must be from brooder areas to other poultry area and should be enclosed with a fence at least 100 ft. from the house.

Preparation on of brooder House

a) Removal of old litter
b) Cleaning and scrubbing the house
c) Cleaning of the equipment
d) Fumigation of the House using 3xconcentration.
   (1x Concentration =20g of $KMNO_4$ + 40ml of Formalin)
e) Cleaning and fumigation of bulk feed bins
f) Treatment of dirty floors with disinfectant solutions.

g) Cleaning of the grounds

Removal of all weeds and debris from the area outside the farm, burning of feathers, mowing of the grass and making necessary road repairs are essential. If a track dip-vat is involved, then it should be made empty, thoroughly cleaned and fresh disinfectants added.

Equipments of brooding

a) Brooders/ Hovers (Electricity/ Gas/ coal brooders)
b) Brooder guards
c) Chick feeder
d) Chick waterers
e) Curtains
f) De-beaker

Requirements of brooding

a) Litter
b) Brooder Guards
c) Temperature
d) Ventilation
e) Floor Space
f) Feed and feeder space
g) Water

Litter: There are many types of litter material and most likely to be used is the most economical. But litters do differ. So to choice a good litter material certain qualities to be looked into

a) Be light in weight
b) Has a medium particle size
c) Be highly absorbent
d) Should dry rapidly
e) Be soft and compressible
f) Should show low thermal conductivity
g) Should absorb a minimum of atmospheric moisture
h) Be in-expensive
i) Be comfortable when sold as a fertilizer

In some cases it may be practicable to use reused litter, but the procedure is often plagued with problems

a. One should not use reused litter if the last brood of broilers was diseased
b. Always depopulate the building when reusing the litter.
c. Disinfection of the building and equipment thoroughly maintaining a low litter pH Very little ammonia will be released when the litter is kept below pH of 7 but is rapid at a pH of 8 or above.

Recommendations for litter treatment

Phosphoric acid - 1.9 litres per 1 m^2 of space

Super Phosphate - 1 kg per 1 m2 of space

Litter material to be covered on the floor to a thickness of 2" (5cm)

Litter Management: During the first 3 weeks of the chick's life the litter should be only slightly moist. After that it should contain about 25% moisture. The brooders should not be started until the day before the chicks are to arrive as this tends to dry the litter too much. When the chicks are placed on exceptionally dry litter, there is a tendency to increase their dehydration. There must be some humidity in the poultry house. Chicks don't grow or feather well in a dry atmosphere.

Brooder Guards: Brooder guards should enclose the heated area. Height of the guard should be 16". The type of the brooder will determine the distance the guards should be from the edge of the hover. But normally the distance should be about 30 inches in winter and 36 inches in summer. Begin increasing the area on 3rd day. Guards should be used for 6-9 days (we can also go up to 18 days, but inner area to be increased frequently) after which they may be removed.

Temperature: It is difficult to recommend any brooding temperature applicable to all types of brooders and all conditions. Usually however a temperature of 90 to 95^{o}F at a point of 6" (15 cm.) outside the canopy and 2" (5cm) above the top of the litter is satisfactory for chicks at 1 day of age.

As the chicks grow older the temperature may be reduced at a rate of 5 ^{o}F per week till it reaches 70$^{.F}$ or room temperature. Thermometer is a poor tool for measuring chick comfort. The chicks themselves should be the indicator. At night they should be down just outside the edge of the hover and completely circle the brooder. If they are too far-out, the temperature is too high, if too far-in, the temperature is too low. Thermometer should be used before the chicks are placed under the hovers, but after 1st two days the same may be removed and stored. Chicks should be fully feathered before supplementary heat is removed. Brooding is done up to 4 Weeks to 5weeks in cold weather a 2nd to 3rd weeks in warm weather.

Ideal brooder should be 5ft. diameter on 2.5 ft. radius. Number of Chicks to be brooded under the hover depends on the brooder size. 10 sq. inch of heating space is normally required for each chick. Two types of brooding area one is brooding or heating area (1/3rd of total area) and the other one is non-brooding or non-heating area (2/3rd of total area). Required floor space should be coordinated with the heating area.

Total number of chicks to be brooded in an area can be calculated using below mentioned formula

$$\frac{\text{Total area } (\pi r^2)}{10 \text{ sq. inch}} = \text{Total no. of chicks.}$$

Brooding defects: Brooding defects happen either due to increase or decrease in temperature. If there is low brooding temperature then chicks will pile up and results in respiratory problems. 62 ^{o}F is the lower lethal temperature of day old chicks. Chicks withstand more cold than more heat. 117 ^{o}F is the high lethal temperature, chicks become dehydrated and results in more mortality.

Ventilation: Inflow of air (for O_2 requirement)—2cu. ft. of air/ 100 chicks/ min. is required for effective ventilation. It can be achieved by the 2-3 air changes. Air changes depend on the no. of birds housed, no. of openings kept and dimensions of poultry house.

Floor Space: It is one of the most important attribute to be looked in to for achieving final performance of the chicks whether it is layer or broiler. More chicks in a specified area lead to cannibalism.

1st week 10 sq. inches/chick

2nd week 25sq. inches /chick

4th week 45 – 65 sq. inches/ chick

A minimum of 700 sq. cm. should be maintained per chick up to 6th week of age.

Feeder space: Optimum feeder space to be given to chicks is 3.5 to 4cm /chick. Mainly we use linear feeder. So it is always wise to hove half of the feeder inside the brooding area and other half in the non-brooding area. Never allow the chicks to go beyond 10’ to take food so we do frequent feeding. When circular pans are used allow about 20% less feeder space /bird. With 15” diameter pans provide one pan for every 33 broilers. Feed requirement depends on the age of the chicks. We use two types of feed i.e. broiler starter and finisher diet.

Water: Chicks must learn quickly to eat and drink. Although they can get along without water and feed up to 3 days after hatching but such a delay will be detrimental. Any postponement will weaken and dehydrate the chicks. Water is very much important as it serves many functions in the body. Water space to be provided is 25 to 100cm for every 100 chicks. Placement of waterer should be in between two feeders and exactly under the hover. Provide two fount type chick waterers for every 100 pullet chicks for 1st and 2nd week. After two days the founts should be placed on stands about 1" (2.5cm) high to keep litter from getting in them. Fill the waterers about 4hours before the chicks arrive. This allows time for the brooder heat to warm the water. The water temperature should be 65 ^{o}F (18 ^{o}C) and over. Use always fresh and potable water. Water consumption is two times than the food consumption.

B. Grower Management

The growing period follows the brooding period and concludes with sexual maturity. Perhaps in this age the chickens command the respect of management. How well a bird is grown will greatly determine how well it does in the laying or breeding house.

There are different methods of growing as mentioned below

a. The Grower House------------------- very good
b. The Brood – Grow House------------ Compatible
c. Grow- Lay house ---------------------- also compatible
d. Brood – Grow –Lay house---------- not compatible

Floor: The type of floor in the growing house will vary the management recommendations. Litter, part slats, part wire, all wire and cages are used for growing pullets and cockerels and alter certain procedures. Floor space needed by different stains and ages of birds is highly variable. However, the requirement of floor space is 0.8 sq. ft. at initial stage and 1.5 sq. ft at last stage of growing. For meat type breeder pullets the requirement is 2.5 to 3.0 sq. ft/bird. Slat or cage rearing is excellent also, we can opt for completely wire floor rearing.

Feeder space allocated is 2" at the beginning and to be increased to 3" by 20th week period, similarly the waterer space allocated is 0.6" (1.5cm) of linear length at the beginning and to be increased to 0.85" (2.2cm) by 20th week. Litter to be very well managed during the growing period very effectively for control of coccidiosis.

Debeaking: One must do debeaking at this grower stage otherwise cannibalism will be a problem. To properly trim the beak of a bird, a part of the upper and lower mandible is removed with an electrically controlled cauterizing blade having a temperature of 1500^{o}F (815^{o}C). Precautions during debeaking are

a) Don't trim beaks when birds under stress
b) Sulfa drugs causes profuse bleeding
c) Trimming machines are sources of infection
d) Watering device may not be satisfactory (problem in nipple or drip type waterers, so better founts type waterers)
e) Increase the depth of feed in troughs
f) Add vitamin-k during the period of stress due to debeaking.

Lighting: Growers do not need artificial light. Duration of light should be 9 hours. Growing birds are susceptible to cannibalism but the vice may be partially eliminated by using light intensities of less than 0.5 fc (5 lx) at bird level. Light not only makes easy for the birds to eat and drink but also it affects the pituitary gland at the base of the brain and the stimulation causes mature pullets to begin the production of eggs.

Pullets tend to come in to the egg production at a younger than normal age if they are grown under natural day light during the time when day light hours are lengthening (**out-of-season** birds). When the days get shorter and those grown during the period have decreasing light are known as (**in-season** birds).

C. Breeder Management: 16-18 weeks is the more ideal for shifting growers to the cage house or layer house – 20 weeks too late and 14 weeks too early. It is of two types

1. Floor management
2. Cage management

1. Layer Management in floor

When the birds are to be moved from a growing house to a laying house just prior to sexual maturity, the usual routine of cleaning the house and equipment are fallowed as usual in brooder house preparation. Add about 3 inches (8 cm) thickness of litter material during summer months and 4 inches (10 cm) during winter months. Crippled, emaciated and blind birds are to be removed before moving to layer houses. If a coccidiostat has been used in the growing period, then continue to feed the same on the slat or wire floor 2 or 3 weeks, and then gradually withdraw it. Nests should be put in the laying house and open about a week before the first eggs are laid. This allows time for the pullets to get accustomed to them prior to the egg production. (Floor eggs can be prevented). Nests to be kept always in darken areas and bedding material to be changed frequently.

Floor space requirement: 2 sq. ft. space for layers in deep litter system. In slat it is 75% of 2 sq. ft. In cage house it is 60% allocation of the deep litter houses.

Feeder space: Allocation is 3” per bird. If pan type then 16 birds / pan. If it is a tubular feeder then 14 birds / feeder. If meat type birds then 3.5” feeder space. Pan type – 14 birds and tubular feeder – 12 bids.

Waterer space: 1” waterer space in linear feeder per bird is required. If the pan (round) type water is used then – 25 birds each.

Grit: Requirement of grit for shell and to build up body reserve. Shall grit is a part of feed only (source of ca.)

House temperature and laying performance

As the ambient temperature rises the laying pullet undergoes many changes. Rising temperature increases water consumption, respiration rate, body temperature and stress where as rising temperature decreases oxygen consumption, blood pressure, interior egg quality, egg shall quality and all. The optimum house temperature should be 80 ^{o}F (27^{o}C)). Both hot and cold weather makes problem to the birds.

Cold weather: Moisture built up and house temperature below freezing needs to be taken care, whereas moisture build up can be solved by the managers ability to regulate the movement of air to remove most of the moisture from the house while conserving the heat as much as possible, but for a house temperature below freezing, only a better house construction is the only positive answer to the difficultly.

Hot weather: At temperatures above 80 ^{o}F (27^{o}C) laying pullets begin to suffer and performance begins to diminish. At 100 ^{o}F (38 ^{o}C) things become serious. Egg production drops drastically and many birds die from heat stress.

Handling the summer stress

1. Insulation of the roof of the ceiling
2. Increase of ventilation
3. Providing fans

4. Lowering the humidity
5. Use of foggers
6. Provision of sprinklers on roof
7. Wet areas outside and around the house
8. Provide cool nests
9. Give cool and fresh water
10. Feeding during morning and evening (cool hours)
11. Keep activity in the house to a minimum

Light management: 17 hours of light duration is required for the birds for optimum production and the intensity is 1 fc (10 lux) at bird's body level. Generally, red coloured lights are useful for broilers. In layers florescent light is enough.

(2) Cage Management: It is otherwise known as wire floor management. At least 70 to 75% of the laying flocks now a days are housed in cages.

Advantages

1. Easier to care for the pullets
2. Floor eggs are eliminated
3. Culling is expedited
4. Less feed required to produce a dozen of eggs
5. Broodiness is eliminated
6. More number of pullets housed in a given house floor space
7. Labour requirements are reduced.

Disadvantages

1. Handling of manure is a problem
2. Flies become a great nuisance
3. Heavy capital investment

Lighting programme is same as in floor management

Production standards

Definition: production standards are not the averages of what the birds will accomplish under field conditions but are somewhat higher.

Importance is to provide the poultry man a guide like material to know the capacity of his own flock whether it is producing at standard, above standards or below from which the poultry men knows whether he is doing a good or a poor job of management.

Production indices: Production indices are a good rule of thumbs

a) **Hen day egg production for one day**: the formula is a measure of the egg productivity of the live hens on any given day -

No. of egg production

------------------------------x 100 = % hen day production for 1 day

No. of live hens

Example: There are 1000 hens alive on a certain day and they produce 750 eggs that day. Their hen day egg production is 75%.

b) **Hen housed egg production for one day:** The formula is the measure of the egg productivity in relation to the number of hen (housed) at the beginning of the laying period.

No. of egg produced

-----------------------------x 100 = % hen housed production for 1 day

No. of hens housed

Example: 1200 hens were housed at the beginning of the laying year. To-day they laid 750 eggs. Their hen-housed egg production is 62.5%.

c) **Hen -day egg production for a log period**- This may be calculated by first computing the number of hen days in the period by totalling the number of hens alive on each day of the period. Then calculate the number of eggs laid during the same period.

No. of egg produced

-------------------------------------x 100 = % hen day egg production for the period

No. of hen days in the period

d) **Hen housed egg production for a long period**: First compute average number of eggs laid per day during the period - the formula is

Average daily No. of eggs produced

--x 100 = % hen housed egg production for the period

No. of hens housed

Measures of performance efficiency in broilers

1) **Feed Conversion Ratio**

$$= \frac{\text{Total feed Consumed}}{\text{Total Body weight}}$$

F.C.R. should be always ≤ 2.

***2*) Performance Index**

$$= \frac{\text{Live weight in pounds}}{\text{Feed efficiency}} \times 100$$

3) Benefit Cost Ratio

$$= \frac{\text{Gross Receipts}}{\text{Total cost of Input}}$$

When we get 1 and above is profitable and less than 1 is loss

Artificial Insemination

Definition: It is one of the processes of fertilization. When the insemination is done artificially or with the assistance of human being without the physical involvement of both male and female birds together is called as artificial insemination.

It involves two processes such as Milking/ semen collection and insemination.

1. **Milking:** During the process of milking the male bird is kept and controlled gently under the left shoulder joint of the person who is catching the bird and then the other man / technician helps in massaging the sub-lumber region of the male birds gently by his left hand which helps to protrude the papillae and the semen is ejaculated which is collected in a clean and sterilized funnel (glass/plastic) by the right hand of the technician. Generally the first ejaculation by a single male bird contains 1(one) ml of semen but subsequently it reduces in volume say 0.5ml on even less. So it is better to milk the birds once only. Then immediately the semen is sucked in to a tuberculin syringe.

2. **Insemination:** In this process also there is involvement of two individuals; one person will catch the female bird in his left hand little tightly to both the legs of the birds. Then with the right hand thumb a little pressure is applied in the inguinal region of the female birds gently, so that the female genital tract protrudes outside. While protrusion of the female genital tract it is not to be confused with the cloaca as it remains to right side and left side is the vagina. About 0.01 to 0.02ml of the total semen quantity already taken into the tuberculin syringe are deposited in to the oviduct of the hen to a depth of 1 to 2'' (2.5to5.0cm) through the vagina depending in the size of the female birds and their reproductive tract. After that the pressure in the inguinal region is relaxed and the bird is left. This completes the process of insemination. The semen must be fresh and insemination must be repeated at every 5-6 days interval to maintain optimum fertility.

Advantages of Artificial Insemination: It is many folds such as

- Requirement of less no. of males: In natural mating one male is allocated for 7-8 females. But one male can produce enough semen to fertilize 50-70 females on a week basis through artificial insemination.
- Less cost on rearing of male birds.
- Best male birds can be utilized for many females to have good progeny performance.
- Fertility is never a problem & within the control of the persons who are executing the A.I. programme.

Disadvantages of A.I

- Labour consuming
- Time consuming

Precaution

- To be executed late in the evening.
- Fresh semen to be used immediately to avoid spoilage & less fertility.
- While milking the excreta not to be mixed with the semen.

Biosafety in poultry production

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Disease prevention is a critically important part of rearing poultry. Healthy poultry are more productive and require less feed and other resources to maintain productivity. On form poultry management and disease control focuses on three areas: decreasing susceptibility to disease, increasing resistant and decreasing exposure to pathogen. Decreasing bird susceptibility to disease is accomplished by optimal management, including proper nutrition, good water, limited stress, prudent antimicrobial use and proper parasite control. Increasing bird resistance to disease is primarily accomplished by vaccination. Decreasing exposure to pathogen is accomplished by Biosecurity which is the cheapest and most effective means of disease control.

Biosecurity can be defined as a set of programmes and procedures that will prevent or limit the build-up and spread of harmful microorganisms and pests in poultry houses, poultry farms and poultry production areas and the biosecurity programme as the implementation of procedures to inhibit the movement of infectious agents harmful to poultry into, within or out of a facility containing poultry susceptible to those agents. Microorganisms can be discharged from infected birds via body orifices mainly the mouth, nose and cloaca, feather and skin debris, eggs, hatched embryos or biting insects. The extent to which organisms are discharged from infected birds depends on where and the degree to which the microorganisms multiply in the bird, whether the infection is modified by the bird's immune system and if the environmental/husbandry conditions to which the birds are exposed cause stress that depresses the bird's immune response.

Whether harmful discharged microorganisms can infect other birds and cause disease depends on:

- The resistance of the microorganisms to the external environment, such as temperature, humidity and sunlight
- Whether they can contaminate aerosol particles, equipment, vehicles, manure, dead birds, people, feed, water or other physical carriers of infectious organisms

- If they can be spread by other animals, rodents, birds and insects
- How far these physical and biological carriers of infectious organisms can travel and whether they come in close contact with poultry
- The number of organisms that are discharged from the original infected source and remain viable to constitute an "infectious dose"

The chain of infection

The aim of biosecurity plan is to reduce the risk of disease exposure and transmission. An understanding of how infections develop and factors that influence this outcome is crucial for implementing biosecurity and other disease prevention strategies. Diseases which can be transferred from one host to another are called infectious diseases. Infectious diseases result from the interaction of agent, host, and environment. A specific chain of events must occur before an infectious disease can be spread. Components, or "links" in the chain of infection include a) an infectious agent capable of infecting poultry, b) a source: an infected host, a reservoir of infection, c) a portal of exit from the source, d) a suitable means of transmission, e) a portal of entry into a new host and f) a susceptible host. This chain must be complete for an infection to occur. If the process of infection is stopped at any component or link in the chain, an infection is prevented. If a pathogen successfully enters a susceptible host the chain is completed, the host becomes a new source of infectious microorganisms and the process of infection continues. For an infectious disease to occur, each link in the chain must be connected. If even one link of the chain is missing, it interrupts the process, and no infection will occur. Biosecurity measures (isolation, traffic control and disinfection) can stop the infection by interrupting the process at all the links that are outside the susceptible host. The chain at the point of susceptible host can be disrupted by other measures of disease prevention and control, which include proper vaccination, good management practices and medication.

Aerosol spread and buffer distances

Geographical separation of farms can limit the risk of spread of disease by aerosols but is not a substitute for good "on farm" biosecurity. For instance, a biosecurity buffer will not protect a poorly managed flock that allows free access of wild birds to sheds. The level of risk posed by a poultry enterprise differs according to its type, size, location and management. It also depends on the diseases present, the level of infection in the flock, the topography of the site and wind direction. In a relative sense, breeder farms are viewed as being at the greatest economic risk because of the value of the fertile eggs derived from these flocks and the productive life of the flocks (8-12 months). Egg layer farms are viewed as the next most significant economic risk because of the lengthy productive life (12 months), and broiler farms have a lower economic risk because of the short productive life of (6-7 weeks). Duck and/or waterfowl farms, whether intensive or extensive, require a higher standard of biosecurity than most other forms of poultry production because of the potential interaction with wild birds, and the possibility that these flocks can act as reservoirs of serious poultry viral disease. Biosecurity buffer distance guidelines are presented in Table 1.

Table 1: A Guide on biosecurity buffer distances

Farm type	**Species**	**Buffer (m)**
New farm	Fowls/turkeys/other avian species eg. ratites, quail	1000
Units in large farm complex	Fowl/turkeys or other avian species	200 - 500
Farm complexes	Fowl/turkeys or other avian species	> 2000
Breeder farms	Fowl/turkeys or other avian species	2000 - 5000
Duck or waterfowl farms	Duck, waterfowl	5000

Three "STOP" Biosecurity Plan

The objectives of biosecurity are to STOP the entry of infectious organisms into poultry operation, to STOP build up and spread of infectious agents within a poultry operation, and to STOP the escape of microorganisms from an infected poultry operation. Biosecurity is a team effort, a shared responsibility, and an on-going process to be followed at all times. From the breeder to the hatchery, to grown-out operators, biosecurity measures have to be observed to contribute to the success of the industry. The major components of biosecurity, as practiced by the poultry industry, include: isolation, traffic control, sanitation, and rodent and insect control. The purpose of these practices is to prevent the introduction of pathogens and to provide the best living conditions for the health of the birds. In this way, the industry can minimize the risk of disease and insure the production of a clean food product.

1. STOP entry of Infectious agents into the farm.

- **Proper location and design of farm**
- **Isolation of facilities**

- **Cleaning and Disinfection of Vehicles/Equipment**
- **Limiting access to the farm**
- **Showering at the entrance of the farm**
- **Purchasing stock from know source**
- **Avoid borrowing equipment, feed, litter, etc. from another farm.**

2. STOP buildup and spread of infectious agents within poultry operation.

1. **Using separate vehicle for handling feedstuffs and handling manure.**
2. **Limiting vehicle and foot traffic within the farm boundaries.**
3. **Travel from the youngest group on the farms to the oldest.**
4. **Proper cleaning and disinfection of sheds, equipments etc.**
5. **Rodent, wild bird and pest control**
6. **Separating the sick birds from the healthy ones**
7. **Proper disposal of dead birds**
8. **Sanitizing Water Lines:**
9. **Checks on feed and water quality**

3. STOP escape of infection agent off the farm

- Self quarantine
- Adopting enhanced biosecurity
- Suspending all unnecessary traffic
- Disposal of dead birds on-farm
- Reporting suspicion of a highly infectious disease
- Alerting neighbouring poultry farms

A. Restricted Access to Birds

It means restricting access to a farm by employing fences and enclosures which creates a barrier between clean areas where poultry are kept and outside environment and it is the most important biosecurity measures for restricting source of infection away from farm and even from the infected farm to other non-infected far. Movement restriction should be applied both at farm as well as at shed level.

a) Movement restriction in general at farm level

1. As far as possible, separate personnel must be made available to each species of poultry to avoid frequent movement between different species units.

2. All the farms should be provided with fence to protect the entry of persons, vehicles, animals etc.
3. Entrance should be forbidden to everyone. The poultry farms can only be entered with the permission of the farm manager or appointed responsible.
4. Permit the access on the farm only to those people that are necessary on the farm e.g. personnel, veterinary services.
5. It should be kept in mind that visiting two different farms within 24 hr should be avoided. If necessary, showering in between visits is highly recommended. Similar instructions should be applied to the team of persons who catch and load poultry.
6. To improve control on the access of the farm, there should only be one entrance and one exit. The road used for such personnel should be cleaned and disinfected daily.
7. At the entry point of the farm, provide boot and wheel dip baths filled with an effective disinfectant. It should be ensured that the baths are renewed on daily basis**.**

b) Movement restriction at shed/ poultry shed level

1. Keep the shed locked at all times.
2. Shed ideally should have a facility for changing room with hand washing facility (if required, showering facility).
3. On clean side there should be facility to put on clean clothes and boots and after use they should be left out in the changing room, and while exiting put on the clothes which the individual was wearing before the entry into the changing room.
4. It should be ensured that all materials, drugs, vaccines etc., are cleaned and disinfected and they should be have passed a quarantine storage period of 10 days in a especially designed storage room which should be cleaned regularly.
5. All material used in farm operations should cleaned and disinfected before and after use.
6. Every shed should be provided boot dips at entrance and exit and they should be ensured that the dips are renewed on daily basis.
7. Fogging of the populated sheds should be a part of a prevention programme to minimize the risk of contamination. The disinfectant should be used with right dilution as per manufacture’s direction**.**

c) Restrict vehicle entry in the farm area

1. Since many poultry diseases are known to be spread by transportation and thus it is of

paramount importance to clean and disinfect vehicles before entry into farm premises.

2. Provision of wheel dip and walk way for personnel is required at the entrance
3. Person doing cleaning and disinfection of vehicles should wear clean and disinfected clothing.
4. It should be ensured to remove all dry litter, straw, mud from all surfaces, wheel arches etc.
5. Remove all equipment from the vehicle that can be dismantled and cannot be cleaned on the spot.
6. For cleaning purpose, use a powerful car and truck cleaning product to soak all surfaces. Attention should be paid to wheels, ceilings; lifts etc and then leave it for 15 to 30 minutes.
7. Clean the removed equipment and other tools of vehicles with a proper detergent. After soaking for some time, rinse all surfaces and equipments under high pressure. It should be ensured that no organic material remain on the vehicle with detergent safe for the vehicle and effective at all temperatures.
8. During disinfection operations, disinfect all surfaces inside and out with the disinfectant. Work your way down from the top to be bottom and attention should be paid to cracks and wheels. It should also be ensured that underside of the vehicle also get disinfected.
9. Then move the vehicle to a clean and disinfected place to let it drain and for drying.
10. Apply restrictions on the movement of driver.
11. Drivers are permitted to enter up to egg storage room only
12. All feed delivery vehicles should be kept clean before loading the feed
13. Transport the feed first to the young flock and then to the older flock.
14. Drivers not to enter poultry houses under any circumstances.
15. Drivers to spray soles of shoes and floorboard of vehicle with disinfectant after every delivery.
16. Wash hands with disinfectant solution before leaving for another shed.

d) Restriction to visitors

1. Allow only essential people to contact the poultry kept in the farm.
2. Build a separate demonstration area and birds kept there should not later be stocked with shed-house birds.

3. If visitors have their birds of their own do not allow them to come near to the birds.
4. Allow entry of the visitors in essential situation after taking all biosecurity measures at farm entry as well after entry into the shed. These measures should include footbaths at the entry of farm and then at shed level, every visitor may change clothes/cap/footwear, (go through shower-in policy if required) and wear clean and disinfected clothes/ cap and boots. Specific coveralls and footwear for visitors are also to be provided.

e) Restriction to farm workers

1. At the outset train the farm workers about the basic tenets of biosecurity
2. Allow only the employees of that farm to handle the birds on a day-to-day basis.
3. Make sure that employees should not have a commercial or private bird operation as they may transmit disease to the birds kept at the farm.
4. Do not allow farm workers to visit any other poultry farm or places where birds are kept. Similarly, the farm workers should not be allowed to visit the bird shows or bird fairs.
5. Workers in engaged in rearing of one poultry species should not be allowed to visit other farms where different poultry species is being reared.
6. All the farm workers should be allowed in the farm after going through all the biosecurity measures as mentioned for visitors.
7. All the farm workers must put off their clothes and boots after finishing their jobs and should go through shower-out policy.
8. All workers must wear clean and disinfected clothes during farm operations.
9. Frequent washing of hands with detergent or soap with sufficient contact time should be encouraged in day to day farm operations.

f) Restriction to carriers of transmission of infection in the farm

1. Some of the mechanical carriers of infection should be restricted to enter into the farm building.
2. Prevent the entry of introduction of new birds to a previously infected poultry house at least for 3 weeks after clean out.
3. Wild birds – resident fowl or migratory birds – should have no contact with the flock through the use of screens or overlying nets.
4. Bird reflectors/ solar fencing may be considered.
5. There should be insect control programme in place since flies of several species are

important in transfer of certain pathogens.

6. Rodents have also been implicated in the transfer of infection. Therefore, control and preventing their movements between houses on a single premise are essential.
7. Steps should be taken to prevent the accumulation of standing water. Since such water bodies can serve as source of water to migratory waterfowl and shore birds.
8. Limit sources of food for wild and free flying birds.

g) Multiple Species rearing and precautions

The following thumb rules may be kept in mind:

1. Poultry units should be distantly located or well bifurcated from each other.
2. Separate hatchery for each species may be considered.
3. Provision of separate feed storage facility at units of different species may also be considered.
4. Equipment meant for different species of birds should be separate.
5. Provision of all-round spray system of disinfectants at the entry of each species units
6. Exclusive infrastructure facility is essential to rear each species separately and to follow all-in all-out system

B Isolation and quarantine of new birds

1. Isolation and quarantine of new birds is necessary in a separate place and enclosure so that infectious agents which may be there in the newly introduced birds may be detected before introduction of these birds with other flocks.
2. If the birds have been used for a show or a fair, keep them isolated from rest of the flock for 21 days after the event and observe for signs of the disease.
3. New birds should be kept separate from old stock for at least 21 days and they should be observed for any disease symptoms to develop and samples (blood, faecal, swabs) should be collected for thorough investigation before mixing to the already existing old stock.
4. It should be ensured that shed houses birds of same age group, even if farm consists of birds of different age group.
5. Pest proofing is recommended before restocking

C. Cleaning and Sanitation

Effective cleaning and disinfection is an essential component of good hygiene and thus one of the key biosecurity measures for disease control. This should be carried out from time to time to reduce the build–up of pathogenic organisms and a disinfectant known to be effective against a large range of pathogens should be used regularly for prevention of this type of virus. It should address the disinfection of materials.

1. Approved disinfectants like chlorine dioxide and per acetic acid for disinfection or sterilization may be used.
2. Farm equipment entering the farm, cleanliness of personnel on the farm, disposal of dead birds and poultry manure and sanitizing the drinking water should be paid attention.
3. The area around poultry sheds should be kept clean from vegetation, food waste, plastic bottles, glass bottles, tins or drums.
4. Water Testing should be done at regular intervals. Water purifier in each shed is required.
5. Air purifier in all sheds is recommended.
6. Testing of Microbial load – at different places is required.

a) Cleaning and disinfection of farm equipments

1. Feeding pans and drinking equipment used in the caged area should be kept clean daily.
2. Scrubbing should be done and then application of hot water followed by disinfection with an effective disinfectant.
3. Make sure all equipments that had contact with the poultry, lawn, garden and poultry equipments are washed and disinfected before taken to another place. The same should be followed where some equipment are to be brought into the farm.
4. Keeping the cages clean prevents pathogens from accumulating and causing health problems. Cages should be disinfected at regular intervals. They may be left in the sun and then they may be disinfected but it is essential to remove manure before disinfecting cages. Disinfectant will not work if there is still manure present on items.
5. Newly purchased equipments should be thoroughly washed with soapy water or otherwise should be disinfected before use.
6. Newly purchased cages should also be subjected to washing with soapy water or should be disinfected.
7. Poultry equipments such as egg crates, cages, shovels or rakes, should not be shared between family or neighbouring farms. Plastic or metal equipment may be preferred over wooden material.
8. Change feed and water daily.

b) Cleaning and disinfection of poultry houses:

Housing cleaning is the most arduous phase of bio-security and it can be divided in two type.

Complete or terminal house cleaning: This is practiced after removal of flock and the following points should be given consideration.

1. After removing the flock, remove the left over feathers, droppings, letter etc. It should be then followed by complete disinfection of the shed. Firstly the house should be fumigated and then it should be subjected to an effective disinfection. Keep the shed empty for a minimum period of 10 days before arrival of new flock.
2. Before introduction of new flock it should be ensured that there should be no extra moisture in litter, otherwise chances of fungal growth are more.

Partial/concurrent house cleaning: This type of cleaning is done while the birds remain inside the house with following considerations:

1. Thoroughly clean the fans and it should be a regular feature.
2. Sweep the house from top to bottom.
3. Remove the caked litter from the house.
4. Place the clean litter in the house.
5. Regularly disinfect the brooder guards, feeders, jugs, drinking water containers using iodophores and 5% sodium hypchlorite. Other chemical effective like sodium dodecyl sulphate, formalin and iodine compounds may also be used.
6. Regularly sanitize the drinking water.
7. Proportion of disinfectant added must be displayed at the entrance of each shed/ hatchery.

D. Personnel hygiene

1. Specific over all clothing for employees must be provided.
2. Wash hands thoroughly before and after entering the farm area. Washing of hands can be done with soap or detergents with contact time of 10 minutes.
3. Wear clean clothes or coveralls while working with birds in the farm. The clothes should be washable with laundry detergent. Preferably for this purpose detergents or oxidizing agents (sodium hypochlorite dilute to give 2-3% available chlorine or vircon @ 2% with contact time of 10 minutes) and alkali (sodium hydroxide 2% solution or sodium carbonate anhydrous 4% solution with 10-30 minutes contact time) can be used. Dirty clothes should be washed with detergent and hung out to dry in the sun).

4. Since disease in poultry can be transmitted easily through boots, therefore, boots should be used after cleaning and disinfection. The best approach would be disinfecting footwear before and after working with birds or keeping a separate pair of shoes to work around birds and changing into other shoes when leaving the premise. The person should use coveralls, which can be
5. When the care personnel needs to attend to chickens or other poultry (e.g. collecting eggs, feeding or watering, change of bedding or repair of fencing material), a change of clothes/ boots should be required.
6. Medical check up of all workers coming in contact with livestock and feed should be done.

E. Hygienic disposal of poultry manure

1. Use of poultry manure and other poultry by-products such as feathers in agriculture and aquaculture as fertilizer and in untreated form as food for pigs and fish may serve as source of infection as many viruses may not be deactivated for several weeks inside the organic matter such as faeces.
2. Poultry manure should be left undisturbed for at least 90 days and then can be used as fertilizer. High risk farming practices such as use of contaminated water and recycling of poultry waste without treatment should be stopped.
3. Effluent generated from poultry processing of manure can also be disposed off after treatment with acids such as hypochloric acid 2% or citric acid 0.2% or with alkali treatment such as Sod. Hydroxide 2% or sodium carbonate anhydrous 4%.

F. Disposal of dead birds

Dead birds should be removed quickly and properly, to ensure no contact with other birds which will be helpful in removing the source of infected foci to poultry as well as to handlers. The best way to dispose off dead birds is by rendering, burial or incineration.

G. Feed safety

1. Subject to financial and practical considerations, feed should be pelleted to achieve pasteurization. This requires a temperature of 82 ^{o}C for at least 30 seconds to eliminate enteric bacteria. Maintaining good manufacturing practices and careful monitoring of the pelleting process will reduce the probability of infection.
2. Either feed plant personnel should be trained in the selection, application and control of

pesticides and rodenticides or a licensed applicator should be used. This may reduce the probability of accidental contamination of feed or contravention of regulations.

H. Period of rest or Rearing of single age group

One prevention measure that can be instituted in the farm but requires good planning and several enclosures is the method of practice of all-in all-out. This method envisages a complete growth cycle of chickens (or other species) from the period of introduction as in day-old-chicks all the way till the birds are sent to market.

The all in-all-out system should be followed in poultry farms maintaining the important germplasms. This system provides considerable advantages in the disease control. Using this system, proper sanitary practices can be effectively carried out, coupled with necessary resting period of the building to ensure no infectious agents are carried over from one batch to another. Birds of multiple ages kept on the same premise/shed constitute a serious disease potential from such birds and recovered carriers, especially when birds of different ages are closely associated together.

It is also important to clean and allow sufficient downtime in between flocks. A period of 10 days should be given after destocking before arrival of new batch. During this period the poultry house should be fumigated and then disinfected with effective disinfectant.

Poultry litter waste management

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Introduction

There are about 12-13 species belong to poultry such as chicken, duck, guinea fowl, turkey etc. Presently poultry, mainly chicken (broiler and layer) industry is one of the largest and fastest growing agro-based industries in the world. There is an increasing demand for poultry meat mainly due to its acceptance by most societies and its relatively low cholesterol content. Eggs and chicken are accepted by all communities and are available at the most reasonable prices. One of the major issues the poultry industry is currently facing is the accumulation of large amount of wastes, especially manure and litter, generated by intensive production, which is causing major environmental problem. To overcome environmental issues related to pollution, environmentally and economically sustainable management technologies are to be evolved to mitigate the adverse effect of poultry waste and evolve the means to utilize those for producing the meaningful by products, which can be used by other stakeholders. Development of management programs should meet the increasing demand for poultry products, while minimizing the environmental effects of poultry wastes on soils, crops, surface waters, and ground waters. Effective environmental management of any poultry waste begins with an understanding of its composition and the physical, chemical, and microbiological reactions that control the fate of potential pollutants in the waste following land application. The three most common poultry wastes are poultry manure or poultry litter, dissolved air flotation (DAF), sludge originating from poultry processing plants and hatchery wastes and dead birds. The major poultry production operations include broiler chickens, turkeys, and eggs. Land application of animal waste is an important management practice to recycle nutrients, to improve or maintain soil fertility, and to improve soil biological and physical properties. The components of an effective waste management program for the agricultural use of organic wastes include site selection; production and collection; storage, handling, and treatment; transfer and application; and utilization. The land disposal of waste from the poultry industry and subsequent environmental implications has stimulated interest into cleaner and more useful disposal options. There are three main alternative disposal routes for poultry litter viz. composting, anaerobic digestion and direct combustion. These technologies open up increased opportunities to market the energy and nutrients in poultry litter to agricultural and non-agricultural uses. Common problems experienced by the current technologies are the existence and fate of nitrogen as ammonia, pH and temperature levels, moisture content and the economics of alternative disposal methods.

Characteristics of poultry litter

Poultry litter is a valuable resource and it contains a significant amount of nitrogen, potassium, phosphorus, calcium, sulphur and many other macro and micro minerals. On the basis of poultry rearing system there are two types of poultry litter: i) birds reared on the floor with sufficient bedding material (saw dust, rice husk or wood shavings etc.). After selling the birds, the excreta with the bedding materials are removed from the house and termed as litter. It contains less water and easy to handle. ii) birds reared in the cage housing system, the excreta is semi solid mass and falls on the concrete floor and needs to be cleaned daily. There is heavy accumulation of flies and insects and also produces bad odour. Most of the manure and litter produced by the poultry industry is currently applied to agricultural land. When managed correctly, land application is a viable way to recycle the nutrients such as nitrogen (N), phosphorus (P) and potassium (K) in manure. However, pollution and nuisance problems can occur when manure is applied under environmental conditions that do not favour agronomic utilization of the manure-borne nutrients. The continued productivity, profitability and sustainability of the poultry industry will likely be dependent on the formulation of best management practices to mitigate environmental consequences associated with air and water quality parameters that are impacted by land application, and the development of cost-effective innovative technologies that provide alternative to land application of poultry wastes.

Effect of litter on environment

Poultry production is indirectly associated with the greenhouse gas nitrous oxide because of the sector's high concentrate-feed requirements and the related emissions from arable land due to the use of nitrogen fertilizer. FAO–IFA reported a 1 percent N2O-N (nitrogen in nitrous oxide) loss rate from nitrogen mineral fertilizer applied to arable land. By applying this loss rate to the total nitrogen fertilizer attributed to the poultry sector, estimated that nitrous oxide emissions from poultry feed related fertilizer to be 0.07 million tonnes of N2O-N per year – about 35 percent of the global nitrous oxide emissions attributed to the livestock sector from mineral fertilizer application. Overall, intensive poultry production (indirectly and directly) contributes an estimated 3 percent of the total anthropogenic greenhouse gas and is responsible for about 2 percent of the total greenhouse gas emissions from the livestock sector. This estimate, however, does not include emissions from land use and land-use change associated with feed production or emissions related to transport of feed. Poultry production in intensive systems and its impacts on the environment has shown that the issues associated with poultry production, as environmental impacts related to backyard or mixed extensive systems are marginal because of the limited concentration of wastes and reliance on locally available sources of feed, such as food residues, crop residues or feed collected by free-ranging birds. Poultry production is associated with a variety of pollutants, including oxygen-demanding substances, ammonia, solids, nutrients (specifically nitrogen and phosphorus), pathogens, trace elements, antibiotics, pesticides, hormones, and odour and other airborne emissions. These pollutants have been shown to produce impacts across multiple media.

Potential risks to human health

Chicken litter can be the basis of a valuable and productive fertiliser for optimal dairy pasture production. It supplies nutrients, organic matter and trace elements. Raw chicken litter may contain contaminants that present a potential threat to human health if permitted to enter the food chain or water resources. It is, therefore, important to use appropriate management techniques to minimise the risk of environmental contamination when applying chicken litter to pastures. Pathogens such as bacteria and viruses can be present in chicken litter. Several affect only poultry or birds, but some may also be harmful to humans. Most of these are fragile organisms, which would not survive on pasture for the three-week withholding period recommended between application of chicken litter and allowing cattle to graze. The health risks to the farmer from these pathogens can be minimised by good hygiene practices. Antibiotics including growth promoters and anti-coccidial agents which are likely to be present at only low levels and persist for a short time in chicken litter and spreading chicken litter on pasture and exposure to sunlight should ensure these substances breakdown rapidly. Heavy metals may be found in chicken litter as trace elements fed to poultry and contaminants of bedding material. Heavy metals need to be monitored to ensure high levels do not accumulate in the soil. High levels in soil may be consumed by cattle or run off into waterways and end up in the human food chain. Agricultural workers are exposed to numerous on-the-job respiratory hazards. Dusts, disinfectants, gases are just a few of the hazards, which may be encountered. Serious respiratory problems can develop from prolonged exposure to any of these airborne contaminants. Farmers may have increased rates of chronic bronchitis. Components of agricultural dusts and gases are sufficiently irritating to the airways of the lung to cause mucus overproduction leading to repeated cough with phlegm. These reparable hazards are also a factor in asthma and allergic problems, (runny nose and irritated eyes) which may occur with initial exposure. To avoid these respiratory illnesses in the poultry house environment, it is important to recognize the specific hazards and wear the proper respiratory protection.

Potential risks to poultry health

Poultry litter is a mixture of bedding materials and enteric bacteria excreted by chickens, and it is typically reused for multiple growth cycles in commercial broiler production. Thus, bacteria can be transmitted from one growth cycle to the next via litter. Litter reuse affects development and composition of chicken gut micro biota. The gastrointestinal (GI) tract of chickens harbours a complex micro biota that plays an essential role in nutrient digestion and absorption, immune system development, and pathogen exclusion. When young chicks are delivered from the hatchery to a chicken house (typically at the age of 1–2 days), their initial GI micro biota is very simple containing a very small number of bacteria belonging to a few species. After being placed in commercial chicken houses where litter serves as the bedding material, chicks are exposed to several sources of bacteria that can gain entry into the immature gut. These exogenous sources of bacteria include litter materials, feed, water, and ambient air. Because there is little colonization resistance in the young GI tract, many bacteria can readily colonize therein. Beginning from approximately day one, chicks begin pecking at and consuming litter materials, inoculating their young GI tract with bacteria present in the litter. Therefore, litter can have a significant effect on the development process of GI micro biota and its eventual composition and structure in chickens. Viral and bacterial pathogens are a significant economic concern to the poultry industry and the ecological epicentre for poultry pathogens is the mixture of bedding material, chicken excrement and feathers that comprises the litter of a poultry house. A study was conducted where high-throughput sequencing was done to assess the richness and diversity of poultry litter bacterial communities, and to look for connections between these communities and the environmental characteristics of a poultry house including its history of gangrenous dermatitis (GD). It was observed that wet litter contained greater bacterial diversity as compared to dry litter bacterial abundance. Overall, the poultry house environment appeared to substantially impact the composition of litter bacterial communities and may play a key role in the emergence of food-borne pathogens. Finally, micro biome analyses of poultry faeces and chicken body sites may also help to elucidate the aetiology of GD and other poultry diseases. The results could be useful in understanding the relationship between the litters and gut micro biota of chickens as it relates to improving the health and well-being of chickens through litter management.

Litter conversion into compost and vermicompost

One of the major issues the poultry industry is currently facing is the accumulation of large amount of wastes, especially manure and litter, generated by intensive production, which is causing major environmental problem. To overcome environmental issues related to pollution, environmentally and economically sustainable management technologies are to be evolved to mitigate the adverse effect of poultry waste and evolve the means to utilize those for producing the meaningful by products, which can be used by other stakeholders. Development of management programs should meet the increasing demand for poultry products, while minimizing the environmental effects of poultry wastes on soils, crops, surface waters, and ground waters. Effective environmental management of any poultry waste begins with an understanding of its composition and the physical, chemical, and microbiological reactions that control the fate of potential pollutants in the waste following land application. Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil:

(i) becomes more resistant to stresses such as drought, diseases and toxicity

(ii) helps the crop in improved uptake of plant nutrients

(iii) possesses an active nutrient cycling capacity because of vigorous microbial activity.

These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers. Earthworms are popularly known as the “farmer’s friend” or “nature’s plowman”. Earthworm influences microbial community, physical and chemical properties of soil. They breakdown large soil particles and leaf litter and thereby increase the availability of organic matter for microbial degradation and transforms organic wastes into valuable vermicomposts by grinding and digesting them with the help of aerobic and anaerobic microbes. Earthworms activity is found to enhance the beneficial microflora and suppress harmful pathogenic microbes. Vermicomposting is an efficient nutrient recycling process that involves harnessing earthworms as versatile natural bioreactors for organic matter decomposition. Due to richness in nutrient availability and microbial activity vermicomposts increase soil fertility, enhance plant growth and suppress the population of plant pathogens and pests.

It can be concluded that environmentally and economically sustainable management technologies should be adopted to avoid pollution and thereby benefitting the end users.

Integrated farming with duck

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Duck, the waterfowl is considered as the second important avian species due to its population and production potentialities. It is one of the earliest domesticated species of poultry which happened around 4500 years ago. Most ducks are the offspring of mallard (*Anas platyrhynchos*) domesticated in South China. Duck is a crucial food source in the rural area in Asia, particularly South East Asia. Muscovy duck (*Cairina moschata*) domesticated in Latin America have spread around Africa and Asia, mainly in South East Asia. Duck meat and eggs is highly nutritious foodstuff. In rice-producing countries, there is a synergy between duck and rice yield. The free-range ducks act as natural predators for insects and snails, and also eat the post-harvest grains (rice). As a predator of insects and producer of natural fertilizer, duck contributes to a higher harvest. Therefore, it is considered as one of the most suitable component which can be integrated with other crops in the same patch of land.

What is integrated Farming?

When two or more agricultural practices are tried combindly in one field with each crop helps other for growth and production: ultimately resulting higher income to farmer is termed as "***Integrated Agricultural Practice"***. The crops selected for integration are important as they need to be helpful to each other in a synergistic way. In integrated agricultural practice always there is one major crop where as other crops are supplementary to the major one and resulted in continuous income source for the farmer round the year.

Benefits of Integrated agricultural practice:

- More efficient use of land and water for production of different crops.
- More yields and more income per unit land / water area.
- Cost of expenditure for each crop is reduced as one crop supplements in some way for growth and production of other crop.
- Enrich the soil and water nutrient for subsequent crops.

- ❖ Cropping intensity is more.
- ❖ Less labour intensive.
- ❖ Availability of more food product to farmer from a piece of land for livelihood & nutritional security.
- ❖ Involvement of farmer's family is better in this type of practice.
- ❖ Farmer will get income throughout the year as the harvesting time varies with crops.
- ❖ Return from one crop may help for investment in other crop; thus the farmer may not need loan / debt towards investment.
- ❖ Loss in one crop due to calamity may be compensated by other crop.

Integrated agricultural practice with Duck:

A) Duck-Fish Integrated practice

The natural habitat of duck is ponds, lagoons or water bodies. They like to spend more time in water during day hours and prefer to stay in a secured shelter house during night. As a normal practice, farmers in villages especially in coastal areas used to rear a flock of duck that graze in rice fields / ponds and collect their feeding from environment during day time. A small shelter house near the pond fulfils their night rest so also the nesting bed for egg laying before Sunrise. However, Keeping the ducks in complete confinement and raising with commercial feed may not be economically viable. The benefits of duck farming for small and marginal farmers are enormous:

Duck farming can be integrated with aquaculture for better profitability. There are certain benefits observed when ducks are maintained in the pond which is used for systematic aquaculture; more specifically for Indian carps cultivation. Some of the advantages are enlisted below:

Benefits of Duck- Fish integrated practice by rural farmer:

- Fish and ducks are maintained in one pond that minimises the space / area required by each species. They grow under one eco-system.
- The dropping of ducks is rich in nitrogen and enhances growth of planktons in the pond which are the major source of feeding for fishes.
- Precipitation on surface of water in pond is avoided by ducks as they continuously swim in the pond in search of food.
- Swimming of ducks help in aeration / oxygenation of the pond water which is very much essential for optimum growth of fishes.
- During summer months temperature of surface water in a pond increases and the surface feeders (catla) move to middle or bottom that causes imbalance in eco-system. However, presence of duck in the pond minimises the temperature difference of water at different depth and helps in maintaining the proper eco-system.
- Besides satisfying the physiological need of water, ducks collect snails, molluscs, predator fishes, weeds and many aquatic plants as their feeding source.
- Ducks rub the bottom of ponds in search of snails and aquatic weeds which not only keeps the pond clean but also releases oxygen from the soil which is made available to the fish.
- Provision of supplementary feed for fishes and ducks are minimised to great extent when they co-exist in one pond. It helps in drastic reduction in production cost of both the crops.
- In systematic aquaculture regular exercise for fishes enhances growth. By swimming from one end to other and dipping head inside, the ducks frightened the fishes and facilitates their exercise.
- Ducks are ornamental species and adds to the natural beauty of the pond
- The economic return from both duck and fish is much higher than any of the single crop. Besides this, the farmer family could able to get animal protein (egg, meat and fish) source round the year which enriches their food and help in extending the nutritional security to the family.

Breeds/ varieties of Ducks suitable for integration:

Majority of ducks in India are indigenous or non-descript type. They are hardy, having mediocre egg production potentiality and are highly suitable for extensive system of rearing. The important Indian breeds include Kuzi, Nageswari, Sanyasi, Keeri, Pati hans, Chara and Chemballi etc. Among the exotic breeds/ varieties, Khaki Campbell is the most popular duck for egg production and White Pekin for meat production. However, Khaki Campbell and Kuzi (found in Odisha coastal districts) ducks are tried in integrated practice with aquaculture and found suitable with better economic return for the farmers.

Khaki Campbell*:*

The origin of Khaki Campbell duck is United Kingdom; but is migrated to different parts of world in due course of time. Khaki Campbell is the best egg laying (~ 300 eggs /yr) duck variety in the world. Under normal management practice with standard feeding regime the female ducks start laying eggs between17-19 weeks of age and the average size of egg is ~ 65 grams.

Khaki Campbell ducks

Kuzi ducks (Odisha native variety)*:*

Kuzi ducks are found in coastal districts of Odisha and West Bengal to some extent. They are medium sized ducks (smaller than Khaki Campbell), multi-colored plumage, attractive and very active birds. They prefer to swim in water for more time and are very good foragers in both water and on land. They are hardy and adjusted in adverse conditions like bad weather or natural calamities. They normally lay 200-220 eggs in a year and initiates egg laying by 20 wks of age.


Kuzi ducks (Native variety)

Varieties of fishes suitable for integration with duck:

Indian carps (***Catla-catla, Rohu*** and ***Mrigal***) are commonly cultivated in sweet water ponds in coastal districts of India. Due to its production potential and quality for consumption, these three carp varieties are liked in the fish farming community. These carps are not only well adapted to our sweet water eco-system, but also fetch good market price for the farmer. Catla (***Catla catla***) is the surface feeder which usually collects its feeding source from 1-2 feet water depth from surface. Rohu (***Labio rohita***) is middle/column feeder and Mrigal (***Cirrhinus cirrhosus***) is bottom feeder. They usually consume planktons (phyto-plankton and zoo-plankton) grown in water. However, balanced feed (mash / pellet) is offered to the fishes in ponds to meet their nutritional requirements for optimum growth and production. Supplementary feeding provision helps in growing more number of fishes per unit area for more harvest. In one acre of pond a farmer can introduce 2000 no (approx) of carp fingerlings at a proportion of 1:1:1 for catla, rohu and mrigal. In the same pond 100-150 nos of adult ducks can be maintained as an integrated agricultural practice. Supplementary feeding for fish is required in this system for optimum growth of fishes. However, pellet feed is not advised to offer as the ducks engulf these while swimming. Applying cow dung and rice bran at frequent interval helps in augmenting plankton growth which acts as the feeding source for fishes. Pellet feed can be offered in the afternoon time when ducks are kept in the shelter house. Under this management system, a farmer can expect 15 quintals (approx) of fish production in a year.

  

Catla **Rohu** **Mrigal**

In this model one hundred day old ducklings are brooded under light with commercial duck starter mash for one months of age. The growing ducks are introduced to the fish pond by 5-6th wks of age. They will partially collect their feeding source from ponds (weeds, snails, mollusks etc). Later on fish fingerlings are introduced to which ducks cannot catch. Both the components simultaneously grow in same pond for 5-6 months. A low-cost duck shed need to be constructed in the bank of the pond for night shelter of the birds. The kitchen wastes, leftover food of the houses, vegetable peels, fish scales and offal are offered to the birds as supplementary feeding source. Their co-existence helps both in various ways. The ducks used to initiate laying eggs by 5th month of age and continued at least for one year. During this period the fishes (carps) attain marketable size. Little feed for fish is offered depending on the stocking density. This model is well adopted by farmers in village condition. However, there is limitation of number of ducks which need not cross 100 per acre of water area. More no of ducks causes degradation of water quality and shortage of feed for them is usually observed.

Duck-Fish integrated practice

2. **"Rice-Fish-Duck Integrated Model":**

In this model rice is the major component followed by fish and duck. Ten feet width and 1.5 ft depth water retaining space is created in the internal periphery of the rice field where water will retain always. Centre space is occupied by rice. Land preparation for rice cultivation and brooding of ducks are continued simultaneously. After 15-20 days plantation of saplings, the growing ducks and fish fingerlings are introduced into the system after which there will be no application of pesticides. All three components will grow simultaneously with their available feeding source from the same land. Almost four months they will co-exist in same environment. Ducks have the low cost house nearby as night shelter. Ducks are avoided to field during flowering stage of rice. After 4 months the ducks will initiate laying when rice are about to harvest and fishes must be attaining 0.6 - 0.8 kg body wt. However, as the water retains for few more days in the deeper periphery, the fishes and ducks can be reared in the field even after the rice harvest. This model is more profitable and viable in coastal states of the country. The benefits of this model:

- ❖ More income per unit land.
- ❖ Less chemical fertilizer is required as droppings of ducks are rich in nitrogen
- ❖ Sufficient plankton growth will be there for feeding of fishes.
- ❖ Biological control of stem-burrower is possible in the rice as the insects when came to water for breeding are swallowed by ducks.
- ❖ Ducks will get sufficient feeding from the field.
- ❖ The model is viable and satisfactory for 100 number of ducks per hectare of land.

Rice-Fish-Duck integrated model

Integrated agricultural practice with duck is undoubtedly a profitable enterprise for progressive farmers. The multipurpose use of soil and water is much emphasised in this concept which is successfully tried in different parts of the globe. It not only enriches the soil and water but takes care of the health of farmers family by providing balanced diet produced from a unit area of land. .

Common poultry diseases and their diagnosis and control

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Newcastle Disease (ND)

Newcastle disease is a highly contagious disease caused by avian paramyxovirus of serotype 1 (APMV-1) belonging to the family of Paramyxoviridae. It affects wild birds and domestic poultry and usually presents as a respiratory disease. Depression, nervous manifestations, or diarrhea may also be the predominant clinical symptoms and mortality.

Newcastle Disease symptoms can be respiratory, nervous, intestinal symptoms for both clinical and subclinical infections. ND can be classified into five different categories:

1. Viscerotropic velogenic, a highly pathogenic form in which hemorrhagic intestinal lesions are frequently seen.
2. Neurotropic velogenic, a form that presents with high mortality, usually following respiratory and nervous signs.
3. Mesogenic, a form that presents with respiratory signs, occasional nervous signs, but low mortality.
4. Lentogenic or respiratory, a form that presents with mild or subclinical respiratory infection.
5. Asymptomatic: a form that usually consists of a subclinical enteric infection.

With velogenic viruses, the disease may appear suddenly, with high mortality occurring in the absence of any other clinical signs. In other cases, clinical signs often begin with listlessness, increased respiration and weakness, diarrhea, ending with prostration and death. In cases involving the neurotropic velogenic isolates, neurological signs such as torticollis or colonic movements of the head or the legs, are commonly observed a few days after infection has started. A dramatic drop in egg production can be seen in layers and breeders. Morbidity rate may reach 100%. The clinical signs induced by isolates classified as mesogenic are usually limited to respiratory signs and drop in egg production in laying hens. Nervous signs may occur but are not common. Mortality rate is generally low. Finally, lentogenic strains do not usually cause disease in adults, but in young, fully susceptible birds, respiratory problems can be observed. Such reactions can be complicated by infections with other pathogens. Apathogenic strains induce no clinical sign (asymptomatic form). Likewise, for clinical signs, the extent and location of the gross lesions depend on the virus strain, the host conditions and all those aforementioned factors affecting the severity of the disease. Additionally, there are no pathognomonic lesions associated to ND.

In the respiratory tract, mucosal hemorrhages, marked congestion of the trachea and airsacculitis may be observed. Hemorrhagic lesions in the digestive tract particularly in the mucosa of the proventriculus, caeca, small intestine and lymphoid tissues such as caecal tonsils and Peyer's patches are commonly seen. In laying hens, egg yolk in the abdominal cavity and flaccid and degenerative ovarian follicles are often found. Finally, even with chickens showing nervous signs, gross lesions are not observed in the central nervous system.

Infectious bursal disease (IBD)

Infectious bursal disease is a highly contagious disease of young chickens caused by a Birnavirus of serotype 1. Virus strains can be divided in classical and variant strains. The virus is very stable and is difficult to eradicate from an infected farm. IBD virus is very infectious and spreads easily from bird to bird by way of droppings. Infected clothing and equipment are means of transmission between farms. Chickens and turkeys appear to be natural hosts.

Clinical IBD occurs usually between 3 and 8 weeks of age depending on maternal antibody levels. Affected birds are listless and depressed, pale, huddling producing watery white diarrhea. Mortality varies. Usually new cases of IBD have a mortality rate of about 5 to10% but can be as high as 60% depending on the pathogenicity of the strain involved. Highly pathogenic strains are called "very virulent" IBD (vvIBD) resulting in high mortality. Subclinical IBD occurs with infections before 3 weeks of age. Early IBD infection result in permanent immunosuppression without mortality. Immunosuppression is economically important due to increased susceptibility to secondary infections especially in the respiratory tract. Gumboro disease related diseases such as inclusion body hepatitis are also more frequent in these birds. In broilers this form of the disease results in bad performance with lower weight gains and higher feed conversion ratios.

Typical clinical signs and post mortem lesions are found after IBD infection. Post mortem lesions; in acute cases the bursa of Fabricius is enlarged and gelatinous, sometimes even bloody. Muscle haemorrhages and pale kidneys can be seen. Infection by variant strains is usually accompanied by a fast bursal atrophy (in 24-48 hours) without the typical signs of Gumboro disease. Also in chronic cases the bursa is smaller than normal (atrophy). The bursa destruction is apparent on histologic examination. The lack of white blood cells (lymphocytes) results in a reduction in the development of immunity and decreased resistance of the birds to other infections. Histopathological examination, serology, virus isolation and PCR are confirming tools. IBD can be confused with sulfonamide poisoning, aflatoxicosis, and pale bird syndrome (Vitamin E deficiency).

No treatment is available for IBD. Vaccination of breeders and young chicks is the best means of control. The induction of a high maternal immunity in the progeny of vaccinated breeders, together with the vaccination of the offspring is the most effective approach to successful IBD control. A variety of live and inactivated vaccines have been developed to enhance the control of classical, variant and vvIBD challenges. Recently, immunocomplex vaccines and a new generation of recombinant vector vaccines based on HVT-vector carrying an insert of the VP2 part of the IBD-virus are available for the control of IBD.

Infectious bronchitis (IB)

IB is probably one of the most widespread poultry diseases around the world, due to its highly contagious nature. It is caused by a gamma coronavirus that affects the respiratory, urinary and reproductive systems of the chickens, causing different disorders depending on the tissue tropism characteristics of the invading viral strain. An additional issue is the high mutation rate and recombination ability of the IB virus. Diseased chickens are the source of infection, spreading IB virus (IBV) by the aerogenous route, as well as some spread via feed and water.

The incubation period of IBV is short and dose-dependent; it may be less than 18 hours when the virus is inoculated intratracheally or 36 hours after ocular application. In chickens up to the age of 4 weeks, IB manifests itself in the form of severe respiratory signs (sneezing, coughing, and rales). Rhinitis and conjunctivitis, depression and crowding around heat sources are observed.

The morbidity rate may reach 100%. The mortality in young chickens is usually insignificant unless a secondary infection with a different agent occurs. In such cases, there is a moderate to severe inflammatory cell infiltration of upper respiratory tract mucosa, resulting in thickened and more compact mucosa.

In one-day old chickens, IB infection can permanently damage the oviduct, influencing egg production and egg quality during the production period. In layer hens infected with the IB virus, oophoritis and dystrophic necrobiotic lesions affecting primarily the middle and the final third of oviduct's mucosa lining are observed. The oviduct is atrophied, cystic, with deposits of yolks or completely formed eggs in the abdominal cavity (the so-called internal layer). The consequences are drop in egg production, appearance and increase in the number of deformed and pigmentless eggs or eggs with soft shells and watery albumens.

The nephropathogenic effect of IBV infection is usually manifested in young chicks and reproductive tract lesions after egg laying begins. The severity of IB-related respiratory infection is complicated by secondary bacterial or viral pathogens, i.e. E. coli, Mycoplasma gallisepticum, Newcastle disease virus etc. resulting in chronic airsacculitis and pneumonia.

The vaccination used at poultry farms will develop the active immunisation against IBV. Live vaccines are generally attenuated, prepared from vaccinal strains selected according to the antigenic spectrum of regional isolates. It is also important to determine the potential for cross protection, mainly applicable for live vaccines. Inactivated oil-adjuvant vaccines against IB are applied as booster vaccines to protect layers and breeder flocks; usually these are available as polyvalent vaccines that also include ND, IBD and/or other vaccinal strains.

Marek's Disease (MD)

Marek's disease is caused by a alphaherpesvirus. The disease is highly contagious. Main transmission is by infected premises, where day-old chicks will become infected by the oral and respiratory routes. Dander from feather follicles of MD-infected chickens can remain infectious for more than a year. Young chicks are particularly susceptible to horizontal transmission.

Susceptibility decreases rapidly after the first few days of age. Species affected include chickens, also quail, turkeys and pheasants are susceptible.

Clinically, infected birds show weight loss, or may exhibit some form of paralysis. The classical form: neurolymphomatosis (paralysis) with leg nerve involvement causes a bird to lie on its side with one leg stretched forward and the other backward. When the gizzard nerve is involved, the birds will have a very small gizzard and intestines and will waste away. Acute Marek's disease is an epidemic in susceptible or unvaccinated flocks causing depression paralysis, mortality and lymphomatous infiltrations/tumors in multiple organs. Subclinical infections result in impaired immune responses as MDV causes a lytic infection in lymphocytes. Mortality usually occurs between 10 and 20 weeks of age and can reach up to 50% in unvaccinated flocks

The presence of tumors in liver, spleen, kidneys, lungs, ovary, muscles, or other tissues is indicative of MD, but they can also be indicative of lymphoid leucosis. However, nerve involvement, either grossly (swelling of leg, wing or other nerves) or microscopically, is typical of MD. Eye involvement can be visible as an irregular constriction of the iris (ocular lymphomatosis). Skin involvement often consists of tumors of feather follicles or in between follicles it is a reason for broiler condemnation in certain parts of the world. A proper diagnosis to differentiate MD from LL requires histological examination. Microscopically, the lymphomas are characterized by a mixture of pleomorphic lymphocytes. The paralysis is caused by lesions and enlargements of the affected nerves. Virus isolation or PCR from buffy coat (fresh blood samples) and/or affected organs can confirm the infection

There is no effective treatment for affected flocks. Vaccination is an effective means of control. It has been demonstrated that MD vaccine only prevents the appearance of Marek's disease tumors and paralysis. It does not prevent the birds from becoming infected with MD-virus. It is therefore of major importance to maintain high hygienic and sanitary measures by good management to avoid early exposure of young chickens. Multiple age farms are big risk to Marek's disease. Vaccination against Marek's disease is performed in the hatchery; there are two routes of application; In-ovo injection into the18 days embryonated eggs or injection in day-old chickens. Most used vaccines are the Rispens (serotype-1), SB1 (serotype-2) and HVT vaccine strains (serotype-3). The choice on the strains for MD vaccination will depend on the virulence of the strains present in the field. In India, serotype 1 vaccines are not permitted, only Serotype 2 and Serotype 3 vaccines are allowed to control MD.

Chicken Infectious Anemia

Chicken infectious anemia (CIA) is a disease of young chickens characterized by aplastic anemia, generalized lymphoid atrophy, subcutaneous and intramuscular hemorrhage, and immunodepression. CIA is caused by Chicken Anemia Virus (CAV) classified into genus Gyrovirus of the family Circoviridae. CAV is non-enveloped and are environmentally very resistant. All ages are susceptible to infection but clinical disease is typically seen only during the first 2 to 8 weeks. The virus is spread both vertically and horizontally. The most important method of transmission is vertical from infected hens. Antibody-negative chicks are most susceptible to clinical disease. CAV also easily spreads via feces among birds in a population.

The only specific sign of CAV infection is anemia characterized by hematocrit values ranging from 6 to 27% (normal hematocrit values are generally 29-35%). Nonspecific clinical signs include depression, pale tissues, depressed weight gain, and secondary bacterial, mycotic, and viral infections. Morbidity and mortality rates depend on various viral, host and environmental factors and concurrent infection with other agents. Uncomplicated CIA may only cause low mortality and poor performance. When complicated with other factors mortality can be 30% or even higher. Early infections with CIAV can interfere with vaccination against Marek's disease or infectious bursal disease.

Marked thymic atrophy is the most consistent lesion. Fatty yellowish bone marrow, particularly in the femur, is characteristic. Bursal atrophy can also be seen in a small number of birds. Hemorrhages in the mucosa of the proventriculus, subcutis, and muscles may also be observed Secondary bacterial infections may occur and include gangrenous dermatitis or blue wing disease if the wings are affected.

A presumptive diagnosis is based upon clinical signs and gross lesions. PCR is the test of choice for identification of CAV in chicken tissues.

Best prevention is by immunization of breeder flocks prior to the onset of egg production (between 13-15 weeks of age but no closer to egg production than 4 weeks). No treatment is available.

Infectious Laryngotracheitis (ILT)

ILT is caused by a Herpesvirus, only one serotype is known. The natural entry of ILT is via the upper respiratory tract and ocular route. Field spread occurs via direct contact from bird to bird and/or transmission by contaminated people or equipment (visitors, shoes, clothing, egg boxes, transport crates). Incubation period varies from 4-12 days. Chickens are the primary natural host but other species (pheasants) can also be affected.

An acute respiratory disease with nasal discharge and moist rales followed by gasping, marked respiratory distress and expectoration of blood-stained mucus in laying birds. Egg production can drop 10-50% but will return to normal after 3-4 weeks. Mortality can vary from 5-70%. Spread through a chicken house is slower compared to IB and ND. Post mortem lesions are found throughout the respiratory tract but most pronounced in the larynx and trachea. Depending on the severity of the infection tracheitis with haemorrhagic and/or diphteric changes are noticed.

Clinical picture with birds showing respiratory distress and expectoration of bloody mucus are indicative for ILT. Laboratory confirmation with: histopathology showing intranuclear inclusion bodies in tracheal epithelial cells, virus isolation from tracheal swabs on embryonated chicken eggs, virus detection with PCR or IFT on tracheal samples. Detecting antibodies from blood samples after infection.

There is no treatment for ILT. Vaccination is the preferred control method. Vaccination in the early stage of an infected flock may reduce the spread and limit the outbreak. The existing live conventional CEO ILT vaccines are effective in controlling clinical problems but have the risk of spreading and reversion to virulence after multiple passage through chickens. Recombinant vaccines based on HVT-vector carrying inserts of important immunogenic ILT proteins show good efficacy and do not spread and cannot revert to virulence because there is not a full ILT virus involved.

High pathogenicity avian influenza (HPAI)

High pathogenicity avian influenza (HPAI) viruses have an IVPI in six-week-old chicken greater than 1.2 or, as an alternative, cause at least 75% mortality in four-to eightweek-old chickens infected intravenously. H5 and H7 viruses which do not have an IVPI of greater than 1.2 or cause less than 75% mortality in an intravenous lethality test should be sequenced to determine whether multiple basic amino acids are present at the cleavage site of the hemagglutinin in molecule (HA0); if the amino acid motif is similar to that observed for other high pathogenicity avian influenza isolates, the isolate being tested should be considered as high pathogenicity avian influenza virus. India notified the first outbreak of H5N1 HPAI virus on 18th February, 2006. Since then, several outbreaks of HPAI have been reported from different parts of the country.

HPAI is a severe form of influenza usually seen in chickens. Viruses of high pathogenicity may cause fatal infections preceded by few signs. Onset is sudden, the course is short, affected birds are quite ill, and mortality may approach 100%. Signs may relate to the respiratory, enteric, or nervous systems. There may be diarrhea, edema of the head and face, or nervous disorders. Classical lesions of HPAI in chickens include cyanosis and edema of the head, vesicles and ulceration on the combs, edema of the feet, blotchy red discoloration of the shanks, petechiae in the abdominal fat and various mucosal and serosal surfaces, and necrosis or hemorrhage in the mucosa of the gizzard and proventriculus.

Clinical history, signs, and lesions may be suggestive of AI, but are similar to other diseases. Confirmation of suspect AI cases requires laboratory tests such as serology (AGID and/or ELISA) and virus detection (real-time RT-PCR and/or virus isolation). Positive samples are then subjected to H5 and H7 subtype specific real-time RT-PCR tests, sequencing and/or inoculating susceptible chickens with the virus. Influenza must be differentiated from other poultry diseases including Newcastle disease, mycoplasmosis, chlamydial infections, and fowl cholera.

Stamping out is policy adopted in India for Prevention, Control and Containment of HPAI. All outbreaks of influenza should be reported immediately to the state veterinarian or other appropriate health authorities so that appropriate measures can be taken. Voluntary isolation of infected flocks is the responsibility of the owner and is necessary to prevent transmission to other flocks. Rigorous measures to prevent the contamination of and control the movement of people and equipment are required in order to stop this disease.

Low pathogenic avian influenza (LPAI)

Low pathogenic avian influenza (LPAI) H9N2 viruses have been isolated from various species of wild birds and domestic poultry in the world. It is the most prevalent influenza subtype circulating endemically in chickens worldwide. Since they got established in poultry about 25 years ago, LPAI H9N2 viruses have continuously evolved antigenically and have spread to new geographic areas, causing huge economic losses to the poultry industry. Despite their classification as LPAI, poultry outbreaks of H9N2 are associated with significant economic losses, largely due to reduced egg production, reduced feed conversion efficiencies, and highly lethal bacterial or viral co-infections. Secondary infections lead to mortality as high as 50% in broilers as well as layers. LPAI H9N2 infections are frequently associated with moderate-to-high mortality in broilers and long lasting drops in egg production in layers and breeders. The primary target of the H9N2 LPAIV is the epithelium and the lymphoid tissue of the respiratory tract. Replication causes lesions and a local immune suppression. The virus spreads to the epithelium of the reproductive tract causing significant drop in egg production in layers and breeders. With no complications AIV H9N2 infected birds may recover without clinical signs. Although H9N2 infections commonly result in low mortality, they make chickens more susceptible to secondary infections, especially Escherichia coli infections. In addition, H9N2 infections can be complicated with other pathogens (MG, IBV, Metapneumo, Avibacterium paragallinarum) and contributing environmental factors (e.g., poor ventilation, high environmental temperature) leading to severe respiratory disease that can cause mortality up to 50-60% in broilers. Summer is the most vulnerable period for broilers and layers as heat stress levels are immensely high (day time temperature touches 47°C in northern parts of India).

The keys to control LPAI are good biosecurity, bird management and vaccination and surveillance. Vaccination is authorized in most infected countries but not authorized in India. Only killed vaccines are available globally. These vaccines used in broiler, layers and breeders are expected to reduce the clinical disease, performance losses (final weight, feed conversion rate, egg production) and virus replication in the respiratory system. The amount of antigenic content, the matching between field and vaccine strains, the ability of the adjuvant to stimulate an immune response, the proper inactivation of live virus are key requirements to ensure sufficient vaccine efficacy.

Avian Encephalomyelitis (AE) (Epidemic Tremor)

Avian encephalomyelitis (AE) is a viral infection of chickens, turkeys, pheasants, and coturnix quail characterized in young birds by ataxia progressing to paralysis and, usually, by tremors of the head and neck. Infected adults usually show no signs.

AE is caused by a hepatovirus belonging to the Picornaviridae family. There appear to be no serologic differences among isolates. All field strains are enterotropic but some strains are more neurotropic than others. Virus is present in the feces of infected birds and will survive there for at least 4 weeks. The virus survives treatment with ether and chloroform and is fairly resistant to various environmental conditions.

During the acute phase of infection in laying chickens, a period up to 1 month, some layers shed virus in some of the eggs they lay. Although vertically transmitted AE may affect hatchability, many of the chicks will hatch and can show clinical signs of the disease as early as the 1st day of age. The infected chicks will shed virus in their feces resulting in horizontal spread to other chicks. Younger chicks tend to shed virus for a longer period of time than older chicks.

Clinical outbreaks are usually observed in chickens and most outbreaks are in 1-3-week-old chicks. In chicks, signs may be present at the time of hatch but usually occur between the 1st and 2nd week of age. Age resistance is marked if exposure is after 2-3 weeks of age. In chicks, signs include dull expression, ataxia progressing to paralysis and prostration and tremors of the head and neck. Tremor may be inapparent but often can be accentuated if the bird is frightened or held inverted in the hand. The morbidity in chicks is quite variable but may go as high as 60%. If most chicks in the flock come from immune dams, morbidity is usually low. Mortality averages 25%. Few birds with signs recover completely. Those that survive often fail to grow or produce eggs normally. Many survivors later develop a bluish opacity to the lens of the eye and have impaired vision.. Layers seldom show signs when infection is going through the flock. However, good production records often reveal a significant decline in egg production generally lasting no more than 2 weeks.

Generally, there are no gross lesions. In chicks, whitish areas in musculature of the gizzard can sometimes be observed. No gross lesions are seen in adult birds. Microscopically there is a disseminated, nonpurulent encephalomyelitis with widespread and marked perivascular cuffing Swelling and chromatolysis of neurons in nuclei in the midbrain and cerebellum, and dense lymphoid aggregates in the muscle of the proventriculus and/or gizzard as well as the myocardium and pancreas.

In chicks, the history, age of the birds, and typical signs of central nervous system (CNS) lesions permit a strong presumptive diagnosis. The diagnosis can often be strengthened by histopathologic examination. Alternatively, the direct fluorescent antibody technique can be used to demonstrate AE viral antigen in infected chicks.

Chicks from immune hens are usually protected by parental immunity during the critical first few weeks after hatching. Breeding flocks can be vaccinated to provide maximum protection to their chicks. Although vaccination is usually conducted prior to the onset of lay, some killed vaccines can be used during production. Both killed and live vaccines are used for vaccination and are effective. Live vaccine is given by the wing web stick method in combination with pox, via the drinking water, or by spray. Chicks from flocks that have been naturally infected will probably receive enough parental immunity so that they will not develop the disease.

Fowl Pox

Fowl pox is caused by a Poxvirus. Introduction of infected or “carrier” birds in a susceptible flock will cause an outbreak by direct contact and water or feed transmission. Mosquitoes and other flying insects can also transmit the virus from bird to bird and also transmit the disease to near-by flocks. The incubation period varies from 4 to 20 days. Chickens, turkeys, pheasants and pigeons can be affected by different Fowl Poxvirus strains.

The lesions of fowl pox can be external (mainly on the head) or internal ("wet pox") in the oral cavity, oesophagus and/or trachea; they can also be found on other parts of the body (skin of legs, cloaca etc.). The lesions on the head, combs, and wattles are usually wart-like in appearance, yellow to dark brown in color. The internal lesions (diptherie) in the mouth, oesophagus and/or trachea are yellow-white and cheesy in appearance. Affected birds will be depressed, lack appetite and when "wet pox" is present they breathe laboriously. Mortality is variable, from a low 1 to 2%, when slight head lesions are present, to over 40% when the diphtheritic form ("wet pox") is more prevalent. Reduced egg production can be observed in laying birds, this will return to normal in a few weeks.

Wart-like lesions of the head particularly of the comb and around the eyes or yellow cheesy lesions of the mucous membranes of the nasal and oral cavities are suggestive of fowl pox. A definitive diagnosis can be made in a laboratory by histological examination (inclusion bodies) or virus isolation in embryonated chicken eggs.

There is no effective treatment. Preventive vaccination using a live vaccine is by far the most successful control method. Even when an outbreak of Fowl Pox has been diagnosed, it is advisable to vaccinate the flock immediately (emergency vaccination) to stop further spreading of the infection.

Inclusion Body Hepatitis (IBH)

Inclusion body hepatitis is a disease of young chickens characterized by sudden onset, increased mortality and hepatitis accompanied with intranuclear inclusion bodies. Most commonly IBH cases involve FAdV8 and FAdV11, but sporadic cases associated with FAdV2 have been documented. 2. HHS has been associated with FAdV4. Outbreaks of IBH are sometimes associated with immunosuppression or exacerbated if affected flocks are immunosuppressed

IBH is characterized by sudden onset of mortality peaking after 3–4 days and usually stopping on day 5 but occasionally continuing for 2–3 weeks. Morbidity is low; sick birds adopt a crouching position with ruffled feathers and die within 48 hours or recover. Mortality might be only slightly elevated but occasionally it might reach values as high as 30%. Higher mortality appears in younger birds less than three weeks of age. IBH is predominantly seen in meat-producing birds and it may start in the first week of life. Disease in young birds is most likely caused by vertical transmission, although no clear differentiation between vertical and horizontal introduction can be made. Immunosuppression induced by IBDV and CAV infection appears to facilitate adenoviruses in producing IBH. In India IBH was often associated with the presence of aflatoxins in the feed). Growth retardation, reduced uniformity, and a higher selection rate are observed.

The liver is swollen, enlarged, yellow to tan, and there may be mottling with focal soft areas with petechial and ecchymotic hemorrhages under the capsule and in the parenchyma. Petechial and ecchymotic hemorrhages may be present in the skeletal muscles of the legs. The skin is pale and may be discolored yellow. The kidneys frequently are swollen and pale or mottled. In addition, there is an accumulation of clear, straw-colored fluid in the pericardial sac and pulmonary edema. Multifocal necrosis in the pancreas is reported in severe outbreaks. Microscopically, there is multifocal to locally extensive. degeneration and necrosis of hepatocytes often with the characteristic large basophilic intranuclear inclusions in the hepatocytes

Duck Plague (Duck Virus Enteritis)

Duck Plague (DP) (Duck Virus Enteritis).

Duck Plague is an acute herpesvirus disease of ducks, geese, and swans characterized by weakness, thirst, diarrhea, short duration, high mortality, and by lesions of the vascular, digestive, and lymphoid systems. All age groups and many varieties are susceptible; however, mostly adults are affected. The virus can be transmitted horizontally from infected to susceptible bird by direct contact or through contact with the contaminated environment (particularly water). Natural infection is limited to ducks, geese, and swans. A carrier state for as long as 1 year has been demonstrated in wild ducks. Vertical transmission has been reported experimentally.

In young commercial ducklings, signs appear 3-7 days after exposure. Ducklings have diarrhea, a blood stained vent, dehydration, and a cyanotic bill. Death usually occurs in 1-5 days. In domestic breeder ducks there is a marked drop in egg production (25-40%) a sudden, high persistent mortality. Sick birds show inappetence, weakness, ataxia, photophobia, adhered eyelids, nasal discharge, extreme thirst, prolapsed penis, and watery diarrhea. They soon become exhausted and unable to stand. They then maintain a position with their head down and drooping outstretched wings. Tremors may be apparent. Morbidity and mortality are usually high but vary from 5 to 100%. Most birds that develop clinical signs die. Wild waterfowl are said to have similar signs. They often conceal themselves and die in vegetation near the water.

Grossly, hemorrhages are present at many sites and there may be free blood in body cavities, gizzard, or intestine. Hemorrhages often occur on the liver, in the mucosa of the gastrointestinal tract (including the esophageal proventricular junction), throughout the heart, in the pericardium and ovary. There may be edema in the cervical region. There is severe enteritis. There may be elevated, crusty plaques in the esophagus, ceca, rectum, cloaca, or bursa of Fabricius. In young ducklings the esophageal mucosa may slough. There is hemorrhage and/or necrosis in the annular bands or discs of lymphoid tissue along the intestine. The spleen is usually of normal or reduced size. Initially the liver may be discolored and contain petechial hemorrhages. Later it may be bile-stained and contain scattered small, white foci as well as many hemorrhages. Microscopically there may be intranuclear inclusion bodies in degenerating hepatocytes, epithelial cells of the digestive tract, and in reticuloendothelial cells.

Typical signs and lesions, along with epizootic losses, are highly suggestive of duck plague. The diagnosis can be strengthened if intranuclear inclusion bodies can be demonstrated or if the virus can be demonstrated in the tissues through fluorescent antibody tests and PCR.

Duck farmers should prevent cohabitation or contact of their ducks with wild waterfowl. All appropriate quarantine and sanitary practices should be followed to prevent disease. Inactivated vaccines are available for prevention. Regular immunization of breeder ducks provides adequate protection. There is no effective treatment.

Duck Hepatitis (DH)

Duck hepatitis (DH) is a peracute, rapidly spreading viral infection of young ducklings characterized by a short duration, high mortality, and by punctate or ecchymotic hemorrhages in the liver. DHV type 1 is a highly contagious disease. The virus is excreted by recovered ducklings for up to 8 weeks after onset of infection. Susceptible ducklings can be infected by direct contact with infected ducklings or their contaminated environment. The virus can survive for 10 weeks in contaminated brooders and for 37 days in feces. The viruses do not appear to be transmitted through the egg and there are no known vectors of the disease.

The incubation period is very short, often around 24 hours in experimental infections, and morbidity is close to 100%. Onset of disease and spread within a flock are very rapid and most mortality occurs within 1 week of onset. Affected ducklings at first are slow and lag behind the flock. Within a short time, they squat with their eyes partially closed, fall on their side, kick spasmodically, and soon die. They often die in the opisthotonos position. Death often occurs within 1 hour of the appearance of signs. Mortality is age related and occurs as follows: ducklings less than 1 week old—up to 95% mortality; ducklings 1-3 weeks old—up to 50% mortality; ducklings over 4 weeks and older ducks—negligible mortality. In older or partially immune ducklings, signs and losses may be so limited that the disease may go unrecognized.

The cadaver may be in opisthotonos, the position in which many of the ducklings die. The liver is swollen and contains punctate or diffuse hemorrhages. The kidneys may be swollen and the spleen enlarged. Microscopically, there may be areas of hepatic necrosis, bile duct proliferation, and some degree of inflammatory response. The sudden onset, rapid spread, short course, and focal, hemorrhagic hepatitis in young ducklings suggest a diagnosis of DHV. There is no treatment for the disease. To prevent this disease, keep age groups isolated and vaccinate breeder ducks with an attenuated live virus duck hepatitis vaccine (to produce maternally immune ducklings).

Chronic Respiratory Disease (CRD)

The underlying cause of CRD is Mycoplasma gallisepticum (MG). The condition is frequently triggered by respiratory viruses such as ND and IB and subsequently complicated by bacterial invasion. The main agents involved in the infection are Mycoplasma gallisepticum and E. coli. Stress caused by moving the birds, by debeaking, other operations/ handlings or other unfavorable conditions e.g. cold or bad ventilation, make the birds more susceptible.

The main problem is that parent birds infected with Mycoplasma gallisepticum can transmit the organism through the egg to their offspring (vertical transmission). In addition, infection can occur by contact or by airborne dust or droplets (horizontal transmission). The incubation period varies from 4 days to 3 weeks. Species affected are Chickens and Turkey

Young chickens (broilers or layer pullets) show respiratory distress. The birds frequently show lack of appetite, decreased weight gain and increased feed conversion ratios. In adult birds the most common signs are sneezing and general respiratory distress. In laying birds a drop in egg production between 20-30 % can occur. In breeders hatchability can be affected and day-old chick quality produced from hatching eggs coming from infected flocks will be reduced. CRD does not normally cause an alarming number of deaths. The effect is more of a chronic nature causing reduced weight gain and higher feed conversion ratios in broilers and lower egg production in breeders and layers. In this way the overall economic losses can be very high.

Grossly a reddish inflamed trachea and/or frothy, cheesy exudate in the airsacs, especially in complicated cases (e.g. with secondary E. coli infections) are observed. In mild MG infections the only lesion might be slight mucus in the trachea and a cloudy or light froth in the airsacs.

Diagnosis of MG infection can be made based on clinical signs and post mortem lesions followed by confirmation in the laboratory using blood (serum) samples for serology or organs swabs for identification by PCR or mycoplasma isolation.

Treatment of MG-infected chickens or turkeys with suitable antibiotics or chemotherapeutics has been found to be of economic value, but will not eliminate MG from the flock. Prevention by monitoring and vaccination has become a more effective method of combating the disease especially in layers.

Mycoplasma Synoviae Infection

Mycoplasma synoviae (MS) infection most frequently occurs as subclinical upper respiratory tract infection inducing airsac lesions. After MS becomes systemic it can induce acute to chronic infection of synovial membranes of joints and tendons resulting in synovitis, tendovaginitis or bursitis. Recently MS was isolated from laying flocks with drop in egg production and/or misshapen eggs (so called “glass window eggs” or “apex Egg abnormalities”). Mycoplasma synoviae is spread horizontally via direct contact and vertically from parent to progeny. Species affected Chickens and turkeys are the natural hosts for Mycoplasma synoviae.

First recognized signs are pale comb, lameness, retarded growth and, as the disease progresses, ruffled feathers, swelling of joints and breast blisters. Respiratory involvement is generally asymptomatic but is possible; usually 90-100% of the birds will be infected. Clinical synovitis varies around 5-15% in an infected flock. Mortality is low around 1% (exceptional up to 10%). More recent strains induced drop in egg production and/or misshapen eggs (so called “glass window eggs”).

In general no lesions are found in the respiratory tract. At post mortem from the early stage of synovitis, a viscous creamy to gray exudate involving synovial membranes of tendon sheaths, joints and keel bursa can be found; other findings are liver and kidney swelling.

Organism confirmatory diagnosis based on isolation and identification of Mycoplasma synoviae can be done by culturing or PCR. Serological monitoring can be done with serum plate agglutination (RPA), Elisa and HI tests.

Treatment Mycoplasma synoviae is susceptible to several antibiotics. Antibiotic treatment will diminish clinical signs but not eliminate MS from a flock. Prevention by monitoring and vaccination has become a more effective method of combating the disease especially in layers. Economic losses in commercial layers can be reduced by proper use of MS vaccines.

Colibacillosis (Escherichia Coli Infections)

Avian colibacillosis is an infectious disease of birds in which Escherichia coli is the primary or secondary pathogen. Infections include airsacculitis, cellulitis, omphalitis, peritonitis, salpingitis, synovitis, septicemia and coligranuloma. Colibacillosis occurs in all types and age groups of poultry as well as in other birds. Most reported outbreaks in poultry have been in chickens, turkeys, and ducks. Many outbreaks occur in poultry raised under a low standard of sanitation, poor environmental conditions, or after a respiratory or immunosuppressive disease. Infection is more frequent in young than mature birds. Colibacillosis is common throughout the world.

The etiologic agent is Escherichia coli (E. coli). The O (somatic) antigen serotypes most commonly associated with disease outbreaks are O1, O2, O35, O36, and O78. The K (capsular) antigens most commonly associated with virulence are K1 and K80. In the intestinal tract of normal poultry, nonpathogenic serotypes far outnumber pathogenic serotypes, with 10% to 15% of intestinal coliforms being potential pathogens. E. coli is present in the intestine of birds and mammals and is disseminated widely in feces. Birds are continuously exposed through contaminated feces, water, dust, and environment. Any time a bird's resistance to disease is impaired, pathogenic or facultative pathogenic strains may infect the bird. Sequestered E. coli in such sites as the intestine, nasal passages, air sacs, or reproductive tract may be a latent source of infection. E. coli has been isolated from the eggs of normal hens. Its presence has been attributed to ovarian infection, oviduct infection, and to eggshell contamination followed by penetration. Chicks may hatch with a latent infection; however, active infection will typically only occur if some environmental stress or lesions initiates the disease process.

A variety of lesions from which E. coli has been isolated include:

1. Airsacculitis: Respiratory signs occur and vary in severity. This pathology may be associated with poor environmental conditions such as dusty litter, poor ventilation, high ammonia levels, sudden variation in the barn temperatures, but also with concomitant respiratory (infectious bronchitis virus, Newcastle disease virus, laryngotracheitis virus, mycoplasmas) or immunosuppressive (infectious bursal disease, chicken anemia virus) diseases. In these cases, E. coli is a secondary pathogen and will cause the airsacculitis lesions. Air sacs are normally thin, glistening and transparent but bacterial infection will cause the air sacs to become thickened,

number of blood vessels within the air sac walls increases and exudate will accumulate within the cavity of the air sac. An acute inflammation will be characterized by the presence of mucous exudate which will eventually become fibrinous. Thickened air sacs and caseous exudate in the air sac will be present in more severe and chronic cases. There often is an accompanying adhesive pericarditis, fibrinous perihepatitis and peritonitis (hence a polyserositis). Airsacculitis occurs chiefly in 3-7-week-old broilers, probably peaking at 5-6 weeks.

2. Pericarditis: Most serotypes of E. coli, after a septicemia, cause a pericarditis. Opaqueness and thickening of the pericardial sac, an edematous epicardium along with myocarditis typically occurs. Pericarditis can also be caused by other bacteria including Chlamydophila sp.

3. Omphalitis and yolk sac infection: E. coli is often isolated in pure culture from organs or the yolk sac of recently hatched birds having depression, septicemia, and variable mortality. With omphalitis the navel is swollen and inflamed and the bird feels wet. Abnormal yolk material and peritonitis is typically seen on necropsy of birds with an E. coli infection of the yolk sac. A great variety of other organisms such as species of Aerobacter, Proteus, Klebsiella, Pseudomonas, Salmonella, Bacillus, Staphylococcus, enteric Streptococcus, and Clostridia are frequently isolated from yolk sacs of embryos and navels of chicks, most likely as mixed infections.

4. Coliform septicemia of ducks (duck septicemia): E. coli, Salmonella, and Riemerella (Pasteurella) anatipestifer produce respiratory signs, airsacculitis, pericarditis, perihepatitis, and peritonitis. In outbreaks of R. anatipestifer, involvement of the air sacs and a dry, thin transparent covering over visceral organs are present. In coliform septicemia (E. coli) usually a moist, granular to coagulative exudate of varying thickness is present on abdominal and thoracic viscera and surfaces of air sacs. The spleen and liver are swollen and dark with bile staining of the liver.

5. Acute septicemia: An acute septicemic disease caused by E. coli resembles fowl typhoid and fowl cholera. Birds are in good flesh and have full crops suggesting acuteness of the disease. This can occur in young or mature birds. There are sudden deaths, and variable morbidity and mortality. Parenchymatous organs are swollen with congested pectoral muscles. Livers are green in color and may have small necrotic foci. There may be petechial hemorrhages, pericarditis, or

peritonitis. Acute systemic disease may also be caused by various Pasteurella, Salmonella, Streptococci, and other organisms.

6. Enteritis: Enteritis caused by E. coli is considered rare but pathogenic attaching effacing E. coli have been reported. Diarrhea and dehydration are noted on clinical examination. At necropsy there is enteritis, often with excessive fluid in the intestines. E. coli may be isolated from parenchymatous organs.

7. Salpingitis: This lesion may occur following entry of coliform bacteria from the vagina in laying hens. It is also likely to develop when the left greater abdominal air sac becomes infected by E. coli, causing a chronic salpingitis. Affected birds usually die during first 6 months postinfection and never lay. The oviduct is distended with exudate that may be caseous and has a foul odor. No specific signs are noted but there may be an upright (penguin) posture.

8. Coligranuloma (Hjärre's disease): Signs vary in this uncommon disease of chickens and turkeys. Nodules (granulomas) occur along the intestinal tract, and mesentery, and in the liver. The spleen is not involved. The lesions resemble those of tuberculosis. The agent is a mucoid coliform, possibly not E. coli. Granulomas of the liver have many causes, some of which would include the anaerobic genera Eubacterium and Bacteroides.

9. Synovitis and osteoarthritis: Affected birds are lame or recumbent. There is swelling of one or more tendon sheaths or joints. Synovitis and/or osteoarthritis are frequently a sequel to a systemic infection. With synovitis many birds will recover in about 1 week. Osteoarthritis is a more severe and chronic condition where the joint is inflamed and the associated bone has osteomyelitis. These severe chronic infections make birds unwilling or unable to walk and necropsy findings often include dehydration and emaciation. Synovitis-arthritis may also be caused by reovirus, or species of Mycoplasma, Staphylococci, and Salmonella.

10. Panophthalmitis and meningitis: Occasional birds have a hypopyon and/or hyphema, usually in one eye, which is blind. Likewise, meningitis is a rare sequelae to E. coli septicemia.

11. Cellulitis : This is one of the most common causes of condemnation at slaughter in broiler chickens. It is recognized primarily at post-mortem inspection, with no abnormality having been noted in live birds. Gross lesions include variable yellowing and thickening of the skin lateral to the vent and extending in severe cases over the ventrocaudal aspect of the breast. On incising the skin a yellow caseous plaque of variable size is noted in the subcutis. Histologically there is cellulitis involving both dermis and subcutis. The inflammatory reaction includes edema and heterophil infiltration in active areas, whereas there is accumulation of a walled-off causative sheet of exudate surrounded by a zone of giant cells in more chronic areas of involvement. Coccobacillary bacteria can be seen in microcolonies within the exudate and E. coli is recovered quite consistently on culture. This condition may affect up to 8% of entire flocks at slaughter resulting in extensive trim-out, downgrading, or whole-carcass condemnation. Cellulitis is caused by the secondary infection of skin wounds. Risk factors such as certain broiler breeds, poor feathering, sex (males more susceptible), skin scratches, increased stocking density and litter type have been associated with this condition.

Diagnosis of primary colibacillosis is based on the isolation and typing of a coliform into one of the serotypes recognized as pathogens. When E. coli is isolated secondary to some other primary disease, it should be diagnosed as secondary colibacillosis.

Measures should be taken to minimize eggshell contamination of newly laid hatching eggs. Eggs should be disinfected on the farm prior to storage and should be stored under ideal conditions. Scrupulous hatchery sanitation, disinfection, and/or fumigation procedures should be practiced. A vigorous sanitation program should be followed in raising poultry. Diseases, parasitism, and other stresses on a flock should be minimized as much as possible. Dust should be controlled. Only feeds free of fecal contaminations should be fed to poultry. Pelleted feeds are more likely to be free of contamination. Treatment of water with halogens and related compounds as well as conversion to nipple drinkers has greatly decreased the incidence of septicemic forms of colibacillosis.

Numerous antimicrobials have been utilized for treatment. These have included tetracyclines, neomycin, sulfa drugs and others but E. coli has developed resistance to many of these commonly used antimicrobials. Antibiotic sensitivity testing is therefore strongly suggested as well as record keeping of treatment history by farm.

Pullorum Disease

Pullorum disease is an infectious, egg-transmitted disease of poultry, often characterized by white diarrhea and high mortality in young birds and by asymptomatic adult carriers. Pullorum disease occurs in all age groups of chickens and turkeys but causes greatest loss in those less than 4 weeks old.

The etiologic agent is S. Pullorum, a nonmotile, Gram negative bacillus adapted to poultry. This organism, like many other Salmonella spp., tends to infect young birds more frequently than older individuals and to establish a bacteremia. S. Pullorum is primarily spread vertically through occasional infected eggs laid by infected carrier hens. Many of the infected chicks hatch and then transmit the organism horizontally to other birds in the hatch through the digestive and respiratory systems. Adult carriers also shed the organism in their feces. Slow horizontal spread to other adults is possible through contamination of feed, water, and the environment. Also, contamination of nests and eggs therein can result in eggshell penetration and infection of chicks that hatch from those eggs. Cannibalism of infected bacteremic birds can result in transmission.

In adults usually there are no signs. The infected adult may or may not appear unthrifty. An infected hen may or may not be a productive layer. A few of the newly hatched birds appear weak or soon die. In others that develop bacteremia sudden death may occur. Mortality may be low during the first few days if only a few of the eggs contained the organism. Morbidity and mortality begin to increase around the 4th or 5th day. Sick birds appear sleepy and weak. There is anorexia, white adherent diarrhea with pasting of the vent area, huddling near heat sources and shrill chirping. A few days later there may be respiratory signs in birds that inhaled the organism in the hatcher. Losses usually peak during the 2nd or 3rd week and then diminish. Survivors often are irregular in size and some are unthrifty, stunted, or poorly feathered. Many remain carriers and disseminators of the etiologic agent. Mortality varies greatly but often is very high and can approach 100%. Mortality is increased by shipping, chilling, or poor husbandry.

Grossly, in adults often there are no lesions. Occasionally there is a nodular myocarditis, pericarditis, or abnormal gonads. An abnormal ovary may have hemorrhagic, atrophic, or discolored follicles, Less frequently there is oviduct impaction, peritonitis, or ascites. Affected testes may have white foci or nodules. In young chicks, there may be few or no lesions in very young birds that die after a short septicemic course. Occasional dead birds feel wet. Many birds have pasted white feces in the vent area. Classically there are nodules in one or more of the following sites: lungs, liver, gizzard wall, heart, intestinal or cecal wall, spleen, and peritoneum. Frequently there are petechial hemorrhages or foci of necrosis in the liver. Later there may be swollen joints in occasional birds. When the intestine is opened, white plaques may be found in the intestinal mucosa and cheesy cores of debris may be found in the intestine or ceca. Plaques and cecal cores occur more frequently in birds that die later in the course of the outbreak.

In young chicks, typical history, signs, and lesions may suggest pullorum disease. Positive agglutination tests, either plate or tube, using sera from convalescent surviving birds may strengthen the diagnosis. Chicks hatched by small, noncommercial operators are more likely to be positive for S. Pullorum. For a definitive diagnosis, S. Pullorum must be isolated and identified.

Prevention is based on establishment and maintenance of pullorum-free breeder and multiplier flocks by serologic testing and other measures. Insofar as chemotherapy perpetuates the carrier state, treatment of pullorum-infected birds is indefensible and should not be recommended under any circumstance.

Fowl Typhoid

Fowl typhoid, caused by Salmonella gallinarum, is an infectious disease, primarily of chickens, with many of the clinical and epidemiologic features and lesions that occur with pullorum disease. S gallinarum shares many antigens with Salmonella Pullorum and the two organisms usually cross-agglutinate. As a consequence, birds exposed to or infected with either disease can be identified by the same agglutination test. Transmission of infection through eggshell contamination may be of somewhat greater importance than with pullorum disease. Also, S.

gallinarum is more frequently transmitted among growing or mature flocks and the incidence and mortality in older birds is usually higher.

Clinical signs of fowl typhoid and pullorum disease are similar in birds less than approximately 1 month old. Semimature and mature birds with fowl typhoid often have pale head parts (comb, wattles, face), shrunken combs and wattles, and diarrhea. Mortality can be substantial.

Lesions of acute fowl typhoid in older birds include: bile-stained ("bronzed") enlarged liver with or without small necrotic foci, enlargement of the spleen and kidneys, Pallor throughout the cadaver and thin watery blood, enteritis in the anterior small intestine, often with ulceration. In older birds, chronic fowl typhoid lesions resemble those seen in pullorum disease. S. Gallinarum should be isolated and identified for diagnosis. Preventive vaccination with SG9R strain is commonly practiced in the poultry industry.

Infectious Coryza

Infectious coryza is an upper respiratory disease caused by *Avibacterium paragallinarum* affecting chickens characterized by decreased activity, nasal discharge, sneezing, and facial swelling. The disease apparently affects only chickens.

Chronically ill or healthy carrier birds are the reservoir of infection for *A paragallinarum*. Chickens of all ages are susceptible; however, susceptibility increases with age. The incubation period is 1–3 days with a typical disease duration of 2–3 weeks. Duration of illness may be longer in the presence of concurrent diseases such as mycoplasmosis. Infected flocks are a constant threat to uninfected flocks. Transmission is by direct contact, airborne droplets, and contamination of drinking water. Transmission does not occur via eggs. "

In the mildest form of infectious coryza, the only signs may be listlessness, a serous nasal discharge and occasionally slight facial swelling. With increased severity extreme swelling of one or both infraorbital sinuses with edema of the surrounding tissues may prevent the eyes from fully opening. In adult birds, especially males, the edema may extend to the intermandibular space and wattles. The swelling usually abates in 10–14 days; however, if secondary infection occurs it can persist for months. There may be varying degrees of rales depending on the extent of infection. In acute cases, only the infraorbital sinuses may be involved and contain copious, grayish, semifluid exudate evident on gross inspection and during histopathologic examination. With chronicity this exudate may become consolidated. Histopathologic features include edema, hyperplasia and erosion of respiratory mucosal and glandular epithelia and edema with infiltration of heterophils, macrophages, and mast cells. Other lesions may include conjunctivitis, tracheitis, bronchitis, and air-sacculitis, particularly if other pathogens are involved.

Isolation of a gram-negative, satellitic, catalase-negative organism from chickens in a flock with a history of a rapidly spreading disease is diagnostic for infectious coryza. Polymerase chain reaction testing has been reported to provide more accurate results versus to bacterial culture.

Sound management practices and vaccination can help prevent infection. Prompt antimicrobial treatment with supportive care of infected birds to aid recovery

Prevention is the only sound method of control for infectious coryza. All-in/all-out flow of animals as part of sound farm management and biosecurity practices are important disease prevention measures.

Vaccination on individual farms should be completed ~4 weeks before infectious coryza outbreaks typically occur.

Because early treatment is important, immediate administration of medication via drinking water is recommended. Erythromycin and oxytetracycline are usually effective. Additionally, several newer-generation antimicrobials (eg, fluoroquinolones, macrolides) are active against infectious coryza. Various sulfonamides, including trimethoprim-sulfamethoxazole, and other drug combinations have been successful for treatment.

Riemerella anatipestifer Infection

Riemerella anatipestifer infection, also known as infectious serositis, duck septicemia, new duck disease, or anatipestifer syndrome is a septicemic disease of ducks, geese, turkeys, and various other birds caused by R. anatipestifer. The disease is prevalent worldwide and causes significant economic loss due to high mortality, weight loss, and condemnations. The acute form of the disease can cause mortality as high as 75% in ducks, especially at farms where infection persists because hatches are frequently moved from one pen to another to create space for the next hatch.

Adverse environmental conditions and concomitant disease often predispose flocks to epomitics of R. anatipestifer infection. The disease is not of public health importance. In the United States, federal or state notification is not required.

The acute form of the disease usually occurs in ducklings 1-8 wk of age. Chronic infections may occur in older birds. Riemerella anatipestifer infections have also been reported in turkeys swans, pheasants, guinea fowl, partridges, quail, and chickens. Clinical signs of the disease include ocular and nasal discharge, sneezing, greenish diarrhea, tremors of the head, neck and legs, ataxia, and coma. The common gross lesions are fibrinous pericarditis, perihepatitis, airsacculitis, and meningitis. In females, the oviduct is filled with caseous yellowish white exudate. Chronic and localized infections result in synovitis/arthritis and dermatitis. Infections originate from exposure via the respiratory tract or through abrasions or cuts in the skin.

Strict biosecurity should be maintained, with regular cleaning and disinfection of facilities. Appropriate vaccines or bacterins (guided by serotyping or whole genomic sequencing) should be administered in naive ducklings and breeder birds on most commercial duck and goose farms. All-in/all-out management systems should be used when applicable and down time should be allotted between flocks.

Sulfaquinoxaline or a combination of penicillin and streptomycin can be used for initial treatment; however, antimicrobial susceptibility testing should be performed because multidrug-resistant strains are becoming more prevalent due to antimicrobial use and development of antimicrobial gene resistance. Enrofloxacin is highly effective in preventing death in ducklings when administered in the drinking water

Aspergillosis

Aspergillosis is an acute or chronic disease, primarily affecting the respiratory system. Peritoneal, visceral and systemic infections especially involving brain and eyes can also occur. The most common etiology is Aspergillus fumigatus but A. flavus can be involved. Aspergillosis occurs frequently in turkeys, chickens, and game birds. This condition has also been reported in penguins, raptors, migratory waterfowl, psittacines and zoologic specimens, such as flamingos. All species of birds probably are susceptible.

Aspergillus fumigatus can penetrate egg shells under ideal growth conditions and thus infect the embryos. Such eggs will often appear green when candled (the embryo will be dead). Infected embryos may hatch with well developed lesions. If infected eggs break in the hatchery, large numbers of spores are released which contaminate the hatchery environment and air systems can lead to severe outbreaks in very young birds (less than 3 weeks of age). Navel infections can also occur. In Adults, infection usually follows inhalation of large numbers of spores from heavily contaminated feed, litter or environment. Conjunctival infections may occur from heavy exposure to airborne spores following traumatic injuries. Infections in the brain, posterior chamber of the eye or other visceral tissues result from systemic invasion from the respiratory tract.

Dyspnea, gasping, cyanosis and accelerated, labored breathing frequently are observed. Other signs include diarrhea, anorexia, somnolence, progressive emaciation, dehydration and increased thirst. Mortality is high in clinically affected birds. Signs of central nervous system disturbance may occur in a small percentage of the birds if there has been spread to the brain. Signs often include ataxia, falling, pushing over backwards, opisthotonos, paralysis, etc. A gray-white opacity may develop in one or both eyes when there is eye infection. Ocular discharge occurs when the conjunctiva is infected and there can be corneal ulceration. A large mass of exudate typically accumulates in the medial canthus under the third eyelid.

Mycelial growth with sporulation may be apparent as fuzzy gray, blue, green or black material (sporulating fungus) or pale yellow plaques on air sac, pleura, pericardium, peritoneum or in the syrinx and main bronchi of the lungs. Pale yellow or gray circumscribed nodules or plaques in the lungs, air sacs bronchi or trachea (usually the syrinx); less often in the brain, eyes, heart, kidneys, liver, or at other sites. In mature birds two patterns of air sac infection are found: disc-like plaques in the recurrent bronchi of the caudal thoracic and/or abdominal air sacs or markedly distended air sacs containing copious fluid and soft fibrinopurulent exudate.

The signs and gross lesions of aspergillosis are very suggestive of the diagnosis which can be confirmed by microscopic demonstration of fungus in fresh preparations made from the lesions or in histologic sections. Microscopic examination reveals septate, branching hyphae within lesions. Hyphae can be seen in fresh preparations cleared with 10% KOH or stained with lactophenol cotton blue. If fungus is grossly visible in the lesions, the typical fruiting bodies and spores can be easily found. In histologic sections, special stains (methenamine-silver, PAS, Gridley) are useful for demonstrating fungi in tissues. Nodules in the lungs usually appear as granulomas containing fungal hyphae. Using sterile technique, the fungus can be cultured by tearing a nodule or plaque open and putting it on fungus media. Aspergillus will usually grow on blood agar in 24-48 hours. Sabouraud's dextrose agar is a more selective medium.

Collect clean eggs, fumigate immediately after collection and store. Do not set cracked eggs or eggs with poor shell quality. Thoroughly clean, disinfect and fumigate incubators and hatchers. Inspect air systems and change air filters regularly in hatcheries. Monitor hatchery environment for mold contamination. Use only dry, clean litter and freshly-ground, mold-free feeds. Store feeds and litters properly so as to inhibit growth of mold. Make sure feed bins and feed lines are kept clean, dry and free of mold growth. Do not permit feed to cake in feeders. Avoid wet litter under or around the waterers or feeders. Mold inhibitors may be added to feed to control fungus growth and prevent infection. Optimize the ventilation and humidity in the poultry house to reduce air-borne spores. Humidity should be kept in the mid-range, neither too low nor too high. The fungus multiplies during the wet period producing abundant spores which then become aerosolized when conditions become dry.

If aspergillosis is diagnosed in a flock, cull clinically affected birds and remove any contaminated feed and litter. Clean and disinfect the house and then spray it with 1:2000 copper sulfate solutions or other fungicide and allow it to dry. Often antibiotics are given simultaneously to prevent secondary bacterial infection.

Coccidiosis

Avian coccidiosis is a common protozoal disease of poultry and many other birds characterized by diarrhea and enteritis. Coccidiosis in poultry affects the intestinal tract, except for renal coccidiosis in geese. Coccidiosis is found in all segments of the poultry industry and has a world-wide distribution. The development of intensive confinement production systems has increased the economic significance of this disease. Subclinical disease has been recognized as having important impact on performance in commercial meat-bird production and negative impacts on flock uniformity of layer and breeder pullets. Coccidiosis can be one of the predisposing factor for necrotic enteritis caused by Clostridia perfringens.

Coccidiosis in chickens is caused by the protozoal species of Eimeria. There are nine described species of Eimeria in chickens Coccidia have a direct but complex life cycle. Infection is by the fecal-oral route. Ingestion of infected feed, water, litter and soil results in infection. Sporulated (infective) coccidial oocyst is ingested, sporozoites are released to initiate a series of asexual replications followed by a sexual cycle that lead to development of thousands of new oocysts in the intestine or ceca. Unsporulated oocysts are shed in the feces. These oocysts sporulate within 24 hr and then are infectious for other chickens. A single oocyst may give rise to more than 100,000 progeny. Coccidia produce lesions in the gut by destruction of the epithelial cells in which they develop and multiply, and by trauma to the intestinal mucosa and submucosa.

Nine species of Eimeria have been described in chickens: E. acervulina, E. necatrix, E. maxima, E. brunetti, E. tenella. E. mitis, E. mivati, E. praecox and E. hagani. The more pathogenic species often cause diarrhea which may be mucoid or bloody. Dehydration often accompanies the diarrhea. Diarrhea and dehydration are soon followed by ruffled feathers, anemia, listlessness, weakness, retraction of the head and neck and somnolence. Growth rate is often adversely affected. In laying hens coccidiosis is usually manifested by a drop in egg production. Depigmentation of the skin may be apparent in well established cases. Morbidity and mortality within a flock may vary greatly, but both can be very high.

E. acervulina is a moderately severe pathogen causing enteritis in the anterior one third of the intestinal tract The enteritis can be mild to severe and cause thickening of the mucosa. **Eimeria necatrix** causes severe enteritis characterized by congestion, hemorrhage, necrosis and blood in the middle small intestine with bloody feces. The lesions with E. necatrix have the appearance of salt and pepper (dark red). Eimeria maxima is moderately pathogenic and may cause moderately high mortality. It causes mild to severe enteritis sometimes with thickening of the intestinal wall and marked dilatation of the middle small intestine, these resemble E. necatrix, but the lesions of E. maxima are bright red. **E. brunetti** causes enteritis in the lower small intestine, rectum and proximal cecum. In severe cases, a fibrinous or fibrinonecrotic mass of debris may cover the affected mucosa or produce caseous cores in the ileum and rectum. **E tenella** is highly pathogenic, causes a marked typhlitis with occasional involvement of the adjacent areas of the intestine. Blood is often apparent in the ceca and feces in the early stages of the infections. **E. mitis** causes no clinical lesions, the lower small intestine which may appear pale and flaccid. **E. mivati** causes reduced weight gain and mortality. **E. praecox** causes watery intestinal contents with mucus and mucoid casts in the duodenum. There may be reduced weight gain, loss of pigmentation, dehydration and poor feed conversion. **E. hagani** causes watery intestinal contents and catarrhal inflammation.

Anticoccidial compounds in feeds are the most common method of control. However, coccidia may become resistant to the anticoccidials, therefore rotation of types of products may be used to prolong efficacy. Several anticoccidials are approved for prevention of coccidiosis, such as Amprolium, Monensin, Clopidol, Nicarbazin, Robenidine, Decoquinate, Lasalocid, Halofuginone, Narasin, Diclazuril and Semduramycin. Care should be taken in choosing the product to be used. Commercial coccidiosis vaccines are available. Planned exposures of young chicks or poults to small numbers of oocysts by coarse spray at the hatchery or in feed, water or gel blocks or in ovo at 18 to 19 days incubation have been used successfully. Chemical agents widely used for treatment include amprolium, sulfadimethoxine, sulfaquinoxaline, sulfamethazine. Sulfas should not be used in layers. Required withdrawal times are usually required prior to marketing. Increasing vitamins A and K in feed or water may reduce mortality and hasten recovery, respectively.

Internal Parasites

The most important internal parasites of poultry belong to the taxonomic group Nematodes (roundworms) and Cestodes (tapeworms).

1. **Ascarids** (Large Intestinal Roundworms): One of the most common parasitic roundworms of poultry (Ascaridia galli) occurs in chickens and turkeys. Heavily parasitized birds may be droopy, emaciated and show signs of diarrhea. Feed efficiency is usually impaired in severe cases. Normal cleaning and disinfecting agents do not kill the eggs.

2. **Cecal Worms:** These worms (Heterakis gallinae) are found in the ceca of chickens, turkeys and other birds. The worms themselves are not considered a major threat, but they are highly considered a major carrier/vector for the agent that causes blackhead (Histomonas meleagridis).

3. **Capillaria** (Capillary or Thread Worms): There are many Capillaria species that affect birds; but in commercial poultry the commonly encountered are Capillaria annulata and Capillaria contorta. These occur in the crop and esophagus of the hosts. These may cause thickening and inflammation of the mucosa. Severe infestation may lead to mortality.

4. **Tapeworms**: Tapeworms or cestodes are flattened, ribbon-shaped worms composed of numerous segments or division. Tapeworms vary in size from very small to several inches in length. Several species of tapeworms affect birds but the most commonly found in poultry are Raillietina cesticillus and Choanotenia infundibulum. Occlusion of the intestines is a fairly common finding.

Birds in modern commercial poultry systems have a lower incidence and worm burden by the less access to many parasites and intermediate hosts; however, the incidence in backyard and free range flocks can be higher with a significant worm burden. Also, clinical disease in all-in-all-out production systems for commercial broilers and turkeys is rare.

Control measures that interrupt the life-cycle are effective for most nematodes with direct cycles of infection. For parasites with indirect life-cycles (some nematodes, cestodes and trematodes), control is often aimed at elimination of the intermediate host such as beetles or other insects, snails or slugs, or preventing access of poultry to the intermediate host. Piperazine is commonly used for treatment for internal parasites in meat and egg producing fowl. Fenbendazole has been used as a feed or water additive has been successfully used against Capillaria, and Heterakis infections. Thiabendazole, mebendazole, cambendazole, levamisole and tetramisole have been used against Syngamus and other nematodes such as Trichostrongylus. Pyrantel tartrate and citarin have also been effective against some nematode infections. Butynorate is approved for treatment of some cestodes of chickens.

External Parasites

The most common external parasites seen in poultry are lice and mites. Typically, these feed on the bird's blood, skin, or dermal structures.

Lice: Poultry lice are tiny, wingless, 6-legged, flat-bodied, insects with broad, round heads. They lay their eggs on the host bird's feathers, especially near the base of the feather shaft. A female louse will lay 50 to 300 eggs at a time, which she cements to the feather shaft. There are several species of lice that affect poultry, and multiple species can affect a bird at any given time. In domestic fowl, more than 40 species of lice have been reported. Some of the most important chicken lice include the Body Louse (Menacanthus stramineus), Head Louse (Culclotogaster heterographa), Shaft Louse (Menopon gallinae), Wing Louse (Lipeurus caponis), Fluff Louse (Gonicocotes gallinae) and the Brown Chicken Louse (Goniodes dissimilis). Birds may be parasitized simultaneously by more than one species. The lice found on poultry do not suck blood, rather they feed on dry skin scales, feathers, and scabs. However, they will ingest blood extruding from irritated skin. The entire life cycle of the lice occurs on the host bird, primarily in the feathers. Eggs are white and commonly appear in bunches on the lower feather shaft. Feathers of infested birds may have a moth-eaten appearance. Due to the feather damage, the bird may have a dull or roughened appearance

Poultry Mites There are two major types of mites found on the body of poultry. They are the Northern Fowl Mite and the Chicken Mite (or Red Roost Mite). The Northern Fowl Mite is the most common external parasite in poultry, especially in cool weather climates. It sucks blood from all different types of fowl. As compared to the Chicken Mite, the Northern Fowl Mite primarily remains on the host for its entire life cycle. These mites are small and black or brown in color, have 8 legs, and are commonly spread through bird-to-bird contact. The Chicken Mite is a nocturnal mite that is primarily a warm weather pest. These mites suck the blood from the birds at night and then hide in the cracks and crevices of the houses during the day. Chicken Mites are dark brown or black, much like the Northern Fowl Mite. The life cycle of mites can be as little as 10 days, which allows for a quick turnover and heavy infestations. Mites can be transferred between flocks by crates, clothing, and wild birds.

Flocks infested with lice or mites show similar general symptoms. Birds will have decreased egg production; decreased weight gain; decreased carcass-grading quality; increased disease susceptibility; and decreased food intake. If any of these generalized symptoms are observed, a visual evaluation is recommended. Inspect birds around the ventral region for signs of lice or mites since infestations usually start in this area of the bird.

Sanitation and cleanliness are the keys to lice and mite control. Sanitation includes cleaning and disinfecting housing facilities and equipment between flocks. Chemical control can include the use of carbaryl. Treat the walls, floors, roosts, nest boxes, and the birds simultaneously. Tetrachlorvinphos and permethrin compounds are commonly used as spray/dip for control of mites and lice

Mycotoxicosis

Mycotoxicosis is a disease caused by a toxic fungal metabolite. Poultry mycotoxicoses are usually caused by fungi that colonize and invade grains and feeds, but other environmental aspects may be involved. Grains used as foodstuffs support the growth of certain fungi when environmental conditions of temperature and humidity are suitable. Some of these fungi produce metabolites that are toxic to humans and animals and cause disease (mycotoxicosis) by either ingestion or cutaneous exposure.

1. Aflatoxicosis: Mycotoxins of the aflatoxin group (B1, B2, G1, G2) are the cause of aflatoxicosis. Aflatoxin B1 is the most common in grains and is highly toxic. Aflatoxin forms in peanuts, corn, and cottonseed, and their products, in other grains, and in poultry litter. A. flavus is the primary producer of aflatoxin in grains. Grains damaged by insects and drought stress, and broken pieces of grain (screenings) are more likely to support fungal growth and toxin formation. Aflatoxin B1 is a potent, naturally occurring carcinogen and thus has special public health considerations. Aflatoxicosis in poultry is primarily a disease of the liver with important ramifications for other body systems, which may ultimately cause production problems and mortality. Affected birds have reductions in growth, carcass pigmentation, egg production, and immune function, and have increased nutrient requirements for protein, trace elements (selenium), and vitamins. The disease may be fatal. At necropsy, lesions are minimal with either transient exposure or exposure to a low concentration of toxin. Jaundice, generalized edema and hemorrhages, tan or yellow discoloration of the liver, and swelling of the kidneys are seen with more severe intoxication.

2. Ochratoxicosis: Ochratoxins A, B, and C are usually produced by toxigenic strains of P. viridicatum but may be produced by other species of Penicillium and by Aspergillus ochraceus. Ochratoxin A is the most toxic and is the greatest threat to poultry production. Clinically, reductions in feed intake and increases in mortality, weight loss, drops in egg production have been reported from Ochratoxin A. Gross and microscopic lesions occur in the kidneys and liver. Visceral gout and reductions in plasma carotenoids, immune function, and certain blood coagulation factors also occur.

3. **Trichothecene**: (Fusariotoxicosis): More than 40 trichothecene mycotoxins are known to exist. T-2 toxin is one of the most toxic to poultry. Chickens with fusariotoxicosis (trichothecene mycotoxicosis) have had reduced growth, abnormal feathering, severe depression, and bloody diarrhea. In chickens, pigeons, ducks, and geese, the caustic properties of the trichothecenes have been manifested as feed refusal, extensive necrosis of the oral mucosa and areas of the skin in contact with the mold, and symptoms of acute gastrointestinal disease. Trichothecene mycotoxicosis may cause necrosis of the oral mucosa, reddening of the mucosa of the remainder of the gastrointestinal tract, mottling of the liver, distention of the gallbladder, atrophy of the spleen, and visceral hemorrhages.

4. Citrinin Mycotoxicosis: Citrinin is a mycotoxin that was first isolated from Penicillium citrinum but is also produced by other species of Penicillium and by a few species of Aspergillus. Citrinin mycotoxicosis in the chicken, turkey, and duckling can cause clinical illness of marked watery fecal droppings related to increases in water consumption and urine output. Metabolic alterations of electrolytes and acid-base balance occur. Young birds have reduced weight gain. Citrinin produces marked functional changes in kidneys, however, gross lesions may be slight or overlooked. Swelling of kidneys and microscopic lesions of nephrosis may occur following severe exposure. In these circumstances, lymphoid tissues may be depleted and necrosis occurs in the liver.

Control: Prevention of mycotoxicoses requires the detection and control of mycotoxin contamination in feed ingredients and the application of feed manufacturing and management practices that prevent mold growth and mycotoxin formation. Mycotoxins can form in decayed, crusted, built-up feed in feeders, feed mills, and storage bins. This can be prevented by inspection of bins between flocks to certify absence of feed residue and by cleaning bins and feeders when necessary. Antifungal agents added to feeds to prevent fungal growth have no effect on toxin already formed, but may be cost-effective management in conjunction with other feed management practices. Several commercial products, most of which contain proprionic acid, should be applied according to manufacturers' instructions. Zeolytes, a class of silica-containing compounds used as anticaking agents in feed formulation, and as aids in the improvement of eggshell quality, show promise as a practical and economical method of reducing the effects of certain mycotoxins. Hydrated sodium calcium aluminosilicate has been shown to bind aflatoxin B1, possibly by sequestration in the digestive tract, and reduce its toxicity to chickens.

Treatment: Remove the toxic feed and replace it with unadulterated feed. Treat concurrent diseases (parasitic, bacterial) identified in the diagnostic evaluation. Substandard management practices should be immediately corrected as they have increased detrimental effects in a flock stressed by mycotoxins. Vitamins, trace minerals (selenium), and protein requirements are increased by some mycotoxins and can be compensated for by feed formulation and water-based treatment.

Vaccination Schedule for Backyard Poultry

Age	**Vaccine**	**Route**
1 day	Marek's disease	S/C injection
5-7 day	Newcastle disease (Lasota)	Intraocular or drinking water

14th day	Infectious Bursal disease (Intermediate Strain)	Oral drop or Drinking water
24th day	Infectious Bursal disease (Intermediate Strain)	Oral drop or Drinking water
30th day	Newcastle disease (Lasota)	Eye drop or drinking water
6th week	Fowl Pox	IM or SC injection
9th week	Newcastle disease (R2B)	S/C injection
Repeat ND Lasota and Fowl pox every six months preferably before summer (Feb/March) and before winter (Sep/October)		

Vaccination Schedule – Commercial broiler

Age	Vaccine	Route
In hatchery	IB (H120)	Intraocular or spray
5-7 day	Newcastle disease (Lasota)	Intraocular or drinking water
14th day	Infectious Bursal disease (Intermediate Strain)	Oral drop or Drinking water
21th day	Infectious Bursal disease (Intermediate Strain)	Oral drop or Drinking water
28th day	Newcastle Disease (Lasota)	Intraocular or Drinking water

Vaccination Schedule for Commercial Layer

Age	**Vaccine**	**Route**
1 day	Marek's disease	S/C injection
5-7 day	Newcastle disease (Lasota) Infectious bronchitis (H120/Ma5)	Intraocular or drinking water
14th day	Infectious Bursal disease (Intermediate Strain)	Oral drop or Drinking water
24th day	Infectious Bursal disease (Intermediate Strain)	Oral drop or Drinking water

28th day	Newcastle disease (Lasota) Infectious bronchitis (H120/MA5)	Intraocular or drinking water
6th week	Infectious Coryza Fowl Pox	IM or SC injection
9th week	Newcastle disease (R2B)	S/C injection
12th week	Infectious Coryza	IM or SC Injection
16 weeks	ND+IB (Inactivated)	IM or SC injection
From 35 weeks onwards repeat ND Lasota & IB (H120/MA5) at every 6-8 weeks interval through drinking water		

Vaccination Schedule for Ducks

Age	Vaccine	Route
3-4 weeks	Duck Cholera (Inactivated)	SC injection
8-12 weeks	Duck Plague (Inactivated)*	SC injection

***Annual Vaccination is recommended**

Chicken Drug List

Active Ingredients	**Route**	**Withdrawal Time (days)**	**Dose**
Amprolium	Water	0	0.006-0.024%
Amprolium	Feed	0	0.0004-0.25%
Arsanilic acid	Feed	5	90 g/ton
Bacitracin methylene disalicyclate	Water	0	100-400 mg/gal
Bacitracin methylene disalicyclate	Feed	0	4-200 g/ton
Bacitracin zinc	Water	0	100-400 mg/gal
Bacitracin zinc	Feed	0	4-50 g/ton
Bambermycins	Feed	0	1-2 g/ton
Ceftiofur sodium[A]	Inject	0	0.08-0.20 mg/bird
Chlortetracycline	Water	1	100-1,000 mg/gal
Chlortetracycline	Feed	2	10-500 g/ton

Clopidol	Feed	5	0.0125-0.0250%
Cyromazine[B]	Feed	3	1 lb/ton
Decoquinate	Feed	0	27.2 g/ton
Diclazucil	Feed	0	1 ppm
Enrofloxacin	Water	2	25-50 ppm
Erythromycin phosphate	Water	1	0.5 g/gal
Erythromycin[C]	Feed	1-2	92.5-185 g/ton
Gentamicin sulfate	Inject	35	0.2 mg
Halofuginone hydrobromide	Feed	4	2.72 g/ton
HygromycinB	Feed	3	8-12 g/ton
Lasalocid	Feed	0	68-113 g/ton
Lincomycin	Feed	0	2-4 g/ton
Lincomycin Het[D]	Water	0	64 mg/gal
Lincomycin/spectinomycin	Water	0	2 g antibacterial action/gal
Maduramicin ammonium	Feed	5	4.54-5.45 g/ton
Monensin	Feed	0	90-110 g/ton
Narasin	Feed	0	54-72 g/ton
Narasin/nicarbazine	Feed	5	54-90 g/ton of combination
Nicarbazine	Feed	4	0.0125%
Nitarsone	Feed	5	0.01875%
Novobiocin	Feed	4	6-14 mg/lb BW/day
Nystatin	Feed	0	50-100 g/ton
Oxytetracycline hydrochloride	Water	5	200-800 mg/gal
Oxytetracycline[E]	Feed	0-3	5-500 g/ton
Oxytetracycline	Inject	5	5-25 mg/bird/day
Penicillin (from procaine penicillin)	Feed	0	2.4-100 g/ton
Piperazine	Water	0	51 mg/bird
Robenidine hydrochloride	Feed	5	30 g/ton

Roxarsone	Water	5	0.002% (21.7g/oz)
Roxarsone	Feed	5	22.7-45.4 g/ton
Salinomycin	Feed	0	40-60 g/ton
Sarafloxacin hydrochloride	Water	0	20-40 ppm
Semduramicin	Feed	0	22.7 g/ton
Spectinomycin dihydrochloride	Water	5	0.5-2 g/gal
Spectinomycin dihydrochloride[A]	Inject	0	2.5-5 mg/bird
Stephmycin sulfate	Water	4	10-15 mg/llb
Sulfachloropyrazine sodium	Water	4	0.03%
Sulfadimethoxine	Water	5	1.875 g/gal
Sulfadimethoxine/ormetoprim	Feed	5	113.5 g/ 68.1 g/ton
Sulfamethazine sodium	Water	10	61-89 mg/lb BW/day
Sulfaquinoxaline	Water	10	0.025-0.04%
Tetracycline hydrochloride	Water	4	200-800 mg/gal
Tylosin tartrate	Water	1	50 mg/lb BW/day
Tylosin[F]	Feed	0-5	4-1,000 g/ton
Tylosin tartrate	Inject	3	25 mg/2 lb BW
Virginiamycin	Feed	0	5-20 g/ton
Zoalene	Feed	0	36.3-113.5 g/ton

[A] For use in 1-3 day-old chicks only.

[B] For use in layers or breeders only.

[C] Do not use high dose level (185 g/ton) in layers.

[D] Use only up to 7 days of age.

[E] Three-day withdrawal only required with 200 g/ton dose.

[F] For layers use 20-50 g/ton dose. Highest dose level (1,000 g/ton) requires 5-day withdrawal.

Role of Biotechnology in Poultry Augmentation

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Abstract:

Biotechnology is extensively used in poultry production besides numerous other potential applications. The biotechnological application like crossing of diverse strains of animals is being used in animals since time immemorial. In the recent past, it is widely used in the poultry production system to meet the ever-growing demand of poultry products. Poultry industry needs to emphasize on the requirement of the consumer. The consumers these days look for low cholesterol or fortified egg/meat where there is active involvement of Biotechnology. Depending upon the high nutrition requirement for ever growing population, higher productivity and improved feed efficiency is the need of the hour. To meet the ever increasing demand, traditional ways to increase the productivity will not prove to be worthy because these ways will be time consuming and expensive. Conventional ways to increase the productivity remains very slow. With the advancement of biotechnology where development of SNP array, comparative and functional genomics are involved, application of biotechnology greatly influences the poultry production particularly in breeding (genomics), health (vaccines and antibiotics), therapeutic protein (transgenic animals) and feed technology (anti-nutritive factors). Limitation of phosphorus content, tannins, trypsin inhibitors and phytates etc. can also be solved by developing genetically modified feed or by manipulating the gut microorganisms.

Introduction:

Selection of animals for the desired traits or selection against undesirable traits has been practiced since the process of domestication started. The primary aim in animal breeding program is to select the parents having high breeding values for a particular trait and pass on this trait to next generation for quick genetic gain. Most of the genetic traits are quantitative in nature and is a result of overall interaction of genetic and epigenetic factors. The animals are selected for their breeding values for a trait (breeding value of an individual is the sum of the additive effects of all loci that contribute towards a particular trait). Usually the breeding value is estimated with sophisticated statistical methods based on best linear unbiased prediction (BLUP) mixed linear model methodology. Though, the traditional selection methods improve the animal productivity but the process is slow, time consuming and costly because most of the traits express at maturity. Advancement in DNA technology enabled the researchers to identify the DNA region associated with a particular trait. The genetic marker for selecting the animal for economic traits, it is imperative to study genotype of animals particularly at those loci which are directly influencing these traits. Previous research picked up genes that have a major effect on a particular trait, however, recent studies suggest that major genes are rare and most of the economically important traits like egg production, meat, fertility, health and growth are influenced/ controlled by group of genes. Targeting groups of genes at a time will increase the accuracy and understanding for selection of birds with desired traits.

Biotechnological tools helped the poultry sector to improve the productivity. The emerging areas are:

1. Production of transgenic animals
2. Feed Biotechnology
3. Genetic Markers and Marker-Assisted Selection

Genetic Marker-Assisted Selection:

With the publication of the chicken genome in 2004, genome wide studies have been taken up. Genomic selection is all about envisaging the genomic estimate of breeding value (GEBV) of an individual using whole genome SNP information. This technique has emerged as the most advanced genetic marker-assisted selection technology. A genetic marker for a trait is a segment of DNA which is associated and segregated in a particular pattern. The genetic marker is a sort of tag of individual gene or a segment of chromosome which influences a particular trait. The selection of animal for a particular trait with the help of genetic marker is called marker assisted selection (MAS). Through MAS the genetic gain can be maximized in a short span of time. Generally, the flavin-containing monooxygenase (FMO) gene family is reported to be conserved across the vertebrate species. However, the loss-of-function mutations in the flavin-containing mono-oxygenase isoform FMO3 is reported in human (fishy odor of urine and other secretions), cattle (fishy off-flavor in milk) and also in chicken (fishy taint of eggs disorder). In chicken, this is the first application of a definitive SNP gene test for metabolic disorder. This is the first report where breeding aspect could be achieved by the DNA rather than phenotyping or feeding. In simulation studies, it has been predicted that breeding improvement can be increased by 20–40% if genomic selection is applied extensively (Avendaño et al. 2009). In genomic selection the effect of each SNP is estimated on the high-density panel using models that includes all SNPs at a time. Genome wide SNP diversity in the population and development of SNP chips of the reference population will provide an efficient means of achieving genome-wide genetic mapping of complex traits that may quickly and cost-effectively provide functional markers for validation and application in molecular breeding programs. With the advancement of sequence technology and the related bioinformatics tool genomic selection for genetic improvement in poultry breeding programme takes place in a big way. Chicken was the first livestock species sequenced and several low to high density SNP chip were developed viz. 3K SNPs (Muir et al., 2008), 42K chip developed by the EW group, 60K chip developed with USDA funding and recently the first publicly available high-density 600K chip, developed with support from the BBSRC and the Roslin Institute. These SNP chips cover the variants from both egg type and broiler breeds. For traits like egg production and egg quality, could be increased by up to 2-fold for selection at an early age using SNP chip with about 23000 segregating SNP accuracy. However, for traits with high heritability comparatively smaller marker SNPs are sufficient to elucidate the variations (Rudolf, 2012). The synergistic effect of genomic and bioinformatics tools may have a great impact on farm animal breeding programme in many ways including enhancement of accuracy of estimated breeding value thereby reducing the chance of inbreeding and the desired animals can be selected without the prior knowledge of phenomics data/parentage. Recently, the genome-wide association study has revealed 12 significant SNPs for body weight at eight weeks of age in Korean native chickens. These SNPs can be used as selection markers for body weight (Cha et al., 2021). In another study, several regions of breed selection signature were identified in Korean native chicken (Cho et al., 2021).

Feed biotechnology

Different biotechnological applications, like editing of bird's genome, transgenically manipulating the micro flora of gut and use of different kinds of antibiotics, probiotics, prebiotics and enzymes, are used to improve the poultry feed efficiency which is profitable for the industry. Feed additives have been extensively used in poultry feed not only for better growth and feed utilization but also to improve the health of the birds (Fadlalla et al., 2010). Some of the commonly used enzymes in poultry feed are ßglucanases (which neutralize certain anti-nutritive factors in non-cereal feedstuffs), phytases (which increase the availability of phosphate), proteases (which enhance protein digestion), lipases (to enhance lipid digestion), and galactosidases. These enzymes are used in the poultry feed mainly to reduce the effect of undesirable anti-nutritive carbohydrates present in the feed. These anti-nutritive carbohydrates reduce digestion and absorption of all nutrients in the diet, especially fat and protein. (Tesso and Liu 2017). For optimum poultry production (egg and meat), there is requirement of a feed with high amount of energy and protein apart from balanced minerals, specific amino acid and vitamins. If there is an imbalance or deficiency in absorption of the required components in the gut then not only it will affect the health of the birds but also reduce the production performance of the birds and hence a loss of the valuable natural resources. Poultry lacks pregastric fermentation ability and all feeds should be digested in the intestine only. Moreover, monogastrics are deficient in production of certain enzymes which are helpful in the catabolic reactions of different feed stuff. To improve the digestibility of different types of feeds, technologically produced enzymes can be added exogenously to overcome the deficiencies. Enzyme quantity and ratio may be adjusted according to the diet/ feed of the poultry. Moreover, this exogenous use of xylanase and glucanase enzymes in the corn, barley, wheat and rye based diets improves FCR , body weight and apparent metabolozable energy (AME) by 2-9%, 4-12% and 3-10%, respectively in broilers, ducks, turkeys, and laying hens (Cowieson et al. 2006). In recent time, many biotechnological approaches have been developed in animal nutrition field that includes use of feed additives, enzymes, probiotics and even there is a possibility to use rDNA technology to create anti nutritional factors free feed or tailor made feed products. The gastrointestinal tract (GIT) microbial biota of chicken plays a causal role in bird digestion physiologically and gut associated immune system. Poultry feed contains mainly cereal grains which are rich in non-starch polysaccharides including xylans. To digest that, chicken intestine requires polysaccharide hydrolases including xylanase in good amount. Recently in caecum metagenome studies of chicken, Darkazali et. al., 2017, isolated a xylanase gene from and over-expressed it. This xylanse catalytic activity and stability was reported even at a very high salt concentration which can be a potential application to digest xylanase in the poultry feed.

Transgenic manipulation of chicken microbial gut has considerable potential for improving digestibility.

Poultry industry currently uses biotechnologically produced amino acids, vitamins, organic acids, other solvents and enzymes. Through biotechnologcal manupulation of microbes, phytase enzyme was produced which in turn help in digesting phytic acid present in cereals and oil seeds which are the main source of poultry feed. This way it helps in providing digestive phosphorus to animal and additional use of organic phorshpous is not required in the feed. It is also reported that through genetically modified microorganism, amino acid like tryptophan and threonine and other amino acids can be produced in large quantity for adding in the feed which can reduce the crude protein in the feed by about 5 percent. Raffinose and stachyose which are anti-nutritional factors present in the soybean can be reduced in the genetically modified soybean. Overall, the limitation in feed technology like anti-nutritive factors limitation of phosphorus content, tannins, trypsin inhibitors and phytates etc. can be solved by developing genetically modified feed or by manipulating the gut microorganisms. Transgenic manipulation of gut microorganisms has significant impact for improving nutrition, gut development and health.

Transgenic Chicken Application:

In recent years, chicken emerges as an important animal model for transgenic research. A transgenic chicken means the bird whose genome has been augmented by stable integration of DNA from a source other than parental germplasm through transgenesis method. Genetically engineered chicken have significantly contributed to our understanding of different aspects related to immunity, infectious diseases, and developmental biology. Due to low success rate in the transgenic technology in chicken, it is not widely used. Moreover, the progress in transgenic chicken technology has lagged behind than that in other mammalian species. But with the advancement in biotechnological tools and shorter generation interval in chicken, transgenic technology proved to be very important for the pharmaceutical and chicken breeding industries. Recently, several new methods like Primordial germ cells (PGCs), DNA microinjection, transgenesis by spermatogonial cells and retroviral vectors have been developed that enabled the successful production of transgenic chickens and chickens as a valuable experimental genetic system. Exploitation of this transgenic chicken production technology, in both basic and applied research, leads to many applications in poultry breeding programme and novel uses. Transgenic chicken can act as a bioreactor for the production of commercially valuable, biologically active therapeutic proteins in egg or meat. As compared to plants or microorganisms, bioreactor poultry has an advantage because it is easy to harvest pure and high amount of recombinant protein (in egg) and secondly because glycosylation patterns of some human proteins are more closer to chicken compared to other bioreactor system (Raju et al., 2000). There are many reports where it has been shown successfully to produce human therapeutic bio-molecules in transgenic chicken. The first successful production of a biologically active recombinant protein in transgenic chicken (egg white and serum) was β-lactamase. The expression level was same in the successive generation that proved that chicken can be used as a bioreactor system for production of biologically active recombinant protein like human erythropoietin fusion protein in serum and egg (Penno et al., 2010). Zhu et al., in 2005 reported that the first fully functional human sequence monoclonal antibodies (mAbs) produced in chicken's egg that possesses enhanced antibody-dependent cellular cytotoxicity (ADCC). To achieve this, they inserted genes encoding antibody and also the gene which control its expression in chicken embryonic stem cells. These cells were introduced into developing chick embryos. The transgeneic chicken so produced contained milligram amounts of the desired antibodies in its egg. In recent time transgenic chickens as bioreactor has been used to produce several kinds of recombinant proteins like antibodies and cytokines in the egg. All these studies show that transgenic chicken can be used as a potential bioreactor system for the production of pharmaceutical proteins apart from vertebrate developmental studies. By using CRISPR/Cas9 methods (Mukae et al., 2021) monoclonal antibodies (mAbs) in egg whites has been produced in transgenic chicken.

Conclusion

There is a continuous improvement in biotechnological aspect to improve poultry nutrition and feed quality, their utilization, reduction of disease incidences, production of pharmaceuticals through transgenic animals and redefining the breeding strategies particularly studying the genome profile coupled with phenomics database with the efficient imputation algorithms which is a viable alternative for faster selection in poultry for a particular trait.

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Sex determination in chicks: A practical experience

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Introduction

Poultry farming has been a lucrative enterprise today as benefit-cost ratio is relatively higher than other livestock farming. Poultry farming is broadly classified into two categories, namely extensive farming and intensive farming. In extensive farming, birds roam in the pasture or open areas or back yard to collect their feed to fill their stomach. There is no extra feed supplement being given to the birds. During night time, they take shelter in the shed made for them and in the morning they go out. No extra care and management are provided to them and only during natural brooding, some feed supplement and water are provided to the mother hen. Birds protect themselves from predators and little medical care is provided to the birds. Hen normally lay in the night shelter or sometimes in the grazing area. On the other hand, in intensive system, birds are reared in the houses and required feeding and watering are provided to them. They are kept in captive condition. Veterinary aids are also provided to the birds both in terms of prophylactic and curative measures. Several managemental facilities are practiced like chicks upto 6 weeks of age are kept in brooder house and then shifted to the grower house. At 18 weeks of age, birds are again shifted to either cage house or deep litter house. As far as feeding is concerned, suitable ration maintaining required level of protein, dry matter, vitamins, amino acids etc. are feed to the birds. During growing stage, some supplements of growth promoters are also provided through diet. During laying stage, required amount of Calcium and Phosphorous are supplemented in the feed, hence, intensive farming is a bit more expensive than extensive farming. Extensive farming is nearly no-input system while in intensive farming, everything is provided exogenously to maintain body requirement of birds. Extensive farming in other way is called backyard farming. However, in both the farming system, sufficient number of male and females birds are required to regenerate future generation. In layer farming, more number of female birds are required as they lay eggs while required numbers of male birds are needed to produce next generation. In broiler farming, both male and females are equally important but the most desire is to have more male chicks as the weight of male birds are higher than their female counter parts. In layer farming, too many male chicks are not desired and hence are culled on day-old age to minimize feed and other managemental costs. Likewise, in broiler industry, more male chicks are preferred to obtain higher body weights. Chicks are sexed at day-old stage and required number of chicks of specific sexes are kept in the farm while remaining are discarded. In poultry farming, feed cost involves maximum expenditure followed by veterinary aids and other managemental requirements. Hence, early detection of sex in the birds are the most essential step in the poultry farming to be conducted at very early stage.

Techniques:

Sex determination can be done by several techniques. Each technique does have its own limitation and advantages. The already known methods of sexing birds have been briefed here. All the methods are not so perfect in all aspects especially type of tissues, tissue collection procedure, complicacy of the method, accuracy, time requirement, age of sexing and economic aspect. Several methods are available to determine sex in chicks. They can be grouped into two classes such as non-invasive method and invasive method. Non-invasive methods are cloacal or vent sexing; feather sexing; feather sexing by colour of the plumage; sexing by digital pad scales; ultrasonographic method and faecal steroid sexing method.

- Vent sexing was devised by Masui and Hashimoto (1933). This method needs a lot of experience and skill. This technique is somewhat stressful and there is a possibility of contamination from chick to chick while sexing. The method is about 95% accurate to determine sex of day old chicks.
- In case of feather sexing, determination of sex is done on the basis of length of wing feather in some breeds of chickens. Female chicks are rapid feathering while male chicks are slow feathering (Card and Nesheim, 1966). The genes controlling feather growth are linked to the sex gene in which slow feathering is dominant over rapid feathering. The main limitation of this technique is that the character is breed specific and it is expressed in some breeds. This method is having accuracy of about 95%.
- Some chicken lines carry sex-linked differences in the colour of the plumage on the neck and back area on the day of hatching. Mating of a silver plumage female with a gold plumage male produces gold female and silver male chicks. The gene for barring is also sex linked, produce barred female chicks and non-barred male chicks. This feather sexing by colour of the plumage method is breed or line specific.

- The shape and number of skin scales on the planter surface of the tip of the third digit of day-old chicks are used as criteria for sex determination (In Sexing by digital pad scales method). This character is sex linked where scales are more in males than females (Hampl, 1992). The accuracy is more than 90%.
- Transcutaneous ultrasonographic method for visualization of gonads of newly hatched chicks is another method of determination of sex (Kaleta *et al.,* 1994). Trans-intestinal ultrasonography is used to detect the gonad (In Ultrasonography method). This method is not suitable for mass application and it is also a tedious method although the accuracy of sexing is high.
- Faecal steroid sexing method estimates level of estrogen and testosterone in faeces of the chicks. The faeces of female chicks have higher estrogen/testosterone ratio than males. This technique is accurate only in adult birds and it needs fresh faeces sample (Swengel, 1996).
- Invasive methods are cytogenetic method, DNA based method, RNA based method, laparoscopic method and hormonal assay. In cytogenetic method chromosome slide is prepared from cultured cells (Blood and other tissue cells etc.), which are collected from the birds through injecting needles. Microscopic investigation of chromosome delineates the presence of either two Z chromosomes or Z and W chromosome through karyotyping technique. The presence of ZZ indicates male and ZW indicates female birds. The accuracy of this method is more than 99%. The limitations of this method are that it is time consuming and laborious, less number of samples can be handled at a time etc.
- In DNA based method, tissue samples are collected from chicks by injecting needle in the vein or any other organs. Genomic DNA is isolated from those tissues and is used for hubridization. W-specific gene based probe can be used to detect the presence of signal in the restriction enzyme digested genomic DNA run on agarose gel through Southern hybridization. Presence of signal indicates female and absence indicates male birds. These DNA based methods are highly accurate but this method is more time to get the result.
- In RNA based method, there are a number of sex specific hormones, peptides expressed in chicks. Female chicks express estrogen while its male counterpart lacks it. The presence of mRNA of those peptides/hormones indicates specific sex while absence

reveals another sex. This method can be applied in adult birds only for sex determination. The accuracy of this method is 99%.

- In laparoscopic method, laparoscopic investigation of gonads determines sex very accurately. This method is better diagnostics of sex at older age than young age. The main disadvantages of this method are the necessity of anesthesia and the risk of accidental injuries. Sometimes, this method is very harmful leading to lethality (Swengel, 1996).
- In hormonal assay, sex specific hormonal assay is an useful technique of sex determination in chicks. Estrogen gene is highly expressed in female but lowly expressed or absent in male chicks. Assays of estrogen accurately diagnose the sex of the birds. The main limitation is that it can be applied only in adult birds where the hormones are expressed.

Molecular sexing:

Using DNA/cells/feather follicles, a molecular sexing method has been developed at our lab. There are three major steps involved in this method and they are collection of tissues, PCR and electrophoresis. The major advantage of this method are as follows.

- This method is non-invasive and does not need to inject/intervene surgically to collect tissues. Two growing feathers are plucked and can be needed to determine sex of day old chicks.
- This method is a single tube method. The product is run in 1% Agarose gel for 30minutes to determine the sex of a bird. This method is very simple and rapid. Within 3 hours, sex can be detected in day old chicks.
- Our method can be employed at any age right from day old to adult stage. For carrying out this method, only two growing feather follicles are sufficient as source of tissue.
- This method is applicable for sex determination in all sorts of birds where female chromosome pattern is ZW type and male is ZZ type.
- This method is not breed specific or age specific.
- This method is less time consuming and sex of chick can be determined within 3 hours after collection of feather follicles.
- A large number of chicks can be handled at a time for sexing.

- Lastly but not least, this method of sex determination is very economical and needs Rs. 40.00 per sample, which is comparatively less expensive and about more than 99% accurate for sex determination at any age group of birds.

Conclusion:

Sex determination is one of the most important aspect of commercial poultry farming particularly regeneration of pure lines. To supply the male or female birds to the farmers or other commercial farms or for selling chicks, the perfect sexing is utmost essential. Inaccuracy in sexing may cause huge loss of pure line poultry Industry since a pair of male and female birds is sufficient to multiply to develop a flock. Although there are many methods are available, keeping the pros and cons in mind, the molecular sexing method is probably the best and can be done at very early days. In pure line breeding, early detection of sex is essential to minimize the cost of rearing un-desired chicks. Hence, it is extremely important to carry out perfect sexing of chicks to prevent the leaks of sex determination in the commercial farm.

Stress management in modern poultry prouction

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In India poultry farming became integral part of livestock farming. Its contribution towards economy can be judged by 76294 crores of Gross Value addition in year 2017-18. The total population of poultry in country is 851.81 million. There are different types of stresses, which affect chicken breeding programs. They may be increase in body weight, feed withdrawal, environmental stress, high stocking density, vaccination and pathogens present in the in house system. These factors increase the stress, decrease immunity and health, which further affects production performance. The endocrine, metabolic, reproductive machinery of the bird gets affected. The commercial growing practices also increase stress in poultry, when stress is induced, chickens become susceptible to pathogens which in turn colonize the different organs of the birds. Present-day, poultry farms rear modern boiler breeds/ layer breeds that are intensively selected for rapid growth and egg production. When the broiler chickens are made to grow faster, it puts lot of stress on the birds metabolism and increases the generation of heat function of other organs. It also affects function of layer birds when made to produce more number of eggs.

To get a better production performance from the chickens, in the modern era proper management of the birds should be taken. There should be constant upgradation, modification & application of new technologies for the multi-faceted growth in poultry. The development should be not only with respect to size but it should be also towards increase in production, quality and use of better equipment's and technologies and at the same time, health of the chickens has to be also monitored.

For keeping the chickens healthy the general principles should be for prevention of diseases

- The procured fields must be periodically tested and they should be free from microbial agents and toxins.
- Storage facilities must be managed to keep it in hygienic manner and supply of clean water is to be ensured.
- Regular inspection of wells, tanks, which are source of water, should be maintained clean.

- Specific vaccination schedule must be practiced.
- Sheds and equipments must be cleaned properly with appropriate detergents.
- Timely disposal of dead birds from the shed should be done.

Nutrition management allows improvement in feed conversion ratio through optimal balanced diets and feed regimes. This helps in improvement of feed digestibility. Feeding antioxidants like vitamin A, plant extract and trace minerals like selenium, chromium, zinc etc. reduce the stress conditions. For this the factors which need to be considered are nutritional requirements of the birds, specific production and growth stages, availability of nutrients in a specific location. Many commercial products probiotics, immunomodulators, eubiotics, organic acids are available which enhance the function and development of the gut. The function of the gastro-intestinal tract plays a crucial growth in supporting basic function of digestion of food and to provide nutrients. The microbiota also play a important role in maintaining health and immune system of the chickens.

The procured feed should be free of fungus and moulds. Many herbal products made from ginger, garlic, turmeric, cinnamon etc. either single /combined in proper proportions can be supplemented to chickens during growth phase to prevent the occurrence of non-clinical and subclinical diseases. This will ensure the birds to remain healthy and also reduction in the usage of antibiotics. It is observed that using antibiotics as a growth promoters or using them at subclinical doses or in a random manner leads to production of resistant bacteria, which can spread to humans through food consumption. Hence, herbal products can be used safely as a preventive measure for the diseases and will be economic also. A healthy bird will give rise to better production performance and profit to the producers. For layers, free layer feed is must which is usually offered two to three weeks before egg production when liver and reproductive organs are increasing in size and calcium reserves are built up to meet the demands of egg shell formation. Sodium levels in the diet should be kept at 0.18 -0.16 g per day, per bird.

The environmental stress to the chickens occurs when the temperature of the environment increases or decreases above or below the comfort zone temperature which is usually referred to as 25- 26^{o}C . It also depends whether birds are reared in tropic or temperate regions. Temperate region birds will be usually adapted to lower temperature and raise of 5 to 10^{o}C above the comfort zone causes stress in the birds. Whereas in tropical regions birds will be adapted to the bit of higher temperatures and more care has to be given when temperature drops below a certain level. Extreme high temperature causes (>35^{o}C) causes stress in birds even in tropical regions. Different light programs can also help to achieve optimum body weight even during times of heat stress. In some regions midnight snack is given to consume feed during cool parts of the day and provide them with calcium for cell formation in the early morning hours. Cool water should be provided during heat stress. It is observed that low water temperature during heat stress improves the performance of both broilers and layers. Quality of the water also affects the performance of the bird. Poor quality leads to wet litter and increase in ammonia production. This in turn reduces performance due to development of toxicity in the shed. Quality of the water in terms of taste, total solids, hardness, color, pH, turbidity and bacterial load should also be checked. If the concentration of toxic bacteria increases it forms biofilm in the pipelines which will be hazardous to the birds.

The indicators for any type of stress in chickens is observed as loss in body weight and decrease in feed consumption. The endocrine factors which has been well established is hypothelamic - pitutary - adrenal axis. In the stressed bird plasma corticosterone levels are elevated, which alters metabolism to increase energy. It also suppresses immune response, which in turn makes the birds vulnerable to diseases. This slows down growth rate and causes imbalances in the no. of microflora in the GIT. Exposure to high temperature and feed withdrawal associates with susceptibility to pathogen colonization of the gut. This results in disruption of different nutrient absorption and excretion of nutrients. During heat stress bird consumes more water which results in excretion wet faeces. Specially, modern broiler breeds that are intensively selected for high feed conversion efficiency & rapid growth have a poor ability of heat tolerance. In intensive production system, with increase in number of broilers it becomes difficult to maintain comfortable temperature in the shed. The problem with the chickens is that, they cannot regulate evaporative heat loss due to absence of sweat glands and coverage of the body by feathers. Long term exposure to higher temperature leads to chronic heat stress which leads to decrease in production performance

The gastrointestinal tract is also sensitive to higher temperature; this can lead to histological changes in the GIT. The structure of villi may change which leads to decrease absorption of nutrients, the mucus layer may get eroded which leads to infiltration of pathogenic bacteria, which in turn affects digestion and feed intake and performance of the chicken. The heat stress also induces oxidative stress this is due to generation of free oxygen radicals, decrease in activity of anti oxidant enzymes, decrease in the activity of enzymes related to energy production and body growth. Free oxygen radicals, disrupt the cell membranes and function of mitochondria, which effects the function of organs and production of ATP molecules which provide energy to the system. With chronic heat stress the birds become fatigue due to increase in metabolism, decrease in feed intake, body weight which finally leads to mortality of the birds. It is recommended to supply feed twice a day during early morning hours and in the evening during the cooler times, this in turn will stimulate feed intake.

There are different types of housing systems. Overcrowding of chickens leads to less space for the chicken to move about. This also leads to stress in chicken .Management of optimum space for required number of birds should be provided. In the deep litter system, birds are kept on the floor. Litter materials usually used are paddy husk, sawdust, groundnut hulls, paddy straw etc . The height of the bedding material should be 3 to 5 inches in depth. The bedding material should be periodically stirred. The deep litter manure is also used as a fertilizer. There are disadvantages also. Bacterial and parasitic diseases can occur often if hygienic conditions are not maintained. Respiratory problems can also emerge. In cage system, the birds are kept in cages which are fitted with stands on floors of the house. Advantages of this system is minimum floor space, better feed efficiency, clean egg production, protection from parasites and no competition between the birds. The disadvantages are, locomotion of the birds is restricted and high initial investments are required. It is easy to identify the unproductive or diseased birds. The poultry house should be located in such a way that long axis should be in East West direction. Each boiler requires one square feet of floor space and layer requires two square feet of space under deep litter system.

In the semi intensive system birds are halfway reared in houses and half way on ground, the stocking density rate of adult birds is 600 to 700 birds per hectare. In the intensive system birds are confined totally to sheds. Either are on floor or in cages. It is efficient and an economic system for modern poultry production with huge numbers. Advantages of this system are Minimum land is required more energy is saved by birds due to restricted movements breeding, feeding practices can be managed easily for a large no. of birds spread of infections is also less feed wastage and clean egg production. Disadvantages are, bird’s movements are restricted. Exposure to sunlight in the shed is less.

The practical application of digital technology in the poultry industry is that of Robots. Poultry houses require constant attention for cleaning and sanitizing collection of eggs and checking of birds. When this is done manually it is time consuming and laborious . If robots are engaged for doing this job it is observed that they are more precise and honest about the work. French based octopus robots prevent and control disease and infection in poultry houses. The bots also evaluate temperature, humidity, carbon dioxide, sound and brightness. Another French company has developed a robot called Tibot which discourages chicken from laying eggs on the floor and keeps the birds moving which helps in welfare of birds. The metabolic robots can increase feed efficiency and can alert the producer of potential disease concern. Nanny robots were used by Thailand company to detect ill birds and alert the humans immediately, these automations improve the safety. For free range chickens drone technology was found to have a better application to protect and monitor them. But adaptation of chickens to drones is a matter of concern.

Sensors are easiest one to implement, which is due to lower cost. In modern poultry housing, Big Dutchman has developed DOL 53 a sensor designed to measure ammonia. Filipino poultry use sensors to regulate and control climate in the houses including ventilation and temperature. ROTEM's sensor is designed for carbon dioxide monitoring. Some poultry houses have used sensors to create a consistent lighting environment with unique lighting system which results in better growth efficiency in birds. University of Michigan have used sensors to analyse how chickens use space which have better understanding for designing non cage system for comfort of hens.

Artificial intelligence has been used for automating the procedure for chicken deboning. This depends on the analysis by the computer the difference in the density and structure of meat versus bone, thereby making the cut precise. So sensors collect the data on these parameters and through artificial intelligence the robots perform eg. GIBBOT ROBOT. Artificial intelligence application has been also used in recording the sounds of the flock to indicate health, comfort etc. AI has been applied to grade eggs, as well as to determine defects. It has been also used to access infertility by scanning eggs. AI is also being used to understand hen behaviour under thermal stress and under comfortable environment. In this case artificial neural networks are created, which makes it possible to teach computers to do task using visual reference and patterns. Sexing of eggs has been done by NOVA TRANS COMPANY through, Ovabright programme which identifies male eggs after laying.

One more application is of internet of things (IOT). IOT collects many of the sensors in a hen house to smartphone, iPad or other devices which is the case with the small poultry producers.

Some new innovations in use of feed ingredients in poultry farming in recent times has been developed. With the help of transgenic new transgenic feeds are produced which contains more quality of essential proteins and ammonia acids. At the same time antinutritional factors like erucic acid, tannins & glycosynolates are reduced in this transgenic feeds.

Some of the modern things which can be used in poultry housing is the use of new equipments

1. Automatic control system having automated showers and use of cooling pads in poultry farms
2. For efficient feed distribution moving chain feeders are used
3. Water system is designed to keep water uncontaminated by preventing dirt, faeces and other pollutants from entering the drinking system.
4. Moving belt system is used to manure culture then partizisation of dried manure system.

For efficient poultry production modern poultry farming related innovation can open the gate for success and prosperity for Indian farmers

Basic concept of poultry nutrition and feeding strategies

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The commercial broilers, layers and breeders are reared under intensive production system. On the contrary, free range system or extensive method is the oldest of all and has been used for centuries. Semi-intensive system is adopted where the area under scavenging is limited. Improved native chickens, guinea fowls and ducks are reared in extensive or semi-intensive system (ICAR, 2013). The number of birds reared under extensive system mainly depends upon the available feed resources, area under scavenging, type of birds, etc.

Nutrients in feed

Energy and protein (amino acids) are two major nutrient components of poultry feed. Energy is required to maintain all biological activities (movement, walking, heartbeat, respiration, panting, etc.), vital processes (consumption, digestion, absorption, transportation, etc.) and chemical reactions occurring in the body for synthesis of proteins, fats, glycogen, eggs, organic molecules, etc (Mandal *et al.,* 2004). It is also deposited in the body in the form of protein as structural component, and fat and glycogen as readymade available source of energy whenever required for vital activities and processes, and chemical reactions. Energy concentration in the diet or its requirement is expressed either as calorie (cal) or joule. One kilocalorie (kcal) is equivalent to 4.184 kilojoules (kj), alternatively one kj is equivalent to 0.239 kcal. Energy requirements are expressed in terms of Metabolizable Energy.

The other important nutrient is protein, which plays an important role in body structural functions, muscle contraction, transportation of nutrients and oxygen, regulating acid-base balance, catalyst in chemical reactions (enzymes), immuno-competence (antibodies), chemical regulation (hormones), blood clotting, dim light vision, growth and production. Growth is a function of protein and energy deposition. Poultry birds require all the 20 amino acids for protein synthesis and other biological functions. Essential amino acids are those that are not synthesized in the animal body at a rate required for normal growth and other production functions, hence must be supplied through diet. These are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tyrosine and valine. In addition, glycine and proline are also essential for broilers. The limiting amino acids are those essential amino acids which are usually deficient in diet. Methionine (Met) is the first limiting AA in broilers on conventional corn-soya-based diets. Threonine (Thr) is the third limiting AA for broilers and first limiting AA in starting egg-type pullets. The ideal protein concept (Kaur *et al*., 2006, 2007, 2008) may play an integral role in precision protein nutrition to minimize the loss of N and dietary P indirectly by improving growth and production. Formulating diets based on digestible amino acid values is also used, which permits higher dietary inclusion of cheaper, alternative protein sources and decrease nitrogen excretion by the bird.

Feed ingredients

The available feed resources, natural or synthetic, are classified as energy supplements, protein supplements, mineral supplements and vitamin supplements. Energy feedstuffs, constituting about 60-70% of the poultry feed, play an important role in cost effective feed formulation and providing bulk. They are divided into high energy and low energy supplements. Maize, wheat, broken rice, sorghum, fats and oils are high energy supplements. Pearl millet, finger millet and other small millets, rice polish or bran, de-oiled rice bran, wheat bran, molasses, tapioca flour, etc. are low energy supplements. Maize is the commonly used energy feedstuff in poultry feed but other ingredients, if available at cheaper rate, can be used to replace it partially or even completely.

Protein supplements are divided into vegetable and animal protein supplements. The former group includes cakes and meals of different seeds like groundnut, soybean, rapeseed, mustard, cottonseed, sunflower, safflower, sesame and cluster bean. Roasted full-fat soybean meal is also very good source of protein and fat, especially for broilers. Maize gluten, rice gluten, dried distillery grains with soluble (DDGS) etc. are also very good sources of protein. Animal protein supplements include fish meal, meat-cum-bone meal, meat meal, blood meal and poultry byproduct meal. These supplements, especially meat-cum-bone meal, meat meal and fish meal provide better quality protein than the blood meal. But caution is needed to procure good quality protein meals and utilizing them following their safe inclusion level. Synthetic amino acid supplements (L-lysine hydrochloride, DL-methionine, L-threonine, L-tryptophan) are also available in the market.

Minerals are supplemented either through a ready-made mineral mixture or through specific mineral supplements. Mineral mixture is available commercially or can be compounded. Specific mineral supplements are also added. In this case, calcium carbonate/oyster shell/ cheap marble are used as sources of calcium, and dicalcium phosphate or monocalcium phosphate as source of calcium and available phosphorus. Common salt is added as source of sodium and chlorine. Trace minerals (Cu, Zn, Fe, Mn, Se, I and sometimes Cr) are added in the form of premix (trace mineral premix). Organic sources of trace minerals are available commercially, which may have better bioavailability.

Vitamins are supplemented either through premixes or through individual vitamins. Two types of vitamin premixes are available in the market. One premix supplies vitamins A, $D_{3,}$ and K and riboflavin (B_2). The inclusion rate is 5.0 to 15 g /q depending upon concentration. The other premix supplies water-soluble vitamins including members of B-complex, vitamin E and sometimes vitamin C. The rate of inclusion is 7.5-25 g/q of feed depending upon concentration of different vitamins. In addition, choline chloride (100, 60 or 50% premix) is also available in the market.

Feed Additives

Besides nutrients, present day's poultry are also fed several other compounds aimed at preventing/minimizing the infectious agents' loads, preventing mycotoxins, augmenting nutrient digestibility etc. Antibiotic compounds have been employed as feed additive in low concentrations throughout the world for nearly 50 years to promote growth and feed conversion efficiency in broilers, and to increase egg production in layers. Probiotics (live bacterial and yeast strains), certain non-digestive feed components (prebiotics) like galacto-oligo-saccharides, fructo-oligo-saccharides, mannan-oligo-saccharides and lactose derivatives have all been tried in chickens, rabbits and other monogastric animals to combat colonization of pathogens (*Salmonella* spp., *Escherichia coli*, *Vibrio cholera*, *S. typhimurium*, *S. enteridis* etc.).

Enzymes for improving nutrient utilization have become very popular in the nutrition of monogastrics like chickens. Non-starch polysaccharidases such as cellulases, pectinases, hemicellulases, arabinoxylanases and beta glucanases are used for releasing nutrients trapped in high fibrous diets. Supplementation of diet with microbial phytase increases availability of phytate-bound phosphorus, calcium, zinc, copper, crude protein and amino acids.

Addition of suitable coccidiostat in diets protects growing poultry birds (below 12 weeks of age) from coccidiosis. Similarly, use of different toxin binders or adsorbents (activated charcoal, bentonites, zeolites, diatomaceous earth, mannanoligo-saccharides, live yeast, etc.) reduce the adverse effects of mycotoxins. Oflate other compounds viz., antioxidants, liver tonics, immunostimulants etc. have also become a regular component of poultry feed.

Nutrient Requirements

The requirements of chickens have been optimized and published (NRC, 1994, BIS 1992 etc.). Use of NRC standards under Indian conditions may not be appropriate as the requirements differ due to several factors such as management practices, genetic makeup, environmental temperature, metabolic and behavioral characteristics, feedstuff qualities and dietary variables. The available requirements are very old and present day's poultry are fed mostly based on company's recommendations. Very recently ICAR has come out with the latest nutrient requirements for poultry (ICAR, 2013).

Daily requirements for different nutrients during starter (0-3 weeks) and finisher (4- 6 or 7 weeks) periods of broiler as a function of metabolic body size and daily body weight gain are given in different equations. The requirement of other amino acids can be calculated as proportion of Lys requirement, i.e. for Arg 110-114, Ile 73, Leu 109, Val 82, Phe 65, His 32 and Trp 18%. Requirement of digestible amino acid is calculated based on the digestibility coefficients, i.e. for Lys 0.90, Met 0.90, Thr 0.84, Arg 00.92, Ile 0.88 Leu 0.93, Val 0.87, Phe 0.89, His 0.88 and Trp 0.91%. The regression values and practical experiences in commercial practice are the basis for prescribing the nutrient requirements during pre-starter phase.

Layer type replacement pullets are generally reared in three phases viz. starter (0-8 weeks of age), grower (8-20 weeks of age) and layer (20 weeks or above). For meeting the nutrient requirement, particularly that of calcium at onset of lay, pre-lay phase (17/18 – 20 weeks) is recommended. Similarly, the laying phase is often divided into phase I (20-30 weeks) and phase II (>30 weeks).

On an average one laying hen showing 90% egg production requires 16-18 g of protein and 285 to 290 kcal ME per day. Meeting calcium requirement is important during overall growth (0.9 to 0.7%), but most crucial during laying phase. Just prior to initiation of egg production, huge amount of calcium is stored in bones, which is sufficient for 6 to 30 eggs. Therefore, calcium concentration is increased to about 2% of diet a week before onset of egg production. White Leghorn hens producing 90% eggs require daily about 3.8 to 4.2 g of calcium.

Feed Formulation

Feed formulation is a mathematical calculation to prepare a balanced ration. Though it is an art, but use of skill and scientific knowledge on nutrition principles, dietary variables, nutrient and dietary interactions, etc. make the formulation effective to exploit maximum performance. Birds are maintained at a low cost without exerting much stress. The important points considered during feed formulation are requirement of nutrients for poultry or composition of a formula in terms of nutrients, analytical nutrient composition of various feed ingredients, maximum effective/ safe levels of inclusion of feed ingredients, availability, wholesomeness and cost of feed ingredients.

Requirement of nutrients: Based on the nutritional research studies, the essential nutrients (energy, protein, amino acids, minerals and vitamins) required for different classes of birds have been given. Though a big list of nutrients is available, the attributes that need consideration are metabolizable energy, protein and amino acids (lysine, methionine, methionine + cysteine, threonine, arginine, phenylalanine), calcium, available P, electrolyte balance (sodium, potassium, chlorine), zinc, manganese, iron, copper, selenium, vitamin A, vitamin D3, vitamin E, riboflavin and other water soluble vitamins.

Feed composition values: The most efficient way to furnish nutrients to the birds is to analyze the feed ingredients for various nutrients. However, under practical conditions it becomes difficult to analyze all the ingredients for desirable nutrients, though it is a must to ensure feed quality. The average nutrient content of the feed ingredients based on the analyses done previously is available in the form of published feed composition tables. These can be used very cautiously using knowledge on nutrition.

Maximum level of inclusion of feed ingredients: There is a need to utilize locally available feed ingredients in the least cost efficient feed mix. However, most of the feedstuffs in their native state harbour one or more of the anti-nutritive substance(s). Inclusion of an ingredient beyond its maximum level may induce imbalance of nutrients, and reduce the palatability of the diet and performance of the birds. Birds are rendered ill due to the presence of anti-nutritional factors beyond tolerance level.

Availability and cost of feed ingredients: The knowledge on the availability and cost of feed ingredients in the local market is a prerequisite for formulating feed. The quality and cost of feed ingredients vary widely, and need consideration. The cost of ingredients based on nutrient density (energy and protein) should get priority over mere cost of ingredients when choosing the ingredients for formulation.

Ideas for hot climate feed formulation

The most important aspects in feed formulation under hot climate conditions are:

- To support daily feed intake
- To limit the heat increment using fat and oil
- To use special supplements

An important aspect in the composition of feed for poultry in heat stress conditions is to limit the heat increment of feeding. This is the increased heat production following consumption and digestion of feed. The different major nutrients cause different quantities of metabolic heat production. The highest increment is caused by the digestion of crude protein, especially if it is used as a source of energy. Crude protein should be adjusted as low as possible, based on the usage of synthetic amino acids and a formulation procedure which is known as the generic term Ideal amino acid nutrition. This tool makes it possible to reduce crude protein in the diet without harming production and in addition, it helps to reduce feeding costs. The digestion of carbohydrates, which is mainly starch, causes a relatively high heat increment as well. It can be limited to some extent by using fat and oil as a source of energy in poultry diets. On an average, fat and oil have three times energy content as in cereals and cause much lesser metabolic heat increment.

The benefits of adding extra fat and oil to the diet can be summarized as follows:

- Increased content of metabolizable energy
- Due to the fatty acid profile (linoleic acid), adjustment of egg weight
- Improved liver health
- Improved palatability of (dusty) mash feed

Vitamin C is considered as one of the most important supplements under heat stress conditions. Normally, birds synthesize sufficient vitamin C, but due to heat stress and severe panting, the balance of electrolytes is affected. Negative effects can be reduced with higher levels of vitamin C. In addition, it will support egg shell quality. The recommended dosage is 100 – 200 mg/kg. With the same target in mind, the use of sodium bicarbonates should be kept as a standard. Sodium bicarbonate or sodium carbonate, should be applied as a standard supplement to achieve a ration of sodium to chloride by 1:1. This is highly beneficial not only for a good egg shell, but also when a higher level of sodium has to be achieved as a result of low daily feed intake.

Vitamin E, which also serves as a natural antioxidant in addition to its nutritional value, should be increased to at least 50 mg/ kg. For breeders, a level of 100 mg/kg has been proven to support hatchability and chick quality. Supplements which will increase the nutritional value of all raw materials are the Non-Starch-Polysaccharide – Enzymes and Phytase. They increase the biological nutritional value of the raw materials which will support nutrient intake under heat stress and/or make it possible to decrease nutrient density of the diet without harming the production.

Feed is the major input (65 to 80%) and feed-cost is the major constraint but is a major mean for manipulating production cost and making enterprise profitable. A sizable quantity of cereals and edible oilseed meals are used in livestock and poultry ration, and thus both livestock and poultry compete with the human beings directly. India's population is also growing (1.58%). Globalization and economic integration are perceived in terms of opening up of economics, liberal movement of goods and services and factors of production. Impact of globalization on livestock and poultry industry has increased the competitiveness for marketing the products in world as well as domestic market. Availability of feed resources could be one of the major constraints in livestock and poultry production in future as the opportunity for the area expansion for cultivation has almost exhausted. Therefore, the more careful approaches to sustain the poultry sector in the competitive market should be the reduction of cost of production, production of safe and quality products to meet the consumers' demands and also to ensure the animal welfare to satisfy consumers. Again production of foodstuffs and thus feedstuffs fluctuates greatly due to frequent monsoon failure, low productivity, insects, weeds, environmental concerns, cost efficiency, sustainability, declining area under cultivation, etc. The farmers are also being encouraged for diversion towards production of cash and commodity crops. The trend for production of food grains is decreasing in recent years. Therefore, the search for newer feeds is urgent need to meet the challenges. However, some of the identified alternate feeds are prone to be a promising for supplementing in the poultry diets, but they also contain some inherent incriminating factors limits their use in poultry diet.

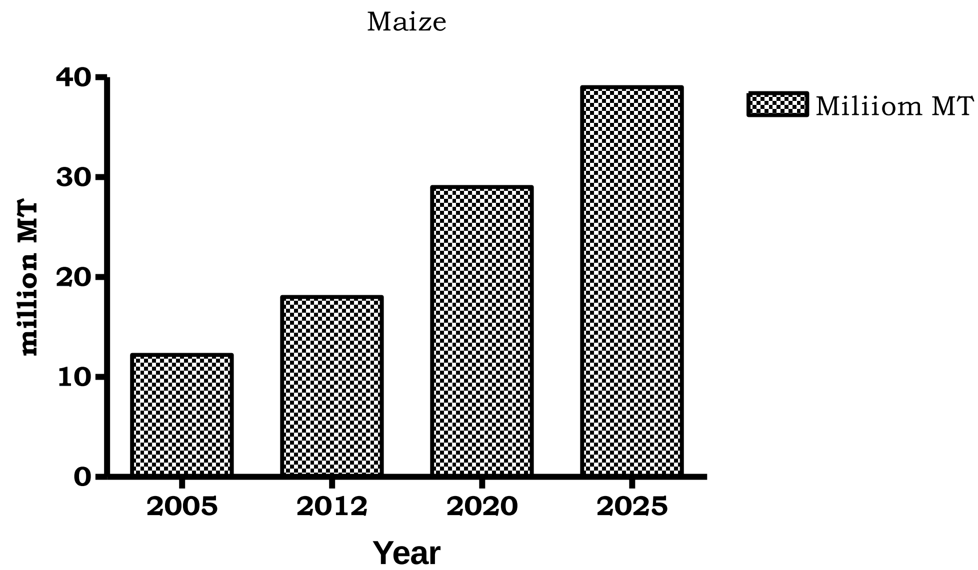
Factors limiting the use of alternative feed ingredients in poultry feed formulations

Nutritional aspects	• Lack of consistency in nutrient quality • Limited information on the availability of nutrients • High fibre content • Presence of anti-nutritional factor • Need for nutrient supplementation (added cost)
Technical aspects	• Seasonal and unreliable supply • Bulkiness, physical characteristics • Need for de-hulling and/or processing (drying, detoxification) • Limited research and development facilities for determining nutrient composition and inclusion levels in poultry diets.
Socio-economic aspects	• Competition with use as human food • Poor prices relative to other arable crops (farmer) • Cost per unit of energy or limiting amino acids, relative to traditional feedstuffs (feed manufacturer) • Cost of processing

Poultry Development Review; Poultry feed availability and nutrition in developing countries, FAO Publication.

In India, the growth rate of agriculture has declined from 3.37% per annum in 1980s to 1.74% per annum since 1990 and food grains production has been lower than population growth for the last four decades. (Basu and Das, 2012). The annual growth in agriculture in the country was hardly 1% against the growth in human population 1.5% apart from increased demand of feed ingredients 8 to 12% for poultry sector.

Projected requirement of Maize at 6% average growth in broilers and layers



The average increase in commodity availability has been 4.33% per annum during 2001-2012, which is far below the growth rate of egg, meat or milk production. Moreover, there is diversion of maize for starch and distilleries. Therefore, only two options are left with either to increase maize production drastically by increasing yield or area under production or to utilize other cereals and cereal by-products as alternate to maize.

Alternative energy sources that can replace maize in poultry diets

Feeds	**Comments**
Cereals	
Wheat	Can be used when cost-competitive Limitation: high non-starch polysaccharide contents result in intestinal digesta viscosity problems; can be used without restriction when xogenous carbohydrases are added
Sorghum	Limitation: tannins lower protein and energy digestibility; low-tannin sorghum can completely replace maize
Millets	Can replace 50–65% of maize, depending on

	millet type Limitations: high fibre contents, presence of tannins
Cereal milling co-products	
Rice bran/polishing/ Wheat bran	Limitations: high fibre, phytic acid, rancidity; good-quality material can be used at levels of 5–10% in broiler diets and up to 40% in layer diets
Roots and tubers	
Cassava root meal	High in starch, excellent energy source Limitations: low protein, powdery texture, needs detoxification to remove the cyanogenic glucosides; can be used at levels of 30–40% in nutritionally balanced, pelleted diets
Cassava peel meal	Limitations: high fibre, very high levels of cyanogenic glucosides, needs processing; carefully prepared meal may be used at 5% level
Sweet potato tuber meal	High in starch, good energy source Limitation: powdery texture; can be used at levels up to 50% in nutritionally balanced, pelleted diets
Fruits and fruit co-products	
Banana and plantain meal	Limitation: low palatability due to tannins in the peel; removal of peels improves nutritive value; inclusion must be limited to 10–20%
Breadfruit meal	Good energy source; can be included at up to 30%
Jack seed meal	Limitations: lectins in raw seeds, needs

	processing; processed meal can be included at up to 30%
Mango seed kernel meal	Limitation: high levels of tannins; processed meal can be used at levels of 5–10%

Poultry Development Review; Poultry feed availability and nutrition in developing countries, FAO Publication.

Methods of feed formulation

Algebric equation : is used commonly when two mixtures are to be combined for arriving at required nutrient concentration. Popular example is with the cereal and protein concentrates.

Pearson square : A simple procedure originally devised to blend milk products to a known fat percentage, and can be used for diet formulation too.

Hit and trial method: This has been the traditional way of feed formulation and still widely used by professionals. The amount of feed ingredients is changed so as to arrive at required nutrient levels in the feed. For this, the ingredients are arbitrarily altered and the nutrient concentration is calculated, which is continued till the desired nutrient level is achieved. The computer applications like MS Excel can be effectively used for quickly formulating the feeds using this method.

Least cost formulation: Is a feed formula that is both nutritionally-complete (within limits) and with a minimum ingredient cost (within limits). It is now-a-days developed and completed through the use of computers using linear-programming software. There are numerous computer software developed on the linear programming for formulating least cost rations, which are widely used by most feed mills/manufacturers. Some of the popular software include Ecomix, Winfeed, Myfeed, FeedMu, Feedsoft, Autofeed, Optimix etc.

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Nutritional Modulation of Egg and Meat Composition for Health Benefits

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Changes in lifestyle, improper nutrition and reduced physical activity have led to epidemic of non infectious diseases, leading to health issues and even death. Therefore, there is increasing interest among the population to eat functional foods which have health benefits. A designer/functional food is a conventional food that is consumed as part of diet and is demonstrated to have physiological benefits and/or reduce the risk of chronic diseases, or minimize the risk of other health concerns. Some of the designer foods in the market are designer eggs, designer meat, designer milk, designer oil, designer vegetables, designer grains etc. The poultry eggs and meat are nutrient rich food and now regarded as an inexpensive, convenient and low calorie source of high quality protein with several other essential nutrients. The nutritive value of eggs and meat can be improved greatly through the dietary manipulation. Eggs and meat enriched with critical trace minerals, vitamins, omega -3 fatty acids, immunoglobulins, carotenoids and antioxidants can be an excellent source of nutrients in human diet. Several attempts were made to modify the eggs and meat by adding ingredients which are beneficial for the health or by eliminating or reducing components that are harmful. This modification resulted in development of functional egg and meat.

Improving consumers' health and nutritional status by designing nutritional profile of poultry egg and meat through dietary approaches is relatively simple and economic. Nutritional diets of birds influence meat qualities in terms of nutritive value, acceptability, human health and processing. Eggs can be designed through dietary approaches either through supplementation of specific nutrients, or certain herbs or specific drugs that have functional and therapeutic properties.

Designer Eggs

Designer eggs are those specially produced eggs which are rich in additional nutrients and health promoting components like carotenoids, chelated minerals, EPA and DHA like omega 3 fatty acids, selenium, vitamin E and other immune-modulating factors. Designer eggs contain 600 mg of omega-3 fatty acids, equivalent to a 100 g serving of fish. Omega-3 fatty acids help in lowering dietary cholesterol content in the diet . Vitamin E, a fat soluble vitamin as well as an effective antioxidant, is enhanced to 100 per cent in these eggs. These eggs prevent cancer causing factors, cardiovascular diseases (CVD), and improve immunity and overall health status. Studies have shown that when 2-3 designer eggs are consumed every day, 100 per cent of the daily requirement of essential fatty acids is met . High-density lipoprotein (HDL) levels are raised while low-density lipoprotein (LDL) levels are decreased, blood fats are reduced, and more than 60 per cent of the daily vitamin E requirement is fulfilled. That's why designer eggs are sold at a premium price and have a better consumer preference than the regular eggs.

Designer meat and its products

There is growing public concern towards coronary heart disease and artherosclerosis with the consumption of meat due to having more cholesterol and saturated fatty acids. Chicken meat is relatively low in fat and cholesterol, thus considered healthier than other animal protein sources. Scientists have tried to alter the fat deposition and cholesterol contents in the meat by supplementation of different herbs, minerals, fatty acids etc.Copper, garlic, herbs and omega-3 fatty acids has been used successfully to reduce the cholesterol content of the poultry meat. Manipulating amino acid concentration and calorie to protein ratio in the diet can enhance the protein and moisture concentration of the breast and thigh muscles.

Omega-3 Fatty Acids enriched eggs and meat

The health benefits of omega-3 polyunsaturated fatty acids (n−3 PUFA) are generally recognized. Unfortunately, in most countries, the recommended daily intake of these compounds is rarely met. Therefore, enrichment of commonly occurring foods can boost intake of these fatty acids. The total fat content in the egg yolk cannot be altered; but its fatty acid composition can be altered, by changing the type of oil used in the hens' diet. Flax seed (linseed), marine algae, fish oil and rape seed oil are added to chicken feed to increase the omega - 3 fatty acid content in the egg yolk, at the expense of saturated fatty acids like palmitic and stearic acids. In designer eggs the N-6 / N-3 PUFA ratio is decreased to about 1.5, from as much as 20 in regular eggs. This favourable change in designer eggs, will supply about 50% of the daily requirement of N-3 PUFA to the consumers, without any change in the sensory quality of the egg. This n-3 PUFA in egg yolk has decreased the serum Triglycerides and increased the serum HDL-Cholesterol levels in human volunteers, when consumed for a period of two months at two eggs per day. Since the

N-3 PUFA will undergo rancidity quickly, it is essential to prevent the rancidity of the designer egg yolk lipids, by incorporating anti-oxidants in the hens' diet.

When poultry meat is enriched with ω-3 fatty acids and selenium, 100 g of enriched tissue meets 70–130% and 30–60% of the recommended daily intake for humans respectively. Some studies have shown that conjugated linoleic acids (CLA) can reduce the risk of cardiac disorders and cancer causing problems, but CLA enrichment makes the meat tough affecting the meat quality. With ω-3 enrichment, poultry meat could contribute to dietary intake of about 75.0 mg ω-3 per person per day.

Micronutrient enriched eggs and meat

The vitamins and trace minerals content of eggs can be increased by manipulating the diet of laying hens. Several studies have confirmed that it is possible to produce novel eggs with higher levels of minerals such as iodine, iron, zinc and selenium and vitamins such as vitamin B_{12} and folic acid. Eggs are served regularly in the noon meal schemes implemented by many state governments in our country. Since tables eggs cannot be adulterated easily and could be a better vehicle for the delivery of micronutrients with high bioavailability, bio-fortified eggs can be produced in large quantities and supplied for public consumption. However, feeding of excess minerals (inorganic) and vitamins in the diet of hens could increase the cost of egg production and sometimes results in mineral – mineral / mineral –vitamin interactions in the diet which necessitates validation studies scientifically. Production of table eggs fortified with micronutrients such as iron, copper, zinc, iodine, folic acid, Vitamins A, D and vitamin B_{12} etc. to tackle the community nutritional problems such as anemia, stunting, iodine deficiency disorders etc. is highly essential.

Low cholesterol egg and meat

Even though the dietary cholesterol is insignificantly correlated with the serum cholesterol levels, the consumers are scared of high cholesterol foods, like eggs. A large egg contains about 200 mg of cholesterol and chicken meat contains about 60 mg per 100 g. Chromium, copper, nicotinic acid, statins, garlic, basil (tulasi), plant sterols, N-3 PUFA supplementation to chicken feed may reduce the yolk and carcass cholesterol levels significantly. Similarly, dietary Linseed oil, Garlic, Basil, Spirulina, Bay leaves, Nicotinic acid, Guar Gum, Grape seed pulp, Tomato pomace , Citrus pulp , Chelated Copper, Organic Chromium, Roselle seeds and many more herbs in chicken diets may reduce the yolk and chicken fat cholesterol levels by 10-25%. Dehydrated alfa alfa reduces cholesterol content and total lipids in chicken breast meat. Sunflower oil, soyabean oil, canola oil, linseed oil reduces fat and cholesterol content in cockerel thigh and breast meat. Moreover, these substances are having synergistic effect in reducing the cholesterol levels. Hence a combination of these supplements will be more beneficial, rather than a single substance.

Carotenoid enriched egg and meat

In many countries, deep yellow or orange colour yolks and yellow skin broilers are preferred over pale yolks and skin. Natural carotenoid pigments like carotenes, xanthophylls, cryptoxanthin, zeaxanthin, lutein present in alfalfa, corn gluten meal, blue green algae - spirulina, marigold petal meal and capsicum will impart rich yellow and orange colours to the yolk and skin. Besides providing attractive colour, they act as anti-oxidants and anti-carcinogenic agents. Some of the pigments are having vitamin A activity. The lutein will safeguard the retina. Most of these natural pigment sources are used in feeds at 1-5 % levels to increase the yolk and skin colour. The active pigments extracted from these sources are sufficient at 0.05 - 0.1 % level, to give the same level of pigmentation. Turmeric powder at 0.5 kg along with red chilli powder at 1 kg / T of feed, not only improve the skin and yolk colour, but also act as anti-microbial agents and anti-oxidants.

Immunomodulating Egg Production

The eggs naturally contain certain specific compound like lysozyme (G1-globulin), G2 and G3 globulins, ovomacroglobulin etc. the globulin antibodies are natural antimicrobials and immune-stimulants in the egg, that can be utilized in the cure of immune-suppressed patients like AIDS patient. These eggs not only high in nutritional value, but also have immune-stimulant and anti-viral properties. The IgY level in the egg can be increased by dietary manipulations. Supplementation of poultry diet with herbs like Basil leaves (Tulasi) , Rosemary, Turmeric, Garlic, Fenugreek, Spirulina, Aswagantha, Arogyapacha etc., which possess immunomodulating properties may improve the efficiency of immunomodulating properties of eggs.

Conclusion

By modifying the diet of chickens with these feed additives, customers can obtain value-added and health-promoting chicken eggs, meat, and products. Omega 3, selenium, vitamins and carotenoid enriched eggs are commercially available. Poultry products enriched with multi-minerals capable of combating anaemia and stunting, on the other hand, are not available on the market. It is equally critical to examine the safety and quality of modified eggs. The product should be of consistent quality so that consumers may be confident that they are receiving the safe and good quality poultry products with improved nutrients.

Advanced molecular genetic approaches for genetic improvement of poultry

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Chicken (*Gallus gallus domesticus*), a subspecies of the red junglefowl, is a type of domesticated fowl, originally from South eastern Asia. Chickens are one of the most common and widespread domestic animals, whose population was 19 billion in 2011 (UN's FAO, July 2011) which increased to 23.7 billion in 2018. Chicken is a scientifically and commercially important species which is used as an accessible model organism for researchers for over 100 years and was also a major food source for the human population. There is an immense development in the poultry industry in the last few decades, but little attention has been given to indigenous chicken, due to its poor producing ability. In India, the total poultry population was estimated to be 1000 million, out of which about 15 to 20% were indigenous or native breeds. The total egg and meat production from our country is around 103.32 billion eggs and 8.11 million tons, with an annual production from commercial egg and meat is around 84.91 billion eggs and 4.6 million tons of poultry meat, ranks 3rd in egg production and 5th in broiler meat production, respectively, in the world (BAHS, 2019). There are about 19 indigenous breeds/varieties of chicken found in India, viz; Ankaleshwar, Aseel, Busra, Chittagong, Danki, Daothigir, Ghagus, Harringhata Black, Kadaknath, Kalasthi, Kashmir Favorolla, Miri, Nicobari, Punjab Brown, Telichery, Mewari, Kaunayen, Hansli, Uttara.

The major causes of low productivity of native chicken population and other livestock in India are both intrinsic (low genetic potential) and extrinsic (poor nutrition/feed management, inferior farm management practices, ineffective veterinary and extension services and inefficient implementation of breed improvement programmes). In the traditional selection program, the breeding value of animal is estimated based upon the information from its related individuals. Moreover, in traditional selection the selection of individuals depends upon availability of phenotypic observations which further depends upon the heritability of the trait. For traits with low heritability, traditional selection may not be possible and it may not provide a clear picture of the value of the animal and this method of selection is difficult to follow for the sex-limited traits, traits expressed later in the animal's life and for the traits that cannot be measured easily. The genomic information of the individual may help in the selection of individuals for these traits. Genomic selection predicts the total breeding values based upon a very large number of marker haplotypes across the entire genome so that all the QTLs for a trait of interest are in linkage disequilibrium with at least one marker. The fundamental concept of genomic selection was first put forward by Meuwissen et al. (2001).

SNP chips are available for chicken; 3K SNP chip; 42K SNP chip; 60K SNP chip; 600K SNP chip. Despite the fact that SNP chips and the other recent molecular genetic approaches has enabled successful genome-wide association studies (GWAS) in livestock species (Meuwissen et al., 2001; Goddard and Hayes, 2009), it also has some known disadvantages. For example, an ascertainment bias is sometimes introduced which is derived from the fact that the SNPs used are chosen to have a minimum rare allele frequency as well as to segregate in multiple breeds. The commercially available SNP arrays or chips cannot be easily modified to suit individual experimental designs. Moreover, relevant experiments cannot be conducted for species that do not have commercially available SNP arrays/chips. Although customized SNP arrays/chips can be manufactured, but they are cost-prohibitive to many researchers.

Although SNP chips for chicken and other livestock are available, a panel of SNPs pertaining to our indigenous livestock breeds is missing. The commercially available chips are based on exotic breeds and gives less polymorphic loci when used for genotyping indigenous breeds. This warrants the need for genome wide SNP discovery for indigenous breeds. Genome wide SNP discovery is mainly by de novo whole genome sequencing or by re-sequencing the entire genome and aligning it to reference genome when the genome assembly is already available. Whole genome sequencing is costly and produces lot of uninformative sequences like repetitive DNA sequences which cannot be aligned. Moreover, the bioinformatics analysis is cumbersome. Furthermore, whole genome sequencing/re-sequencing is technically unnecessary, because linkage disequilibrium relationships can be high among genetic markers within a genomic region. In practice, only one of the highly linked markers is usually selected as a tagged SNP in data analysis.

Reduced representation approaches for genetic improvement

In order to address the limitations associated with whole genome sequencing/re-sequencing for genome wide SNP/marker discovery, the research community has been developing alternative strategies, which are cost effective. These alternative techniques are NGS-based and aim at reducing genome complexities and are known as reduced representation approaches. In contrast to whole genome sequencing/re-sequencing, a basic feature associated with these techniques is to have a subset of a genome sampled and sequenced without loss of much information of genome. Various methods which use restriction enzymes to reduce the genome complexity is known as Restriction-Site Associated DNA sequencing (RADseq).

RADseq is a reduced representation next generation sequencing and genotyping technique using restriction enzymes where homologous tags spread throughout the genome are sequenced. Here SNPs are identified and genotyped simultaneously. This method is cheaper and faster. Also known as Genome Wide Sampling Sequencing (GWSS).

The term RADseq was originally used to describe one particular method (Baird et al., 2008) but has subsequently been adopted to refer to a range of related techniques that rely on restriction enzymes to determine the set of loci to be sequenced. These methods are also grouped under the term 'genotyping by sequencing' (GBS). As with RADseq, the term GBS was also originally used to describe one specific method (Elshire et al., 2011); however, this term is less descriptive than RADseq, which captures the fundamental feature of these methods, like, the use of restriction enzymes to obtain DNA sequence at a genome-wide set of loci. The RADseq methods (Baird et al., 2008 Andrews et al., 2016) involves the following steps (Fig. 1)

1. Digestion of multiple samples of genomic DNA with one or more restriction enzymes, and attachment of adaptors to the fragment ends
2. A size selection or reduction of the resulting restriction fragments
3. NGS of final set of fragments which is normally less than 1 kb in size

The RADseq family consists of different methods like: -

1. Complexity reduction of polymorphism sequencing (CRoPS):

   Complexity reduction of polymorphic sequences (van Orsouw et al., 2007) uses two enzymes and AFLP primers for complexity reduction
2. Reduced representation libraries (RRL):

   Reduced representation libraries (Van Tassell et al., 2007) use a blunt-end common-cutter enzyme, followed by a size selection step.
3. Restriction site associated DNA sequencing (RAD seq):

   Restriction site-associated DNA sequencing (Baird et al., 2008; Miller et al., 2007) digests the genomic DNA with one restriction enzyme, followed by mechanical shearing to make fragments size suitable for sequencing. A modification of RADseq, the 2bRAD (Wang et al., 2012; Guo et al., 2014) method uses type IIB restriction enzymes, which cleave DNA upstream and downstream of the recognition site, thus producing short fragments of uniform length

4. Genotyping by Sequencing (GBS):

   Genotyping by sequencing (Elshire et al., 2011) uses a common-cutter enzyme, and PCR preferentially amplifies short fragments.

5. Double-digest RAD (ddRAD seq):

   This is a modified form of RADseq method. Double-digest RAD (Peterson et al., 2012) uses two restriction enzymes along with adaptors specific to each enzyme, and size selection by automated gel cut. These modifications have given ddRAD the following advantages over other methods:

   a) Low cost and less time to prepare the sequencing libraries
   b) High level of multiplexing
   c) Precise size selection
   d) Less reads to achieve high confidence SNP calling

Comparison of various RADseq methods/GBS methods have been summarised in table 1

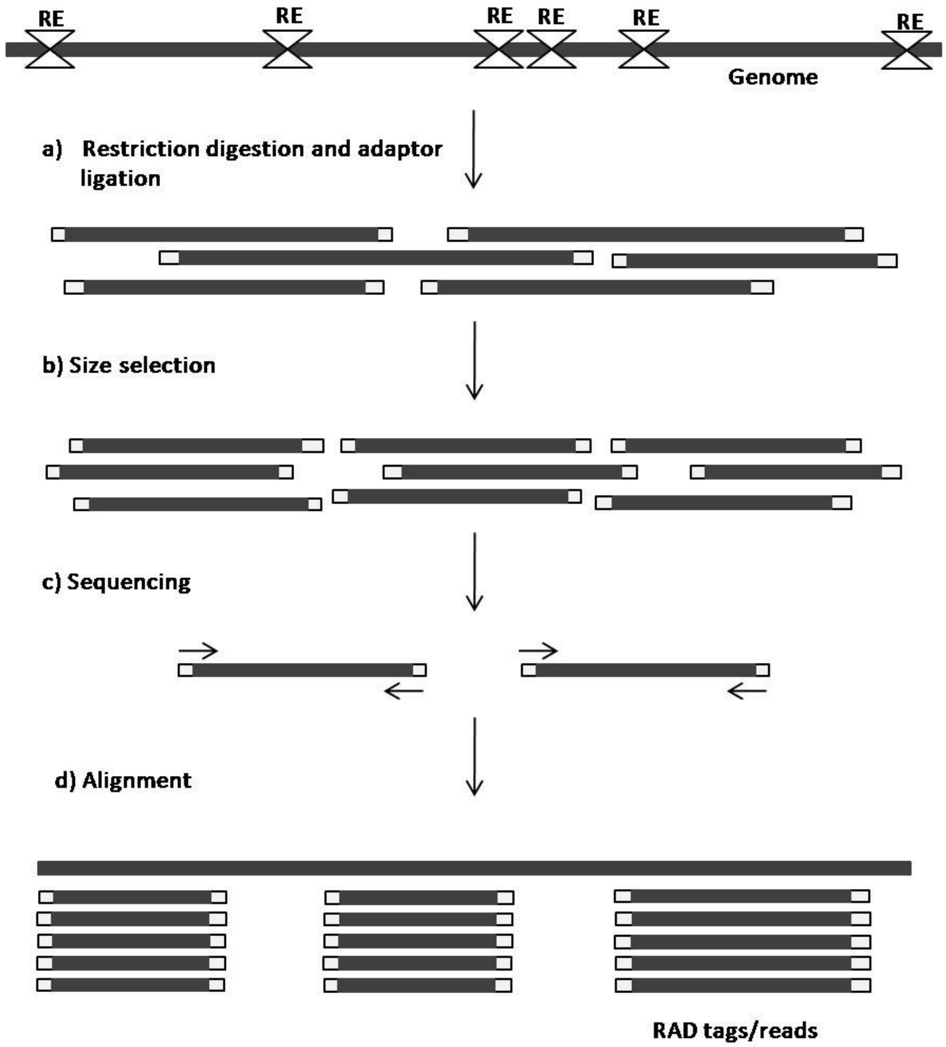

Fig.1: Basic workflow of RADseq approach

Comparison of RADseq with Whole Genome Sequencing and SNP chips

The cost of RADseq covering nearly 200,000 markers in human genome was found to be 35 times less as compared to whole genome sequencing for covering the same number of markers (Davey et al., 2011). RADseq is highly cost effective in case of genotyping a large sample size as it provides the freedom of discovering the population specific unique SNPs along with genotyping. Although SNP arrays are the preferred method of genotyping large sample sizes for genome wide SNPs, they cannot genotype novel/population specific SNPs thus creating bias. Moreover, in case of chicken/cattle/livestock the available SNP chips are based on the SNPs identified on exotic breeds, thus has a reduced efficiency in genotyping indigenous breeds. Studies comparing RADseq methods with SNP chips have shown that they have similar genome coverage at less than half of the cost of SNP chips (De Donato et al., 2013; Bajgain et al., 2016).

Table 1. Comparison of various RADseq methods

Method	No. of REs used	Fragment sequenced	Type of size selection	Remarks
RRLs	One	Adjacent to restriction enzyme cut sites	Direct	No multiplexing, identification of individual samples not possible
GBS	One	Flanked by two restriction enzyme cut sites	Indirect	No efficient size selection
RAD	One		Direct	DNA loss, variable fragment sizes at each locus
CRoPS	Two		Indirect	Additional (AFLP) primers are required
ddRAD	Two		Direct	Easy library preparation

RADseq method has been extensively used in plants, non-model organisms and livestock species. The SNPs identified and genotyped using RADseq method have been used for a wide range of downstream applications like development of SNP arrays, construction of genetic maps, MAS, GWAS, GS, genetic introgression and genomic diversity studies conservation and phylogenomics studies.

RADseq in livestock species

The different RADseq methods have been used for SNP discovery in livestock species (table 2). It was found that GBS is a robust, cost-effective method to identify SNPs for GWAS.

Table 2. SNP discovery using reduced representation approaches in livestock

Species	Method	SNPs	Reference
Chicken	RAD	75587	Zhai et al., 2015
Cattle	GBS	52748	De Donato et al., 2013
Buffalo	GBS	49607	Imartino et al.,2013
Sheep	GBS	300000	Clarke et al., 2014
Pig	GBS	185206	Tan et al., 2016
Camel	GBS	310311	Holl et al., 2016

RADseq for GWAS and GS

Reduced representation methods like genotyping-by-sequencing (GBS) approach was used to provide dense genome-wide marker coverage (>47,000 SNPs) for Genome-Wide Association study (GWAS) plants (Sonah *et al*., 2015) and animals.

GBS has been shown to be useful for GS of wheat (Poland and Rifee, 2012) and maize (Crossa et al., 2013). At present GS in livestock are almost solely based on SNP genotypes called from commercially available SNP chips data. In practice, combinations of high and low-density SNP arrays along with imputation are used to reduce the costs of genotyping (Cleaveland and Hickey, 2013; Wellmann et al., 2013). This genotyping strategies reduces costs and enables increased intensity of selection through the genotyping of large numbers of selection candidates or increased accuracy of estimated breeding values (EBV) by expanding the training population size. Reduced representation approaches offer great potential for developing GS in livestock populations because it makes it possible to cover large fractions of the genome in affordable cost and to vary the sequence read depth per individual. Gorjanc et al.,2015 evaluated the potential of GBS compared to SNP array genotyping for GS in livestock populations and found it to increase the accuracy of predictions by increasing the size of training populations and thus increased intensity of selection by genotyping a larger number of selection candidates. Low coverage sequencing methods RADseq is advocated to be the method for sequencing millions of animals for genomic selection in the future (Hickey et al., 2013)

RADseq and conservation

The conservation genetics uses molecular markers to study the organisms in their natural habitat and also to investigate the effect anthropogenic disturbances. Most of studies uses small number of neutral molecular markers (like microsatellites and AFLPs) which covers a small subset of genome. The data generated by these neutral markers could be used to deal with issues related to demographic factors affecting the genome (like genetic drift, diversity, effective population sizes, genetic relationship of populations). But they have limited power to investigate specific loci that are under selection or adaptive evolution and to estimate diversity for specific parts of genome. The genomic approach using methods like RADseq offers a marked increase in the number of variable genetic markers used (mainly SNPs) and enables the researchers to investigate specific genomic regions which may have undergone natural selection while helping in improving the precision for identifying demographic factors by increasing the number of neutral markers assayed. RADseq can bypass the arduous process of marker characterization, primer development and genotyping required for microsatellites and produces more reproducible results than the microsatellites. Moreover, it opens up the prospects of screening individuals and population s for adaptive loci, which is one of biggest potential contribution of genomics to conservation.

The prospects of RADseq in conservation genetics have been summarized in table 3.

Table 3 Prospects of RADseq in conservation genetics

Category	**Possible contribution of RADseq**
Population history and structure	Improved accuracy and precision [RADseq derived SNPs used to construct population informative SNP panels to delineate population units in Salmon (Dann et al., 2013)]
Adaptive genetic variation	The most promising contribution of ddRAD to conservation
Quantitative genetic variation	Application in detection of quantitative trait loci in livestock like genome-wide association studies
Taxonomic identification /Phylogenetic studies	Improved hybrid detection and phylogeny construction [RADseq was used to identify species diagnostic SNPs and to calculate the admixture between native and invasive trout species (Hohenlohe et al., 2013)] [RADseq succeeded in generating a highly resolved phylogenetic tree for 16 species of cichlid fish in Lake Victoria where prior analysis using AFLP and microsatellites failed (Wagner et al., 2013)]
Inbreeding detection	[Genome wide heterozygosity estimates using RADseq SNPs had a higher correlation with fitness associated traits than did with microsatellites (Hoffman et al., 2014)]
Effective Population size	Better estimates [Thousands of RADseq generated SNPs were used to estimate effective population size in North American Salmon (Larson et al., 2014)]
Maternity/paternity/kinship	Can supplement the information provided by microsatellite

analysis	when their power is limited

The FAO State of the World's Animal Genetic Resources report says that about one-third of all breeds is considered to be at risk. Also, within the livestock breeds that dominates, intensive selection and use of a few sires has led to low effective population sizes and loss of genetic diversity (Taberlet et al., 2008)

Genomic tools like RADseq can contribute to livestock genetic resource conservation and management through accurate estimation of genetic uniqueness and control of inbreeding. The main areas in livestock conservation where RADseq can be utilized are discussed in brief here.

1. Breed identification

Identification of breeds is a basic prerequisite for conservation. NGS based methods like RADseq can help in cost effective identification and comparing of genome wide SNPs in different breeds and thus help in identifying breed signatures. These signatures can be used for developing assays for breed identification.

2.Breed prioritization for conservation

Conservation of all breeds may also not be necessary or scientifically justifiable, depending on the goal of the conservation programme. Some breeds may be judged to have no particularly unique or valuable characteristics worth conserving, either for the immediate or long-term, and have little historical or cultural significance. In other cases, a group of breeds may be genetically similar, meaning that conserving only a subset of breeds can capture a sufficiently large proportion of the genetic diversity of the group. Assuming that all livestock genetic resources cannot be conserved, a process of prioritizing breeds is necessary.

A variety of factors contribute to the decision regarding the priority of breeds for conservation., The primary objective of a conservation programme is to preserve as much genetic diversity as possible. In case of livestock genetic resources, it refers to conservation of as much intra-species diversity as possible. To meet this, conserving diversity both within and among breeds is important. The main parameters used assess the genetic diversity of a breed are pedigree information or knowledge of a breed’s history and can be expressed quantitatively through estimates of population genetic parameters such as effective population size. But in many cases especially in developing countries pedigree information will not be available in all the breeds.

An alternative strategy is to use molecular genetic information and selectively neutral genetic markers (mainly microsatellites) have been the genomic tool of choice for studying the genetic diversity of livestock genetic resources (Boettcher et al., 2010). Such markers give an insight into breed history and provide information regarding both the distinctiveness (across-breeds) and the (within breed) diversity of a breed. Phenotypic performance for traits associated with productivity and adaptation may also influence priority for conservation. Molecular information about known genes with putative effects on traits of current and future interest may also be considered in the priority of a breed for conservation, as breeds with high frequencies of favourable alleles would generally be preferred. For the above-mentioned factors RADseq method provides a good prospect by identification of genome wide markers (both neutral and non-neutral), identifying adaptive loci and helps in candidate gene studies.

3. Selecting animals for Gene Bank/in vitro conservation

In case of ex situ/in vitro conservation like gene bank, genomic approaches like RADseq can be used to select/choose candidates so as to maximize the genetic diversity conserved in the gene bank. By selecting animals with more genetic diversity at genomic level for Gene Bank more diversity is conserved with less samples.

4. Detection of adaptive variation

The most exciting use of RADseq is that they can be used for studying the adaptive variation in the livestock. The emerging genomic tools like RADseq sequencing helps to identify and study genetic variation affecting fitness which are potentially involved in local adaptation. The inclusion of markers that reflect local adaptation would augment the identification of conservation units and improve detection of genomic regions causing inbreeding depression. Identifying adaptive markers would also be useful for conserving evolutionary processes and genes associated with increased relative fitness could be propagated via selective breeding. This aspect of conservation genomics has the potential to provide information on the species, population, and individual level that was inaccessible using traditional genetic markers like microsatellites. The adaptive variations with respect to thermal stress, better utilisation low quality forage can be made use in livestock. For example, native breeds well adapted to local conditions may provide genetic material commercial breeds and isolated populations of same or similar breeds. This is of high importance in view of future climate change where adaptations to factors such as hot, arid and saline conditions play a major role for survival (Kristensen et al., 2015)

Breeding plans can be designed based on the genome wide variation within the populations. Studies have demonstrated the use of genome wide data to design breeding programmes helping to reduce the loss of genetic variability within a small population by prioritizing mating between individuals with low pair-wise identity-by state (Pertoldi et al., 2014)

Conclusion

Majority of the studies on genome wide marker identification/ genotyping has been carried out in chicken and other livestock and there is scanty information about genome wide markers discovery in indigenous breeds of India, mainly due to economics associated with it. Use of cost-effective method of whole genome SNP genotyping like RADseq in the indigenous chicken breeds will facilitate the genetic improvement as well further studies on domestication history, population structure thus supplementing to the conservation efforts and also aid in genetic improvement by trait mapping, GWAS and GS in the future.

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Improved Varieties for Rural Poultry

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Impressive growth has been achieved in commercial poultry farming but the rural poultry sector remained unchanged. Chicken population in rural areas increased marginally from 63 million to 73 million in past 35 years. Back yard poultry contributes around 20% (including ducks) to total egg production of the country. Majority of the population still lives in villages and they are getting access only to 25% of total poultry products. The incidence of protein deficiency among the susceptible groups like children, women, pregnant mothers and aged people can be alleviated by adopting small scale poultry farming in back yards of rural households. In rural areas it is observed that the poultry products are sold at 10-40% higher price than the prices at urban and semi urban areas. The back yard poultry production relies on minimal cost inputs in the form of kitchen waste, cheap locally available grains, tender leaves, worms, insects and other material available for scavenging. In every village it is essential to establish backyard poultry to provide high quality protein to vulnerable groups and supplemental income using minimum inputs. Commercial poultry farming will not be affected by growth of rural poultry farming as observed in most of South East Asian countries. It has been reported that 75% of eggs and meat produced in Africa and 50% in south Asian countries is derived from traditional backyard poultry production. About 70% of the total eggs in China comes from rural poultry production (Sharma and Hazary,2002). Local poultry breeds with production potential of 120 eggs/ year/ bird constitute china's poultry population although China is the largest producer of eggs and second largest producer of meat in the world. Therefore, there is need to improve / augment rural/ backyard poultry production under free range and scavenging conditions. To achieve this we should have stocks which need to in between *desi* and exotic birds with regard to plumage colour, growth rate, egg production and better Immuno competance under harsh climate and low input feeding system.

Present scenario in India

At present, India sands at 3rd and 5th position, respectively in the worlds' egg and chicken meat production.(DAHHDF& CII, 2006). Poultry industry contributes around Rs. 352 billion to the GDP and providing direct employment to about 1.5 million people and indirect employment to about 2 million people in our country. Annually about 2 million tons of valuable organic poultry manure is produced.

Rural Poultry

Chicken rearing is an age old practice since ancient years and it became a part of routine life in rural areas. Generally desi birds are used for rearing in backyards in rural and tribal areas of the country. Though the native chicken reared in the backyard contribute about 20% of the total egg production in India, their productivity is far below (55-65 eggs/year) than those reared under intensive farm conditions (310 eggs/year). About 317 millions of native birds of different genetic potential and adopted for several centuries are available in India, which accounts for 38% of the total chicken population.The chicken varieties available are not suitable for this purpose as the production potential is very low. The exotic bird were tried for rearing in backyard / rural poultry production But they are not successful because of high mortality and poor performance due to low input management and harsh climatic conditions. Therefore, it is necessary to develop chicken varieties which can produce significantly better than native chickens and survive and sustain under adverse climatic conditions utilizing minimum inputs in terms of feed, health care and management. The crosses of mediocre performing birds proved to be useful for backyard rearing. The need of the hour is to develop suitable germplasm with mediocre growth rate (1.5-2.0 kg at 12weeks of age) and egg production (120-140 eggs per year) with coloured plumage as the choice of the rural/Tribal populations.

Prospects of Backyard Poultry Farming

1. Family poultry plays a significant role in the cultural life of rural people in the following ways:

a) as a gift to visitors and relatives,

b) as starting capital to youths and newly married maidens,

c) as sacrificial offerings in traditional worship,

d) as a potential source of employment and easy source of income for small scale farmers.

2. Family poultry requires little intervention in rearing, the major intervention is in the areas of feed and water supplementation, over night housing and to a much lesser degree, health management.
3. Family poultry can easily integrate with other agriculture, aquaculture and livestock farming practices.
4. Poultry products from family poultry have social and spiritual benefits and play an important role in rural economy.
5. Free-range poultry helps in pest control and weed clearance etc.
6. Better export value for eggs and meat from free-range poultry farming in developed countries.
7. Low investment, maintenance cost and risk
8. Good demand and higher price for eggs and birds of native fowl
9. Easy to manage and handle
10. Traditional liking
11. Serve as an efficient waste disposal system by converting every leftover feed materials.
12. About 15 chicken produces 1-1.2 kg of manure per day.
13. Contribute to the village economy.
14. Women in rural areas can operate family poultry farming and women involvement is easy

Chicken varieties suitable for rural poultry farming.

Having realized the importance of RPF in India, several research institutes developed different varieties (Table 1)These are the varieties that are being now effectively being raised in different parts of the country by the rural farmers. These birds were selected based on growth rate, egg production, Immunocompetance and plumage colour. These birds are able to thrive in harsh climatic conditions of free range/ semi-intensive farming in India. Going by the present international consumer market trends, eggs and meat from free range farming will have a great demand in the days to come. In view of its varied agro-climatic conditions and vast flora in most parts, India has a great potential for poultry production in the free-range conditions and capturing a great share of the International market. The good experience of other South East Asian and African countries, where commercial poultry farming and the village poultry farming are working simultaneously for improving local poultry production will aid as guiding forces for the Indian poultry industry to march ahead in this direction.

Table 1 Rural poultry varieties

Variety	**Type**	**Developing agency**
Vanaraja	Dual	DPR, Hyderabad
Gramapriya	Egg	DPR, Hyderabad
Srinidhi	Dual	DPR, Hyderabad
Vanasree	layer	DPR, Hyderabad
KrishiBro	Meat	DPR, Hyderabad
Giriraja	Dual	KVAFSU, Bangalore
Girirani	Egg	KVAFSU, Bangalore
Krishna J	Egg	JNKVV, Jabalpur
Nandanam 99	Egg	TANUVAS, Chennai
Gramalakshmi	Egg	KAU, Kerala
Kalinga Brown	Egg	CPDO, Bhubaneswar
CARI Nirbeek	Egg	CARI, Izatnagar
CARI Shama	Egg	CARI, Izatnagar
Upcari	Dual	CARI, Izatnagar
Hitcari	Dual	CARI, Izatnagar

The germplasm developed for backyard farming has the following features

1. The colour pattern of the germplasm is more attractive than *Desi* hen. Because of coloured plumage these birds have camouflagic characters to protect themselves from predators.
2. They can thrive well under adverse environmental conditions like poor housing, poor management and poor feeding.
3. Broodiness is rarely seen in the hens.
4. Nutritional value, aroma and taste of eggs and meat from these birds are similar to Desi hen.
5. Less fat content in meat of these birds makes it acceptable to even aged peoples.
6. These birds can thrive well and perform better even in adverse environmental conditions.

7. These birds are sturdy compared to commercial birds because of their better immune competence.
8. These birds can perform well with diets high in crude fibre. It has better feed efficiency even with diets containing low energy and protein diets based on common feed ingredients available in rural / tribal areas like rice bran, broken rice, small millets (like foxtain millet, finger millet, pearl millet etc.).
9. At eight weeks of age males of these germplasm weighs about 1250 g with a feed conversion ratio of 2.2 under intensive rearing practice.
10. Mortality is less than 2.0 % up to eight weeks of age.
11. The eggs are heavier (55 to 63 g) and colour of the eggs is brown or tinted, attractive and resembles that of Desi hen.
12. Fertility and hatchability of their eggs are 87 and 80 %, respectively, and the farmer can get more number of chicks from a these birds compared to a Desi hen by using broody hen.
13. It can perform better in backyard conditions by eating green grass and insects available in the fields.
14. The performance of Desi hens can also be improved by crossing them with males of germplasm developed for backyard farming.

Improved varieties developed at PDP

The Directorate of Poultry Research, Hyderabad has developed several promising crosses namely Vanaraja, Gramapriya, Srinidhi and Vanasree and. Vanaraja is a dual-purpose bird, while Gramapriya is having good egg production potential.

Performance of varieties developed at ICAR-DPR, Hyderabad

(g)Name	Type	Colour	Body wt. 6 week(g)	Egg production		Egg weight (g)
				Farm	Field	
Vanaraja	Dual	Brown	800-900	150-160	110-120	53-58
Gramapriya	Egg	Reddish Brown	400-450	235-240	160-180	52-56
Srinidhi	Dual	Multi colour	700-800	230-235	140-160	53-56
Vanasree	layer	Light brown	350-400	150-160	130-140	48*50

Performance of varieties developed at AICRP

Name	Developed	Type	Colour	Body wt. 6 week(g)	Egg Production	Egg weight(g)
Pratap Dhan	Mpuat,Udaipur	Dual	Brown	400-450	160-165	53-58
Narmadanidhi	NDVSU, Labalpur	Egg	Blackish	350-400	180-190	49-50
Kamarupa	AAU, Guwahati	Dual	Multi colour	400-450	130-140	52-53
Jharsim	RJU, ranchi	Dual	Multi colour	350-400	160-165	52-54
Himsamrudhi	CSHPKVV, Palampur	Egg	Reddish Brown	300-350	160-180	52-54

Performance of varieties developed at ICAR-CARI,Izatnagar

(g)Name	Type	Colour	Egg Production	Body weight(g)		Egg weight (g)
				Male	Female	
CARI-Nirbhik	Egg	Brown	190-200	1847	1350	52-54
CARI-Shyama	Egg	Blackish	200-210	1460	1120	52-53
UPCARI	Dual	Multi colour	210-220	1685	1285	55-58
HITCARI	Dual	brown	190-200	1756	1320	55-58

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Introduction to indigenous and exotic chicken breeds

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Introduction

The genetic variation that has been accumulated over the course of evolution and domestication form the basis of classification of species into different sub groups. These can be termed as breed, variety, strain and lines in chicken. The classification is made on different conditions viz., purpose for which the bird is developed (egg, meat or both), pattern of plumage colour, size/morphology (light, heavy, medium), birds developed for industrial purpose (high producers, medium level producers and indigenous stocks.

The earlier method in vogue for classification of chicken was based on type or economic potential of the bird. This included egg type, meat type (heavy/game), dual purpose, desi and miscellaneous type. This classification found that there is overlapping of several birds under different types. Hence this is not being much used in present day classification chicken.The official or standard classification of chicken has been given by the American Poultry Society. There are about 53 breeds and 176 strains officially classified by the society. The basic taxonomy of classification is at four stages viz., class, breed, variety and strain.

Class includes a group of chicken comprising of certain breeds, placed together because of geographical origin, likeness in some traits, etc. The Standard of Perfection groups chicken breeds into fourteen classes. The most important classes are American, Asiatic, Mediterranean and English. Minor classes include Continental class (North European, Polish and French), oriental class, Game class and miscellaneous class.

Breed: a distinct group of fowls all members of which are descended from a common ancestry, which have distinctshape and conformation and perpetuate their own special characteristics. Each breed is distinct and is developed for a specific purpose.

Variety: a division of a breed usually differentiated by plumage colour and /or by special comb appearance orpresence of a beard or muff.

Strain: these are a group of birds under the variety which are developed by a breeder for some special characteristics

Standard of Perfection: This book contains the authorized descriptions of all recognized breeds, according to theAmerican Poultry Association's demands. A complete list (beyond the scope of this article) of recent classification of chicken (2010) can be had from http://www.amerpoultryassn.com/PDF%20Forms/APA%20Recognized%20Breeds%20and%20 Varieties%20Sept2012.pdf

Standard breed classification

Characteristic	**American class**	**Asiatic class**	**English class**	**Mediterranean Class**	**Continental - North European Class**	**Continental - Polish class**	**Continental - French class**	**Oriental class**
Ear lobes color	R	R	R	W	W	W	W	R
Skin color	Y	Y	W	Y	W	W	W	Y
Shanks color	Y	Y	Y	Y	Y	SB	W	Y
Egg color	B	B	B	W	W	W	W	B
Comb type	S	S	S	-	S	VS	VS	P

Shank feathering	A	Pr	A	A	A	A	A	A

R=Red, W=White, Y=Yellow, SB= Slaty blue, B=Brown, S=Single, P=Pea, A=Absent, Present =Pr, 'V'shaped=VS

Different classes and chicken breeds

Class	**Breed**
American	Plymouth Rocks, Dominique, Wyandottes, Javas, Rhode Island Reds, Rhode Island Whites, Buckeyes, Chanteclers, Jersey Giants, Lamonas, New Hampshires, Hollands, Delawares
Asiatic	Brahmas, Cochins, Langshans
English	Dorkings, Redcaps, Cornish, Orpingtons, Sussex, Australorps
Mediterranean	Leghorns, Minorcas, Spanish, Andalusians, Anconas, Sicilian buttercups, Catalanas
Continental	Hamburgs, Campines, Polish, Houdans, Crevecoeurs, La Fleche, Faverolles

Characteristics of different breeds of chicken

Breed	**Size**	**Purpose**	**Egg Production**	**Egg Size**	**Egg Colour**	**Comb Type**	**Climate Hardiness**	**Broodiness**
Ameraucana	Standard	Dual	Medium	Medium	Blue/Green	Pea	All Climates	Average
American Game	Standard	Ornamental	Medium	Medium	White	Pea	All Climates	Frequent
Ancona	Standard	Egg Layer	High	Large	White	Single	All Climates	Seldom
Andalusian	Standard	Egg Layer	High	Medium	White	Single	All Climates	Seldom
Appenzeller Spitzhauben	Standard	Ornamental	Medium	Medium	White	V-Shaped	All Climates	Seldom

Araucana	Standard	Dual	Medium	Medium	Blue/Green	Pea	All Climates	Frequent
Araucana	Standard	Dual	Medium	Medium	Blue/Green	Pea	All Climates	Average
Aseel	Bantam	Ornamental	Low	Medium	Light Brown	Pea	All Climates	Frequent
Australorp	Standard	Dual	High	Large	Brown	Single	All Climates	Average
Barnevelder	Standard	Dual	Medium	Medium	Brown	Single	All Climates	Average
Belgian D Anver	Bantam	Ornamental	Low	Small	White	Rose	All Climates	Seldom
Belgian D Anver	Bantam	Ornamental	High	Small	Light Brown	Rose	All Climates	Frequent
Belgian D Uccle	Bantam	Ornamental	Medium	Small	White	Single	All Climates	Average
Belgian D Uccle	Bantam	Ornamental	Medium	Small	White	Single	All Climates	Average
Booted	Bantam	Ornamental	Medium	Small	White	Single	Heat	Frequent
Brabanter	Standard	Ornamental	Medium	Large	White	V-Shaped	All Climates	Seldom
Brahma	Standard	Dual	Medium	Large	Light Brown	Pea	All Climates	Average
Brahma	Bantam	Dual	Medium	Small	Light Brown	Pea	Cold	Average
Brahma	Standard	Dual	Medium	Large	Light Brown	Pea	All Climates	Average
Buckeye	Standard	Dual	Medium	Medium	Brown	Pea	All Climates	Average
Campine	Standard	Egg Layer	Medium	Medium	White	Single	All Climates	Seldom
Catalana	Standard	Dual	High	Medium	White	Single	Heat	Seldom
Chantecler	Standard	Dual	Medium	Medium	Light Brown	Cushion	Cold	Average

Cochin	Bantam	Ornamental	Medium	Small	Light Brown	Single	Cold	Frequent
Cochin	Standard	Ornamental	Medium	Small	Light Brown	Single	Cold	Frequent
Cornish	Standard	Meat Bird	Low	Medium	Brown	Pea	All Climates	Average
Cornish Cross	Standard	Meat Bird	Low	Medium	Brown	Pea	All Climates	Seldom
Crevecoeur	Standard	Dual	Medium	Medium	White	V-Shaped	Heat	Seldom
Cubalaya	Standard	Ornamental	Medium	Medium	Light Brown	Pea	All Climates	Average
Delaware	Standard	Dual	High	Large	Brown	Single	All Climates	Average
Delaware Blue Hen	Standard	Ornamental	Low	Medium	White	Single	All Climates	Frequent
Dominique	Standard	Dual	High	Medium	Brown	Rose	All Climates	Average
Dominique	Standard	Dual	Medium	Medium	Light Brown	Rose	Cold	Average
Dorking	Standard	Dual	Medium	Large	White	Single	All Climates	Average
Dutch	Bantam	Ornamental	Medium	Small	White	Single	All Climates	Frequent
Easter Eggers	Standard	Egg Layer	Medium	Medium	Blue/Green	Pea	All Climates	Seldom

Breed	**Size**	**Purpose**	**Egg Production**	**Egg Size**	**Egg Colour**	**Comb Type**	**Climate Hardiness**	**Broodiness**
Faverolles	Standard	Dual	Medium	Medium	Light Brown	Single	All Climates	Seldom
Fayoumis	Standard	Ornamental	Medium	Small	White	Single	Heat	Seldom
Frizzle	Standard	Dual	Medium	Medium	Light Brown	Single	All Climates	Frequent
Hamburg	Standard	Egg Layer	High	Small	White	Rose	All Climates	Seldom

Hamburg	Bantam	Ornamental	High	Small	White	Rose	All Climates	Seldom
Holland	Standard	Dual	High	Medium	White	Single	All Climates	Seldom
Holland	Standard	Dual	Medium	Medium	White	Single	All Climates	Average
Houdan	Standard	Ornamental	Medium	Medium	White	V-Shaped	All Climates	Seldom
Houdan	Bantam	Ornamental	Low	Small	White	V-Shaped	All Climates	Seldom
Hungarian Yellow	Standard	Dual	Medium	Medium	Light Brown	Single	All Climates	Average
Japanese	Bantam	Ornamental	Medium	Small	White	Single	All Climates	Average
Java	Standard	Dual	High	Large	Brown	Single	All Climates	Average
Jersey Giant	Standard	Dual	Medium	Large	Light Brown	Single	Cold	Seldom
Lakenvelder	Standard	Egg Layer	High	Small	White	Single	All Climates	Seldom
Langshan	Standard	Dual	Medium	Large	Brown	Single	All Climates	Frequent
La Fleche	Standard	Dual	Medium	Large	Light Brown	V-Shaped	Heat	Seldom
Legbar	Standard	Egg Layer	Medium	Medium	Blue/Green	Single	All Climates	Seldom
Leghorn	Standard	Egg Layer	High	Large	White	Single	All Climates	Seldom
Leghorn	Standard	Egg Layer	High	Large	White	Rose	Cold	Seldom
Leghorn	Bantam	Ornamental	Medium	Small	White	Single	All Climates	Seldom
Malay	Standard	Ornamental	Low	Medium	Light Brown	Strawberry	Heat	Seldom
Marans	Standard	Dual	Medium	Large	Dark Brown	Single	Cold	Average
Minorca	Standard	Egg Layer	High	Large	White	Single	Heat	Seldom
Modern Game	Bantam	Ornamental	Low	Small	White	Single	Heat	Frequent
Naked Neck turken	Standard	Dual	High	Large	Brown	Pea	All Climates	Average
New Hamp. Red	Standard	Dual	High	Large	Brown	Single	All Climates	Frequent

Old English Game	Bantam	Ornamental	Medium	Small	Light Brown	Single	All Climates	Frequent
Orpington	Standard	Dual	Medium	Large	Light Brown	Single	All Climates	Frequent
Orpington	Standard	Dual	Medium	Large	Light Brown	Single	All Climates	Frequent
Phoenix	Standard	Ornamental	Low	Small	White	Single	Heat	Average
Plymouth Rock	Standard	Dual	High	Large	Light Brown	Single	All Climates	Seldom
Plymouth Rock	Standard	Egg Layer	Medium	Medium	Blue/Gree n	Single	Heat	Average
Polish	Standard	Ornamental	Medium	Medium	White	V-Shaped	All Climates	Seldom
Polish	Standard	Ornamental	Medium	Medium	White	Rose	All Climates	Seldom
Production	Standard	Dual	High	Large	Brown	Single	Heat	Average
Pyncheon	Bantam	Ornamental	Low	Small	Light Brown	Single	All Climates	Average
Redcap	Standard	Dual	High	Medium	White	Rose	All Climates	Seldom
Rhode Island	Standard	Dual	High	Large	Brown	Single	All Climates	Seldom
Rosecomb	Bantam	Ornamental	Medium	Small	White	Rose	All Climates	Frequent
Russian Orloff	Standard	Dual	Medium	Medium	White	Walnut	All Climates	Average
Russian Orloff	Standard	Dual	Low	Medium	Light Brown	Walnut	All Climates	Seldom
Sebright	Standard	Ornamental	Low	Small	White	Rose	All Climates	Seldom
Serama	Bantam	Ornamental	Medium	Small	Light Brown	Single	Heat	Frequent
Showgirl	Bantam	Ornamental	High	Small	Light Brown	Walnut	Cold	Average
Sicilian Buttercup	Standard	Ornamental	Low	Small	White	Buttercup	Heat	Seldom
Silkie	Bantam	Ornamental	Medium	Small	Light	Walnut	All Climates	Frequent

					Brown			
Sizzle	Bantam	Ornamental	Low	Medium	Light Brown	Walnut	All Climates	Frequent
Star	Standard	Dual	High	Large	Brown	Single	All Climates	Seldom

Breed	**Size**	**Purpose**	**Egg Production**	**Egg Size**	**Egg Colour**	**Comb Type**	**Climate Hardiness**	**Broodiness**
Sultan	Standard	Ornamental	Low	Small	White	V-Shaped	Heat	Seldom
Sumatra	Standard	Ornamental	Medium	Medium	White	Pea	All Climates	Average
Sussex	Standard	Dual	High	Medium	Brown	Single	All Climates	Average
Vorwerk	Bantam	Dual	Medium	Medium	Light Brown	Single	All Climates	Seldom
Welsummer	Standard	Dual	Medium	Large	Dark Brown	Single	Cold	Seldom
White Faced Black Spanish	Standard	Egg Layer	Medium	Large	White	Single	Heat	Seldom
White Faced Black Spanish	Bantam	Egg Layer	High	Small	White	Single	Heat	Seldom
Wyandotte	Standard	Dual	High	Large	Light Brown	Rose	All Climates	Frequent
Wyandotte	Standard	Dual	High	Large	Brown	Rose	Cold	Frequent
Yokohama	Standard	Ornamental	Low	Small	Light Brown	Walnut	Heat	Average

Indigenous chicken breeds:

India is one of the richest poultry genetic resource countries in the world with 18indigenous breeds and various subtypes out of 72 breeds found in Asia. Poultry genetic resources in India can be broadly classified into three categories. The first consists of 18 indigenous pure breeds present in small numbers mostly with some fanciers and non-descript indigenous birds with their derivatives in the countryside, thriving as scavengers and constituting about 14 percent of the total poultry population. The second category is those of exotic pure breeds/ lines and grandparents (GPs) imported by the private sector and institutions that have been used as pure breeds/ crosses. Institutions and private sector breeders have extensively used pure lines and GPs to develop commercial broiler and layer crosses which are sold by different brand names and constitute the industrial forming the third category and accounts for about 85% of the present poultry population. There are several breeds of indigenous chicken available throughout the country.

S.N.	**Breed**	**Home Tract**	**Accession number**
1	Ankaleshwar	Gujarat	INDIA_CHICKEN_0400_ANKALESHWAR_12001
2	Aseel	Chhattisgarh, Orissa and Andhra Pradesh	INDIA_CHICKEN_2615_ASEEL_12002
3	Busra	Gujarat and Maharashtra	INDIA_CHICKEN_0411_BUSRA_12003
4	Chittagong	Meghalaya and Tripura	INDIA_CHICKEN_1319_CHITTAGONG_12004
5	Danki	Andhra Pradesh	INDIA_CHICKEN_0100_DANKI_12005
6	Daothigir	Assam	INDIA_CHICKEN_0200_DAOTHIGIR_12006
7	Ghagus	Andhra Pradesh and Karnataka	INDIA_CHICKEN_0108_GHAGUS_12007
8	Harringhata Black	West Bengal	INDIA_CHICKEN_2100_HARRINGHATABLACK_12008

9	Kadaknath	Madhya Pradesh	INDIA_CHICKEN_1000_KADAKNATH_12009
10	Kalasthi	Andhra Pradesh	INDIA_CHICKEN_0100_KALASTHI_12010
11	Kashmir Favorolla	Jammu and Kashmir	INDIA_CHICKEN_0700_KASHMIRFAVOROLLA_12011
12	Miri	Assam	INDIA_CHICKEN_0200_MIRI_12012
13	Nicobari	Andaman & Nicobar	INDIA_CHICKEN_3300_NICOBARI_12013
14	Punjab Brown	Punjab and Haryana	INDIA_CHICKEN_1605_PUNJABBROWN_12014
15	Tellichery	Kerala	INDIA_CHICKEN_0900_TELLICHERY_12015
16	Mewari	Rajasthan	INDIA_CHICKEN_1700_ MEWARI _12016
17	Kaunayen	Manipur	INDIA_CHICKEN_1200_ KAUNAYEN _12017
18	Hansli	Odisha	INDIA_CHICKEN_1500_ HANSLI _12018

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Newer feed additives for improving poultry health and production

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Introduction

There has been tremendous growth in poultry industry in India during last 3 decades. This has been possible though introduction of superior germplasm, a host of growth promoting and disease prevention measures. Research has been intensified to develop various feed additives for poultry during last two decades across the globe to cope up with intense competition for reducing production cost through improving efficiency and reducing disease incidence. Climate change associated increased heat stress are also impacting performance of fast growing or high producing chicken in a more intense manner. Growing concern on antimicrobial resistance also stimulated research on numerous alternatives to antibiotics. Globally feed additive market is growing at about 6.1% CAGR. With opening up of market there has been flooding of market with various feed additives from international market into Indian market. Often farmers or producers are facing difficulty in choosing minimum essential and effective feed additives. The present review aims at highlighting some of the promising newer feed additives, their bioactive principles, mode of action and experimental evidences, if any, in improving growth and productivity.

Phytase superdosing

Phytic acid, also called phytate or phytin are the major form of phosphorus in plants. This compound complexes to positively charged molecules such as dietary proteins, amino acids and proteolytic enzymes, reducing the digestibility of amino acids. During the digestion of lipids, the calcium-phytate complex can react with fatty acids to form insoluble soaps in the intestinal lumen. Phytate can also bind to starch, inhibiting the action of amylase and consequently reducing the digestibility of carbohydrates (Kornegay, 2001; Woyengo and Nyachoti, 2013).

Broiler diets are based on feed ingredients from plant sources, seeds or seed products, with 60 to 80% of their phosphorus content in the form of phytate and thus unavailable to broilers. Typical broiler diets contain from 2.5 to 4.0 $g\,kg^{-1}$ of phytate (Ravindran, 1995). As broilers cannot hydrolyse phytate since they do not synthesise specific digestive phytases, the use of costly exogenous sources of inorganic phosphorus, such as minerals or feeds of animal origin, is necessary to avoid P deficiency in the poultry metabolism. Unutilized plant origin phytate form of phosphorus are excreted to environment causing pollution of soil and water . To circumvent the problem microbial phytases are routinely used with low inorganic P diet usually at the dose level upto 500 phytase unit (FTU) per kg diet (Selle and Ravindran, 2007) which hydrolyses upto 35% of dietary phytate. More recently, the concept of superdosing (Cowieson et al., 2011) has demonstrated further improvements to weight gain and feed conversion rate (FCR) compared with standard doses, due to phytate destruction rather than phosphorus (P) provision. It has been shown that about 30-35% of the superdosing benefit of phytase is brought about through the production of myo-inositol (MYO) which is subsequently absorbed and utilised in a number of biological functions within the animal (Lee and Bedford, 2016, Lee et al., 2017). It has been shown that superdosing of phytase (over 1000 FTU/kg upto about 2000 FTU/kg) besides removing as much as Phytate (IP6) as possible, it can also degrade phytate breakdown products- IP5, IP4, IP3-which are lower phytate esters and have been shown to be associated with poor utilization of protein, energy and minerals. Brocha et al.(2018) recommended that for broiler chicken high dose of 2973 FYT per kg had the best weight gain from 1 to 21 days of age wheras, from 21 to 42 days, 2051 FYT /kg and 2101 FYT per kg showed the best weight gain and feed conversion ratio, respectively. Although in broilers superdosing of phytase has been shown to be effective, in layers where diet normally contain high level of Ca, superdosing of phytate has been shown to have no or negative impact (Skřivan et al., 2018). Phytate can bind to cation Ca2+ in the small intestine, reducing the solubility of phytate and thereby reducing its accessibility by Phytase. Ca binding to phytate occurs mainly in the small intestine when the pH level is above 5 (Dersjant-Li et al. 2015). Calcium has recently been shown to reduce the efficacy of hydrolysis of the lower phytate esters to a greater degree than the extent to which it decreases IP6 hydrolysis (Bedford and Rousseau, 2017).

Supplementation of the diet with superdoses of phytase (2000 FYT/kg) significantly increased growth performance, improved feed efficiency (Table 1), and amino acid (Met, Cys, M + C, Thr, Val, Iso, Leu, Phe, Lys, His, Arg, Trp, Asp, Ser, Glu, Pro, Gly, Ala, Tyr) digestibility, particularly in diets formulated to contain between 75 and 82% of the assumed dgM+C requirement (Carrie and Rama Rao, 2018). The effect of superdoses of phytase on the dgM+C sparing in the diet was between 14 and 19% for growth performance and AID of amino acids. Similarly Lee et al. (2017) reported that superdosing (1500 FYT/kg) reduced feed conversion rate (FCR) at all P levels ($P < 0.05$), although this effect was more pronounced on the low P diet, suggesting that sufficient P being released from the phytase itself to re-phosphorylate MYO and hence improve FCR. The significant improvement in FCR was greater with superdosing than with MYO alone, and the combination led to no further improvement in FCR compared with superdosing alone, signifying a phytase and MYO interaction ($P < 0.05$). From these results, it can be estimated that MYO is providing around 30% to 35% of the total response to superdosing.

Table 1. Effect of phytase superdosing on performance of broiler chicken

Phytase, FYT/kg	21d (Experiment 2)		42d (Experiment 1)	
	BWG, g	FCR	BWG, g	FCR
0	931	1.378	2409	1.740
2000	956	1.317	2489	1.696
P	**	**	NS	**

BWG body weight gain; FCR feed conversion ratio

Source: Carrie and Rama Rao, 2018

NSP degrading enzymes

Poultry diets are largely composed of plant (-based) materials that hold non-starch polysaccharides (NSP). NSP are non-a-glucan heterogeneous group of polysaccharides with varying degrees of structure, size and water solubility. NSP include cellulose, hemicellulose (arabinoxylans), b-glucans, fructans etc. Cellulose, arabinoxylans, and b-glucans comprise most of the fiber in cereal grains fed to the poultry. The inclusion of NSP rich ingredients often reduces feed cost, but hampers a proper digestion due to anti-nutritional factors (ANF). Soluble NSP (Arabinonxylans (hemicelluloses) and b-glucans) for instance increases digesta viscosity (Veldman and Vahl, 1994) by absorbing water and forming gel in intestine which leads to slow passage of digesta, hinder the efficiency of digestive enzymes and promote growth of pathogenic and toxin producing microbes as they are suitable food for them and by creating strict anaerobic condition by lowering oxygen tension in gut. Insoluble NSP (cellulose) in plant cell walls encapsulate nutrients and render them unavailable for digestion (Meng and slominski, 2005). Most of the unconventional grains are rich in NSP. Wheat contains larger amounts of high molecular weight arabinoxylans with 7.3% of total dry matter, while barley contains large amounts of b-glucans and showed considerable anti-nutritive properties. These two grains are viscous grains, and causes viscosity problem whereas corn is considered as non viscous grain. Non-ruminants are physiologically unable to hydrolyze NSP in their small intestine. Hence, supplementation of NSP enzymes to broiler diets can improve digestibility, whilst economizing the formula using cheaper NSP rich ingredients. The NSP enzyme market is globally dominated by endo-1,4-β-xylanase and endo-1,3(4)β-glucanase (Adeola et al., 2011). This corresponds with arabinoxylan and glucan substrates as the predominant NSP types in common broiler diet raw ingredients. Furthermore, cell wall polymers of protein rich plant-based ingredients such as soybean meal contain an equally important share of pectic substances (Knudsen, 2014). Consequently, pectinase might additionally improve energy and protein digestion of certain types of raw materials. Indeed, enzyme combinations at high concentration, targeting arabinoxylan, glucan, and pectic substances are potent blends to depolymerize NSP and hydrolyze NSP-protein complexes (Meng et al., 2005). Cardoso et al. (2018) reported exogenous enzyme supplementation improved the nutritive value of wheat based diet. Yildiz et al. (2018) reported that xylanase based enzyme supplementation improved egg production and decreased intestinal viscosity regardless of the inclusion rate of distillers dried grains with solubles (DDGS). It has been studied that use of xylanases and b-glucanases in wheat and barley diets reduced the viscosity of the digesta by 30 to 50% and 300%, respectively (Juanpere et al., 2005). Reduced viscosity leads to improvements in protein digestibility, apparent metabolizable energy, feed consumption, body weight gain, and feed conversion. Xylanases were also found to increase the overall apparent ileal digestibility of amino acids by 15% in a corn based diet while this improvement for wheat and rye based diets were 16% and 30%, respectively (Cowieson and

Bedford, 2009). However, several studies have reported no effect of enzymes on performance of bird (Olgun et al. (2018), Walters et al. (2018)) probably due to variation in structure of NSP and that of ideal substrate required for the enzymes. Cozannet et al. (2017), first used the term new generation feed enzymes (carbohydrases) for those enzymes rich in xylanase and arabinofuranosidase with ability to debranch xylan chains having an ability to improve the digestibility of all nutrients with unique heat stability, a broad pH range and high level of activity.

Supplementation of fibre hydrolyzing enzymes will be more beneficial in diets containing alternate protein sources for soybean meal. Majority of alternate protein feed ingredients like cotton seed meal, sunflower seed meal, safflower seed meal, guar meal, etc contain higher levels of fibre which is the main limiting factor to include these ingredients at higher levels in diets. Therefore, inclusion of NSP hydrolyzing enzymes (xylanase 3250, glucanase 1200, cellulose 890, mannanase 4000 and protease 4000 units/kg) in diets containing higher levels (20%) of guar meal improved the performance of *Vanaraja* birds (Table 2) compared to those fed the guar meal diet without the enzyme supplementation during 1-42d of age (Rama Rao et al., 2014).

Table 2. Effect of NSP hydrolyzing enzyme supplementation on performance of Vanaraja chicken (1-42d of age)

Treatment	BWG, g	FCR
SBM diet	784.0a	2.175
Guar meal (20%)	607.3c	2.351
Guar meal+NSP enzymes	664.4b	2.312
P	**	NS

BWG body weight gain; FCR feed conversion ratio

^{abc} means having different superscripts in a column vary significantly

Source: Rama Rao et al., 2014

It is a usual practice that phytase is supplemented as a regular commodity in poultry diets at regular dose i.e. 500 FYT/kg diet. Phytase is also give matrix values for other nutrients like

ME, protein, amino acids in addition to P and Ca while formulating the diets. Fibre hydrolyzing enzymes are also being supplemented in diets to economize cost of feeding. Supplementation of both NSP enzymes and phytase together need to be verified for their additive effects on the bird performance. Data generated from the author's lab suggested additive response between phytase and NSP enzymes was not observed when phytase was supplemented with xylanase enzyme in broiler diet deficit in 100 kcal/kg diet (Table 3). The improved performance was associated with significant improvement in utilization of dietary energy with enzymes supplementation.

Table -3. Effect of supplementing product Z along with phytase and NSP enzymes on performance of commercial broilers fed low calorie diets

Treatment	BWG, g	FCR	Energy retention, %
Positive Control (PC)	$2,467^{A}$	1.725^{D}	75.62^{A}
Negative Control (NC)	$2,356^{C}$	1.781^{A}	71.03^{C}
NC + P	$2,424^{AB}$	1.728^{CD}	75.74^{A}
NC + X	$2,396^{BC}$	1.760^{B}	73.47^{B}
NC + P + X	$2,387^{BC}$	1.746^{BCD}	74.13^{AB}
P	0.001	0.001	0.001

^{ABCD} means having different superscripts in a column vary significantly

BWG body weight gain; FI feed intake

Source : Personal Communication

Proteases

Endogenous proteases do not digest all dietary protein in the small intestine (Lleme et al., 2004). Therefore, exogenous counterparts can strengthen the bird's own protease community and potentially achieve increased prececal amino acid (**AA**) digestibility in broiler chickens, and thereby reduce the dietary CP level. The effects of protease supplementation on prececal CP and AA digestibility have been found to be inconsistent. Studies on broiler chickens and turkeys showed that the pc digestibility was increased for all AA (Cowieson et al., 2017) or some AA

(Vieira et al., 2013). Whereas, in some other studies, no effects (Erdaw et al., 2017) or decreasing effects (Walk et al., 2018) of protease supplementations on prececal digestibility were described.

Plant source of protein hydrolyzing enzymes are being promoted due to its natural origin. A trail was conducted at the author's lab with papaine at two different doses in broiler chicken diet (Table 4). The performance data indicated lack of influence of the enzyme supplementation on body weight gain. However, feed efficiency was improved significantly with papaine supplementation compared to the control diet. However, dressing and breast weights reduced with papaine supplementation, which needs further verification.

Table 4. Effect of papaine supplementation on performance of broilers fed graded levels of protein

Papaine, g/Ton	BWG, g	FCR	RTC	Breast	Abdfat
0	2288	1.696^{A}	731.6A	256.6A	16.01
250	2299	1.682^{B}	707.1B	242.7B	16.34
500	2321	1.674^{B}	703.1B	231.2C	16.76
P values	0.154	0.001	0.007	0.001	0.674

BWG body weight gain; FI feed intake; RTC ready to cook yield; P probability

^{ABC} means having common superscripts in a sub column do not vary significantly (P<0.05)

Source : Personal Communication

Nano minerals

Nanotechnology, deals with the conversion of larger molecules to nanometer size. The process of converting these larger molecules to tiny one causes changes in the innate physical and chemical nature of the base material. These changes includes, change in solubility, absorption, transport mechanism, excretion and importantly antagonisms. Chen et al 2006 specified the different mechanisms of action of nanoparticles as follows: Nanoparticles that tends to increase the surface area for better interaction with biological support, Prolonged the compound residence time in gut, Reduce the influence of intestinal clearance mechanisms, Penetrate deep into tissues by fine capillaries, Cross epithelial lining fenestration, Enable cells for efficient uptake, Effective delivery of functional compounds to target sites and thereby better bioavailability. In broiler chicken, supplementation of 1.20 mg /kg Se (Nano-Se) showed a wider range between the optimal and toxic dietary levels of Nano-Se with efficient retention in the body compared to sodium selenite. Also in the same study, addition of nano-Se (60 nm) to the broiler diet showed an elevation in survival rate, average daily gain and feed to gain ratio with 0.15-1.20 mg /kg Se concentration(Hu et al., 2012). In layer chicks, nano-Se of 0.3 mg /kg of dry diet was found to have better physiological effects (Mohapatra et al., 2014). A study on nano zinc showed that supplementation of 0.06 ppm in the basal diet of broiler birds showed improved immune status and bioavailability compared to inorganic zinc (Sahoo et al., 2014). When broiler birds are fed with nano form of calcium phosphate by replacing upto 50% requirement of dicalcium phosphate, they showed a best feed conversion ratio (1.39±0.02) (Vijaykumar et al., 2014). Liu et al. (2015) examined the effects of corn-soybean diet supplementation with sodium selenite, nano-elemental selenium, and enriched yeast A and B on chicks and observed that there were no significant ($P > 0.52$) differences between each treatment in terms of growth performance. Selenium-enriched yeast B significantly ($P < 0.05$) increased selenium concentration in the liver and breast muscles in comparison with other diets. No significant ($P > 0.66$) differences were observed in the liver and breast muscle Se concentrations between other utilized enrichments. The study indicated that nano minerals may not always exert intended result and can be inferior to organic minerals. Further, application of nanoparticles pose a certain risk of increased bioavailability, induced inflammatory digestive diseases, alteration in the nutrient bioavailability by disrupted effects on protein and enzyme stability, possible effects on nanoparticle biocomplexes in the process of heating or storage (FSAI,2008). Loghman et al .(2012) reported that higher levels of nanosilver (8 and 12 ppm) may induce severe lesions in broiler liver.

Osmolytes

Heat stress has been shown to increase mortally probably by impairing intestinal development (Garriga et al., 2010) or disrupting barrier function (Quinteiro-Filho et al., 2010). It increases radiant heat loss through the redistribution of blood flow from the body core to the periphery, where it can more readily radiate to the environment. This redistribution of blood flow during HS arguably underpins hypoxia and tissue damage within the gastrointestinal tract (GIT) (Lambert et al., 2009). In addition, reductions in barrier function are likely to inflict a portal of entry for pathogens and thus increasing disease risk. Feeding osmolytes like betaine has been shown to give some protection to chicken from dehydration during heat stress conditions. Betaine accumulates within the intestine of broilers when included in diets. It serves as an extracellular osmolyte, lowering the activity of Na+/K+ ATPases and therefore reducing overall energy expenditure [(Moeckel et al., 2002, Tsai et al., 2015). Because the GIT accounts for a disproportionately large amount of whole-body energy expenditure, the GIT is particularly sensitive to perturbations in blood flow and it has been proposed the reducing the GIT energy demand with betaine may serve as a protective mechanism against heat stress (Cronjé et al., 2005, Saeed et al., 2017). Furthermore, BET acts as a methyl donor wich has wide-ranging effects, including DNA methylation and increasing methionine remethylation from homocysteine to increase protein synthesis. Finally, osmolytes act as chaperones, stabilising protein folding. In broilers, etaine supplementation improved villus morphology, including following coccidian infection (Kettunen et al., 2001). It has been established that growth performance improved with 0.5–2 g/kg added betaine, and within the range of 0.5–1 g/kg, the increase in the improvement is proportional to the increase in the dosage of betaine in the diets, with 1 g/kg being the most ideal dosage for such improvement; while BET 1–2 g/kg, albeit effective, did not improve growth performance any further than BET 1 g/kg did (Zhan et al., 2006, Attia et al., 2009).

Betaine anhydrous supplementation (800 mg/kg diet) was found effective (Rama Rao et al., 2011, Table 5) in enhancing growth (starter phase), feed conversion efficiency, breast yield and lymphocyte proliferation in broilers fed a diet containing sub-optimal concentrations of Met (15 g/kg CP). Bet supplementation was found ineffective at the higher concentrations of Met tested in the present study.

Table 5. Body weight gain (g) in broiler chickens fed betaine

Betaine, mg/kg	21d	42d
0	679b	2151b
800	715a	2214a

P	**	**

Source : Rama Rao et al. (2011)

Immune modulators

Numerous feed additives have been tested in broilers for their immunostimulatory effect. These include probiotics, prebiotics, plant extracts or phytogenic feed additives, animal by products (lactoferrins), vitamins, amino acids, organic acids, minerals, enzymes, algae, see weeds, etc.

Most commonly used probiotics are Lactobacillus spp., Bacillus spp., Enterococcus spp., Bifidobacterium spp., Saccharomyces spp., Streptococcus spp, Aspergillus spp., Pediococcus spp. and Clostridium spp. As reviewed by European food safety agency (EFSA, 2015) birds with the Lactobacillus diet showed an increase in intra-epithelial lymphocytes (IEL) expressing the surface markers CD3+, CD4+, CD8+, and αβTCR. Lactobacillus spp. induces IL-1, IL-12p40, IL-10, IL-18, TGF-4, and IFN-γ in gut-associated lymphoid tissues of chicken. The immunomodulatory action (inflammatory / anti-inflammatory response) of Lactobacillus is dependent on the characteristics and quantity of the strain involved. Lactobacillus spp. was also efficient in stimulating the production of total intestinal and serum IgA and IgG. Similar properties were also reported with other probiotics.

Commonly used prebiotics in poultry are mannan oligosaccharides (MOS) the yeast cell wall, glucan, fructooligosaccharides and inulin. As reviewed by EFSA in 2015, MOS and other prebiotics has been shown to upregulates lysozyme activity and affects oxidative phosphorylation; involved in immunomodulation of both TLR2b and TLR4 pathways in the ileum and caecal tonsil and in the cytokine upregulation of ileal IL-12p35 and IFN-γ in the ileum indicating a pro-inflammatory effect, via T-helper type-1 cell-associated pathways, in order to control early stages of infection.

The commonly used immune modulating plant extracts include *Thymus vulgaris* derivatives, Allium derivatives, carvacrol, Curcuma longa derivatives , Astragalus derivatives, Origanum derivatives and Chinese herbs. Most of these has been shown to influence intestinal barrier function, antioxidant properties and immune response.

Other categories of commonly used immune modulators include organic acids derivatives / fatty acids, vitamins, minerals, amino acids and derivatives, fungi / mushroom , enzymes , etc. Each group of substances /agents includes several products, each with different modes of action. Due to the complexity of the data, a summary of the mode of action for each group cannot be described within this report.

The data from the authors lab indicated that both cell mediated immune response and antibody titres against ND vaccination were improved with inclusion of mannon oligosaccharides (MOS) in diets compared to the broilers fed diets with AGP supplementation and without AGP in diet (Table 6). Supplementation of MOS also reduced lipid peroxidation and improved the anti-oxidant enzyme activity in serum.

Table 6. Effect of supplementing yeast cess extract on immune responses (CMI and HI) and lipid peroxidation in broilers fed antibiotic free diets

Treatment	CMI, %	HI titre, log 2	LP (ηM MDA)	GSHPx (units/ml)
AGP	75.50b	7.917b	2.798b	392.6a
No AGP	77.75b	6.833c	3.092a	368.0b
NC MOS	118.6a	9.333a	2.412c	396.3a
P	0.001	0.001	0.001	0.001

CMI cell mediated immune response to PHA-P antigen ; HI humoral immune response ; LP lipid peroxidation; GSHPx glutathione peroxidise; AGP anti-biotic growth promoter ; MOS, mannon oligo saccharides; P value probability value

[a b c] ..means having common superscriot in a column did not differ significantly (P<0.05

Source : Personal Communication

In an Sea6Energy pvt Ltd sponsored research carried out at ICAR –DPR it was observed that supplementation of dried aqueous extract of sea weed K. Alvarezi @ 1g per kg diet increased immunity (HI titre), expression of intestinal immunity related genes and improved BW gain by 7.11% (Paul et al., 2020).

Phage therapy

Bacteriophages are a group of viruses whose replication is dependent on invasion of bacterial cells. Bacteriophages are specifically associated with a particular bacterial strain and exhibit strong bactericidal activity against Gram-positive and Gram-negative bacteria. Some phages display specific affinity for single types of bacteria, while others have a broad range of activity. Their specificity and range of activity is determined by the presence of receptors located on the surface of bacterial cells, among which LPS fragments, fimbriae and other surface proteins are important (Rakhuba et al., 2010). Bacteriophages exhibit wo types of activity against the bacterial cell: lytic activity, which is characteristic of virulent phages, and lysogenic activity, involving integration of the genetic material of the bacteriophage with the bacterial chromosome and replication as part of the bacterial DNA, resulting in the appearance of a prophage. The use of bacteriophages to eliminate pathogens seems quite promising, especially as they are present in every ecosystem and number 10^{31}, which is more than 10 times the number of characterized bacteria. The effectiveness and safety of phage therapy in comparison to antibiotics is partially due to the specificity of bacteriophages for particular bacteria, manifested as the ability to infect only one species, serotype or strain. Thismechanism of action does not cause destruction of the commensal intestinal flora. Self-replication of bacteriophages takes place during treatment, which eliminates the need to apply them repeatedly. Another advantage of phages is that they cannot bind to and replicate in eukaryotic cells. Further phages are not toxic and the phage therapy can limit horizontal bacterial infection in uninfected birds in contact with infected birds. Despite its numerous advantages, the use of phage therapy is substantially limited, partly because single bacteriophages cannot be used to combat broadspectrum infections. In many cases complex identification and characterization of the aetiological agent is necessary. Moreover, not all bacterial viruses meet the criteria for use in treatment, particularly lysogenic phages, which encode genes of bacterial toxins and thereby transform harmless bacteria into pathogenic ones.

They can also be involved in transferring drug resistance genes among bacteria. Bacteria can also acquire resistance to phages rapidly (Andreatti Filho et al., 2007). Another adverse phenomenon in phage therapy is that phages can be cleared by the reticuloendothelial system, reducing their half-life in the organism and limiting the effectiveness of treatment (Chibbar and Kumari, 2012). Phages used in treatment have been effective in preventing infections and in treatment of colibacteriosis in poultry (Barrow et al., 1998). The effectiveness of phage therapy has also been confirmed in infections of broiler chickens by anaerobic *Clostridium perfringens* during the course of necrotic enteritis (Miller et al., 2010). Fiorentin et al. (2005) observed that single oral application of a cocktail of phages (CNPSA1, CNPSA3 and CNPSA4) at a dosage of 10^{11} plaque forming unit (PFU) decreased the occurrence of Salmonella Enteritidis strains by 3.5 log units and shown that applying a single dose of a bacteriophage suspension with a high titre was highly effective in reducing the population of pathogenic bacteria in the digestive tract, in contrast with long-term application of a lower titre.

Conclusion

There has been a spurt in introduction of feed additives in poultry production. Several newer additives have proven their worth in consistent manner in several experimental trials. Phytase superdosing has been more or less consistent in delivering response in broiler and has tremendous potential to improve P utilization and reduce excretion but in layer or high Ca diet it has limited effects. New generation NSP degrading enzymes that can act on any substrate seems promising although more experimental evidence is required. Proteases remains ineffective in most of the studies. Nano minerals have good prospect although sometimes organic minerals cane be more efficient and safer. Phase therapy is a potent but difficult to employ technology. India should work aggressively on this technology. Osmolytes like betaine has shown to be beneficial under heat stress in most of the studies. A lot of immune modulators have been tested and some of them including prebiotic-probiotics and phytogenic feed additives can also be used as safe alternative to antibiotics. There is urgent need to increase research on some of these newer feed additives in India to test their effectiveness under Indian condition. Further, impact of these additives on gut microflora, gut health and other safety aspects need also to be investigated.

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Postmortem Examination: Important Gross Lesions for the Diagnosis of Poultry Diseases

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During farm visit, a veterinarian closely observes the birds and their housing conditions and look at the mortality chart and other performance data, vaccination and medication programs. In order to verify his hypothesis, he has the possibility of opening carcasses on the farm to verify for the presence of lesions. The necropsy is essential to quickly observe the internal lesions, establish a differential diagnosis and decide on the course of action. Ideally, necropsy should be performed on birds representative of the condition. Indeed, the challenge of a good poultry diagnosis is to identify the most significant flock problem(s) rather than focusing on individual bird pathologies. For large poultry flocks, approximately five dead birds as well as five individuals showing clinical signs should be selected for necropsy. Euthanasia of the sick birds should be performed rapidly and humanely in accordance to ethical standards. For further analysis and confirmation of your tentative/preliminary diagnosis, birds or samples should be sent to an animal diagnostic laboratory. Some samples can be taken when birds are alive (e.g. blood samples, tracheal swabs, Cloacal swabs, feathers pulp etc) or at post-mortem. Important gross lesions for diagnosis of disease are presented in Table 1.

Table 1. Important Gross Lesions for the Diagnosis of Poultry Diseases

1. Viral Diseases

Disease	Gross Post Mortem Lesions
Newcastle Disease (Ranikhet Disease)	Pin point haemorrhages at the tips of proventricular glands, haemorrhagic ulcers in intestine, caecal tonsils, serous membranes and heart. Spleen atrophied and mottled. In per acute form, congested or ruptured ova may be found in peritoneal cavity.

Avian Influenza (AI)	Haemorrhages on serous surfaces of proventriculus, gizzard, intestine and muscles. Sinusitis with mucopurulent or caseous exudates. Fibrinopurulent pericarditis, airsaculitis and peritonitis. Yellowish grey necrotic foci are seen in spleen, kidneys, liver, lungs and pancreas. Congestion and hemorrhages are commonly observed in heart, skin and subcutaneous tissues. Spleen enlarged and mottled while kidneys swollen and pale.
Infectious Bronchitis (IB)	Nasal cavity and sinuses show the presence of catarrhal or cheesy exudates. Bronchi filled with small caseous plugs at the point of entry into the lungs. In reproductive form of disease, oviduct may show cystic dilation and atrophy. Laying hens may have ruptured ova and yolk fluid in the abdominal cavity. Kidneys enlarged grayish and mottled due to urate deposits. Ureters distended with pasty uric acid. Bursa markedly atrophied.
Infectious Laryngotracheitis (ILT)	Cheesy material may be found in nasal cavity and infra-orbital sinus. In acute form, congestion of larynx and trachea with blood tinged exudates may be found.
Infectious Bursal Disease (IBD)	In acute form there is enlargement of bursa with gelatinous exudates filled in. In more virulent form of IBD, BF appears haemorrhagic and blackish brown in colour, having blood clots and mucopurulent exudates. Kidneys swollen and pale due to urate deposit. Linear or achymotic haemorrhages are seen in proventricular mucosa just at the junction with gizzard. Spleen slightly enlarged with small gray foci on the surface. In later stages of disease, spleen and BF become atrophied and reduced in size.
Fowl Pox	In cutaneous form, there is formation of grayish yellow nodules on featherless part of body e.g. comb, wattles and skin of faces. In diphtheritic form, yellowish cheesy

	materials deposited on mucosa of tongue, palate or laryngeal orifice leaving ulcers when removed. In ocular form, there is conjunctivitis and cheesy exudates accumulate under eyelids.
Marek's Disease (MD)	In acute MD, tumors are found in liver, spleen, lungs, heart, kidneys, proventriculus, intestines and gonads. In chronic or classical form of MD, lesions are seen in peripheral nerves i.e. sciatic, brachial, vegus and mesenteric nerves. The nerves become slightly thickened and rounded instead of normally flat and loose its glistening appearance, sometimes becomes headed.
Lymphoid leucosis (L.L)	Grayish yellow nodules in liver, spleen, heart, lungs, ovary and serosal surfaces including bursa of Fabricius causing diffuse enlargement of organs.
Reoviral arthritis	Tendon sheaths of foot pad and hock joint are swollen with yellowish or purulent fluid. The articular surfaces of tibia and metatarsal may show erosions.
EDS-76	Lesions are confined to uterus which includes oedema of uterine folds. There are inactive ovaries and atrophied oviduct. Mild splenomegaly, flaccid ovules and eggs of various developmental stages in the abdominal cavity.
Chicken Infectious Anemia (CIA)	Pale yellowish bone marrow and marked atrophy of thymus, bursa, petechial hemorrhages of breast muscle, leg muscle, heart and proventriculus. Anaemia is prominent.
Inclusion Body Hepatitis (IBH)	Liver is swollen and mottled with pin point hemorrhagic spots and areas of necrosis. BF many be small and atrophied. Muscles of breast, thigh, serosal surfaces of other organs and intestine show petechial hemorrhages. Kidneys show hemorrhages and prominent lobulations.
Hydropericardium-Hepatitis Syndrome (Angara Disease/ Leechi Disease)	Excessive straw-colored fluid distending the pericardium (up to 10ml). Enlarged, pale friable liver and kidneys. Congestion of carcasses. Lungs edematous.

2. Bacterial Diseases

E. *coli* infection	**Colibacillosis:** Presence of milky fluid in pericardium due to pericarditis. Air sacs become thicker and cloudy. Liver may show a thin covering of fibrinous exudates and becomes dark in color. Common lesions include dehydration, swelling and congestion of the liver and spleen and kidneys and pinpoint hemorrhages in the viscera. Fibrinous to caseous exudates in the air sacs, heart and on the surface of the liver and lungs is a characteristic lesion. The intestines may be thickened and inflamed and may contain excess mucus and areas of hemorrhage. **Omphalitis:** Characteristic lesions are poorly healed navels, subcutaneous edema, bluish color of the abdominal muscles around the navel and unabsorbed yolk material that often has a putrid odor. Often yolks are ruptured and peritonitis is common. **Salpingitis:** Develops when left abdominal air sac is infected with E. coli. It is characterized by a large caseous mass in dilated thin walled oviduct. **Colisepticaemia:** An acute infectious disease due to E. coli infection seen in mature nad growing chickens and turkeys. Affected birds are in good flesh and have full crop. The most characteristic lesions are green liver and congested pectoral muscle. **Coligranuloma:** (Hjarre's disease) of chickens and turkey is characterised by granulomas in liver, ceca, duodenum and

	mesentery. Serosal lesions resemble leucotic neoplasms.
Pullorm Disease	Chicks may have haemorrhagic streaks on liver with grayish necrotic spots on liver, spleen and heart. Unabsorbed and coagulated yolk in peritoneal cavity. Adult birds having deformed, cystic, greenish or brownish ova.
Fowl Typhoid	In acute case, liver and spleen gets enlarged with characteristic copper color. Necrotic spots many be seen in liver, lungs and gizzard. Catarrhal enteritis with or without ulcers may be found. Ova may get deformed and discolored. In chronic cases synovitis and arthritis may occur. Heart may show small nodular granulomae with necrotic gray spots.
Necrotic Enteritis	Usually involve the lower half of the small intestine, but in some instances the entire length of the tract is involved. The intestine is dilated, contains dark offensive fluid and a diphtheritic cauliflower like membrane that involves the mucosa.
Ulcerative Enteritis (Quail disease)	The entire intestinal tract often has button-like ulcers but the lower portion is most often affected. These ulcers often perforate, resulting in local or generalized peritonitis.
Mycoplasmosis (**CRD**)	Cloudy appearance of air sacs having cheesy materials. Trachea and conjunctiva may be congested. Fibrinous pericarditis and perihepatitis, when complicated with E. *coli*.

3. Fungal Diseases

Aspergillosis	Lungs show uniform, raised, pin head sized yellow nodules. Airsacs become thickened and cloudy. Necrotic foci may be seen in liver, spleen, kidneys, proventriculus etc. Affection of eyes may lead to blindness.
Candidiasis (**Thrush**)	Crop, oesophagus and proventriculus have characteristic diphtheritic lesions. Mucosa of crop gives turkish towel like appearance. Ulcers may also be seen in mouth and oesophagus.
Aflatoxicosis	Liver: Swollen and discolored initially but later becomes cirrhotic and nodular. May have necrotic foci. Ascites and hydropericardium are frequently present and may have generalized edema. Petechial hemorrhages at various sites and renal swelling may be present. Marked catarrhal enteritis is usually a feature.

4. Protozoan Disease

Coccidiosis	Haemorrhagic pin point spots are seen in various parts of intestines. Caeca may be filled with blood tinged contents. In chronic cases cheesy haemorrhagic cores seen in congested caeca.

5. Nutritional Diseases

Vit. A **Deficiency** (Nutritional roup)	Mucosal surfaces of oesophagus show swollen glands and form vesicles or pustules. Ulcers may be found in mouth having cheesy exudates. In kidneys there may be urate deposits.
Rickets	Long bones become soft and break easily. Well defined knobs are present on inner surface of ribs at the costochondral junction i.e. rachitic rosary, beading of ribs.

6. Metabolic Disorders

Gout	i) **Visceral gout:** Acute form of disease, characterized by deposition of crystals of uric acid in the form of urates in kidneys liver, heart and serosal surfaces. ii) **Articular gout:** Chronic form of disease, lesions observed are urate deposition around joints, ligaments and tendon sheaths.
Ascites Syndrome (AS)	It is a chronic congestive cardiac failure characterized by accumulation of large amount of serum-like fluid in the abdominal cavity with pulmonary edema and hydropericardium
Fatty liver syndrome (FLKS)	FLKS is a metabolic disorder characterized by fatty changes in liver and kidneys. Affected birds show enlarged, yellowish friable liver which may rupture with internal hemorrhage. Abdominal wall and subcutaneous tissues are generally full of fat. Severe fatty infiltration in most of the hepatocytes.