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Duck production in India - A review

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ABSTRACT

In India, the contribution of ducks for egg and meat production is next to chicken. There are many advantages of duck production over chicken. The important available ducks in the country are few exotic breeds and locally available indigenous ducks. Ducks can be reared under intensive, semi-intensive and extensive rearing system. However, in India, ducks are mostly reared in small flock size as subsidiary source of income. The major duck based integrated farming system are duck-fish, duck-rice and duck-rice-fish integrated farming system. Feed is the major factor in livestock and poultry production system as it accounts about 70-75% of the total cost of production. To minimize the cost of production, many locally available alternate or unconventional feed ingredients, viz. azolla, cassava, broken rice are used for feeding of ducks. The constraints of duck farming are mainly the unavailability of suitable germplasm, scarcity in natural feed resources, drying of natural water bodies, difficulty in the availability of vaccines, poor marketing facilities, etc. In India, there is ample scope for duck production to meet egg and meat demand of the country. Suitable duck breeds or varieties need to be developed for rural backyard duck farming. Comprehensive feeding packages along with scientific management practices for different types of ducks should be formulated for economic production of duck eggs and meat. There is a need for establishment of hatcheries and other infrastructures in rural areas to promote duck farming for sustainable livelihood of the people.

Keywords: Duck, Farming, India, Production

India has approximately 1.41 billion human population and stands 2nd in the global rank (Anonymous 2022a). The total population of fowls and ducks in India was 841,405 thousands in 2019, including 807,894 thousands fowls and 33,511 thousands ducks (i.e. only 3.98%). However, as compared to 2012, the duck population has increased more than the fowls population (42.36% vs 16.64%) and the increase in the total fowl and duck population of the country was 17.48% (Anonymous 2019). The total egg production in the country in 2018-19 was 103.32 billion and has increased by 8.5% than the previous year (2017-18). However, only 1.15% of the total egg production of the country was contributed by ducks including 0.89% by Desi ducks and 0.26% by improved ducks; and the major chunk (98.85%) of the total egg production was from fowls including 87.33% by improved fowls and 11.52% by desi fowls. As compared to 2017-18, the annual growth rate of egg production in 2018-19 was 8.51%. The total meat production in the country in 2018-19 was 8.11 million tonnes including 4.06 million tonnes (about 50.06%) from poultry. Further, in 2018-19 as compared to 2017-18, the increase in meat production from poultry was more than the total meat production (7.8% vs 6%) of the country (Anonymous 2019). The requirement for egg and poultry meat in India is 180 and 10.8 kg per person per annum, respectively; however, the per capita availability of egg and poultry meat is only 86 and 2.2 kg (Anonymous 2021, 2022b). Although, the average yield of the improved duck per year per layer from both backyard (178.71) and commercial (202.20) is lower than that of the backyard (226.20) and commercial (283.91) improved fowls; the average yield of the Desi duck per year per layer from both backyard (110.97) and commercial (181.12) is higher than that of the backyard (108.99) and commercial (112.22) Desi fowls (Anonymous 2019). Therefore, other alternate species, particularly ducks should be explored for both egg and meat production, to become self-sufficient and for sustainable nutritional security of the country.

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Classification of ducks

The classification of ducks has been well explained by Makram (2016). Ducks are mainly classified into two types, i.e. wild ducks and domesticated ducks. The domestic ducks belong to the Kingdom-Animalia; Phylum-Chordata; Class-Aves; Order-Anseriformes; Family-Anatidae; Sub-Family-Anatinae; Genus-*Anas* and *Cairina*; Species- *A. platyrhynchos* and *C. moschata;* Sub-species- *A. p. domesticus* and *C. m. domesticus.* Almost all varieties of the domestic ducks (*Anas platyrhynchos domesticus*) are descended from the Mallard or wild ducks

(*Anas platyrhynchos*) except the Muscovy duck (*Cairina moschata*). The domesticated ducks are mostly raised for eggs and meat purposes; however they are also kept for show and as pets (Makram 2016). The male and female ducks are known as drake and duck (hen). The drake and duck can be differentiated from external appearance, sound, behaviour, and internal anatomy. The drakes have generally more colourful feathers and bills, prominent curled feather near the tail, softer and harsher quack sound, extended or elongated genital organ and are larger in size. However, the ducks have generally dull feathers and bill colour, absence of curled feather near the tail, distinctive loud quack sound, cone-like genital organ, and are smaller in size.

Duck population and production

The duck population and production in India has been well documented (Anonymous 2019, Naik *et al.* 2022a). The top 10 states with respect to duck population in India are West Bengal (37.87%), Assam (35.95%), Kerala (5.30%), Manipur (5.13%), Jharkhand (5.09%), Tripura (2.55%), Bihar (2.05%), Andhra Pradesh (1.07%), Odisha (1.05%) and Uttar Pradesh (0.65%). In India, the population of ducks in rural areas (95.98%) are more than the urban areas (4.02%). Further, both in rural and urban areas, ducks are mostly kept in backyard (97% and 96.89%, respectively) than in farm (3% and 3.11%, respectively) conditions. The top ten duck egg producing states of India are West Bengal (51.52%), Assam (10.53%), Kerala (9.96%), Andhra Pradesh (6.24%), Bihar (5.61%), Tripura (4.77%), Jharkhand (3.13%), Manipur (2.09%), Andaman and Nicobar Islands (1.42%) and Uttar Pradesh (1.11%). The average egg production in ducks per layer per year is 168.23, which includes 146.05 in Desi ducks and 190.46 in improved ducks (Anonymous 2019). In the eastern plateau region of India, the average flock size was more in Chhattisgarh (11.76) compared to Jharkhand (9.51) and Odisha (9.47); and the average annual egg production per duck in Jharkhand, Odisha and Chhattisgarh was 50-70, 60-80 and 52-111, respectively (Kamal *et al.* 2020a).

Advantages of duck farming

Among the alternate poultry species, the contribution of ducks for egg and meat production is next to chicken. The advantages of duck production over chicken are long production year, large size eggs, early morning egg laying, hardiness to diseases, suitability for integrated farming and different types of rearing system including backyard farming, survivability in moist land, easily tamed, maintenance under minimum input system of management, etc (Meulen and Dikken 2004, Panda *et al.* 2005).

Important duck breeds

In India, the important available ducks are few exotic breeds (Khaki Campbell, White Pekin, Indian Runner, etc.) and locally available indigenous or non-descriptive breeds (Pati, Maithili, Nageswari, Chara, Chemballi, etc.). However, only Pati duck of Assam (Accession Number: INDIA_DUCK_0200_PATI_11001) and Maithili duck of Bihar (Accession Number: INDIA_DUCK_0300_MAITHILI_11002) are registered under ICAR, New Delhi (Anonymous 2022c).

Khaki Campbell ducks: The origin of Khaki Campbell (KC) ducks is United Kingdom. It is mostly kept for egg production. There are three colour varieties of KC ducks i.e. khaki, dark and white. The KC drake is mostly khaki colour with a darker head usually olive green, green bills and dark orange legs and toes; while the KC duck has khaki colour plumage covering the entire body, greenish black bills and brown legs and toes. The body weights of adult KC drake and duck are about 2.2-2.4 kg and 2.0-2.2 kg, respectively and have the annual egg production potential of about 250-340 with egg (off-white colour) weight of about 70 g (Panda *et al.* 2005, Bais *et al.* 2014, Giri *et al.* 2014a, Makram 2016). The mean body weight (BW) at day old, 4th week and 8th week of KC ducks were 37.86-40.13 g, 555.14-685.34 g and 1165.47-1292.97 g, respectively (Padhi *et al.* 2009, Padhi and Sahoo 2012, Padhi 2014, Joshi *et al.* 2015). The age at sexual maturity and age at peak egg production of KC ducks were 167.5-210 days and 180.5-196 days, respectively (Rashid *et al.* 1995, Islam *et al.* 2002). However, Nageswara *et al.* (2005) reported that the age at first egg production, age at 50% egg production and duck day egg production (DDEP) % of KC ducks were 143-150 days, 173-239 days and 53.9-60.7%, respectively. However, Rashid *et al.* (1995) reported 67-92 egg production up to 300 days. In north-eastern India (Assam), the age (days) at sexual maturity for KC was 195-210; and the annual egg production per duck was 120-140 (Islam *et al*. 2002). In West Bengal, the age (days) at first egg production of KC was 172 and the average annual egg production was 193 (Roy *et al*. 2017). In Jharkhand, the age (days) at first egg production, annual egg production and egg weight (g) in KC ducks were 151, 126.58 and 61-64, respectively (Jha and Chakrabarti 2017). In Bihar, the age at first egg production (days), average annual egg production % (up to 40 weeks of age), egg weight (g), egg colour and hatchability % (total egg set basis) in KC ducks were 178.92, 32.05, 54.71, creamy white and 60, respectively (Kamal *et al*. 2020b). In KC ducks, feed conversion ratio (unit weight gain per unit of feed consumed) of 2.38-3.24 (0-4 weeks), 5.02-7.79 (4-8 weeks), 5.03 (4-8 weeks), 4.54-4.93 (5-8 weeks) and 3.60-4.87 (0-8 weeks) had been reported by the earlier workers (Padhi *et al.* 2009, Joshi *et al.* 2014). However, in layers, the feed conversion ratio (feed consumed in kg per kg egg mass) was 3.41-5.52 (Das *et al.* 2003, Nageswara *et al.* 2005). In Odisha, the duck day egg production and feed conversion ratio (amount of feed consumed in kg to produce one dozen eggs) of KC ducks were 74.44-76.25% and 1.987-2.038, respectively (Swain *et al.* 2020).

White Pekin ducks: The origin of White Pekin duck (WP) is China. However, now it is the most popular duck breed in United States and is also known as Pekin or American Pekin or Long Island duck. It is mainly used for meat purpose; however, they are also used for egg and fancy purposes.

The WP ducks have upright carriage with little bit nervous temperament. They have creamy white plumage, orange yellow bills, reddish yellow or bright orange shanks and feet, yellow skin, dark blue eyes and bulky cheeks. The adult body weight of WP drake and duck can attain about 4.0 kg and 3.5 kg, respectively. They have potential to reach about 2.84-3.40 kg BW in 8 weeks and annual egg production (first year) of about 160-200 eggs with large sized tinted white eggs (Panda *et al.* 2005, Bais *et al.* 2014, Giri *et al.* 2014a, Makram 2016). However, earlier researchers (Padhi and Sahoo 2012, Padhi 2014) have reported body weight of WP ducks as 859.98 g and 2462.05 g at 4th week and 8th week, respectively; and higher body weight gain (g) between 4-6 weeks (979.04) than 2-4 weeks (570.37) and 6-8 weeks (623.03). In Odisha, body weight (g) was 894.23-1115.68, 1549.47-1833.27 and 2155.02-2248.04 at 4th week, 6th week and 8th week, respectively in WP ducks; and the body weight gain between 2-4, 4-6 and 6-8 weeks was 610.35-795.53, 643.23-736.44 and 334.17-653.46, respectively. The feed conversion ratio (feed consumed in kg per kg body weight gain) in WP ducks up to 4th week, 6th week and 8th week was 2.26-2.54, 2.58-2.70 and 2.75-3.25, respectively (Naik 2022). The duck day egg production (DDEP) % in WP ducks during early phase (23-40 weeks), mid phase (41-52 weeks) and second year (53-72 weeks) of laying was 65.11-72.63, 55.00-64.44 and 49.57-50.00, respectively; and the feed conversion ratio (feed consumed in kg per dozen egg produced) was 2.62-2.79, 2.93-3.31 and 4.13-4.32, respectively, under intensive rearing system (Naik 2022, Naik *et al*. 2022b). In Odisha, the duck day egg production and feed conversion ratio (amount of feed consumed in kg to produce one dozen eggs) of WP ducks was 38.85-56.91% and 4.277-6.362, respectively (Swain *et al.* 2018).

Indian Runner ducks: The origin of Indian Runner is Indonesia and Malaysia. These are egg type of ducks. Indian Runner ducks are also known as Penguin ducks or Baly soldiers; as they stand erect like penguins (resemble penguins) and run rather than waddling. There are three varieties of Indian Runner, i.e. fawn and white, white and pencilled. The fawn and white variety of Indian Runner is fawn or grey or white colour with a white neck and a lines of white strips running up to the eyes and extending around the bill. The back, shoulders and the upper part of the breast and wings are fawn, but the lower part is white with orange red shanks and toes. The bill of the young drake and duck is yellow (later becomes greenish yellow) and yellow spotted with green (later becomes dull green), respectively. The white variety of Indian Runner is white with yellow bill and orange shanks and toes. In the pencilled variety of Indian Runner, the head of the drake and duck is dull bronze green and white and medium fawn and white (with white markings in plumage resembling the drake), respectively. In drake, the back has a soft fawn ground, finely stippled with a slightly darker shade of fawn; with medium fawn body and upper part of the breast; and dull bronze green tail. In duck, there are medium fawn coloured markings (throughout), with a light line of fawn colour running round the edge of each feather and darker shade border. The adult Indian Runner drakes and ducks can attain body weight of 1.6-2.2 kg and 1.4-2.0 kg, respectively; and has the potential to produce about 200-300 eggs per year with white egg colour (Panda *et al.* 2005, Bais *et al.* 2014, Giri *et al.* 2014a, Makram 2016).

Pati ducks: The home tract of Pati duck is Assam. It is reared for meat, egg and ritual sacrifices in backyard production system in rural areas. They have squat body posture. The drakes have dark brown plumage with greyish black head, and black and white feathered tail; while the ducks are solid brown. A white ring may or may not be present at the neck in both drakes and ducks. The bill, shank and feet are predominantly yellow. The adult body weight of drake and duck is about 1912 g and 1800 g, respectively, with average body weight of about 1580 g. The age at sexual maturity, egg production per annum and egg weight is about 220-240 days, 75-90 and 60.5 g, respectively (Rithamber *et al.* 1986, Mahanta *et al.* 2001, Islam *et al.* 2002, Anonymous 2022c, 2022d). In north-eastern India (Assam), the age (days) at sexual maturity of Pati was 225-240; and the annual egg production per duck was 80-90, respectively (Islam *et al*. 2002).

Maithili ducks: Maithili ducks are mostly found in Motihari, Sitamarhi, Madhubani, Araria, Kishanganj and Katihar districts of Bihar. They have uniform light or dark brown feathers covering the entire body with circular spots on the feathers in mosaic pattern. The drakes are dark brown to ash in colour. The head of the drake and duck is bright black to greenish black and brown, respectively. The body carriage is slightly upright and bill shape is horizontal. The body weight ranges from 1.12 to 1.24 kg with an average of 1.18 kg at 6 months of age. The age (days) at first egg production ranges from 159 to 223 with an average of 191.12. The annual egg production of Maithili ducks ranges from 33-71 with an average of 54.6; with egg weight of about 49.53 g (Anonymous 2022e). The age (days) at first egg production, average annual egg production % (up to 40 weeks of age), egg weight (g), egg colour and hatchability % (total egg set basis) were 191.12, 21.46, 56.76, white and 58, respectively (Kamal *et al*. 2020b).

Nageswari ducks: Nageswari ducks are distributed in the Barak Valley basin areas of India. They are locally called as Nagi or White Breasted Nagi. Nageswari ducks are mostly egg type ducks. In north-eastern India (Assam), the age (days) at sexual maturity of Nageswari was 180-195 while the annual egg production per duck was 140-150 (Islam *et al*. 2002). Sharma *et al.* (2002) reported that the eggs of Nageswari ducks of Assam are large sized (62.45 g), thick shelled and of good quality with appealing greenish blue colour. In Bangladesh, the 9th week body weight, the age at first egg production, hen day egg production and annual egg production per duck of Nageswari ducks were 1076.11 g, 130 days, 55.67% and 204.23, respectively (Bhuiyan *et al.* 2017).

Kuttanad ducks: The morphological characteristics of Kuttanad ducks have been studied by Harikrishnan and Ponnuvel (2012). The Kuttanad ducks have specific physical characters, having grey, brown, bronze, white, black colours and spots. Generally, the ducks are known as Chara and Chemballi, Thoovella, Pulli, Pandi, depending upon the colours and spots. These ducks require less management, have high adaptability and are suitable for nomadic duck farming. Kuttanad ducks attain more than 2.2 kg at 8 weeks of age and the age at first egg laying is about 129 days. They lay an average of 200 eggs per annum with average egg weight of 70 g (Harikrishnan and Ponnuvel 2012, Anonymous 2022f). In Kerala, under Aroor system of duck rearing (i.e. rearing of Chara and Chemballi in Aroor region of Kerala in semi-intensive system), the regular laying starts at the age of 300 days and the production declines after 2-3 years of regular laying; further, on an average, 50% of birds lay eggs everyday and the maximum production recorded was 85% (Abraham and Ravindran 2009). In Assam, the average age at first egg laying of Chara and Chambelli ducks reared in backyard system was 154.57 days and the annual egg production and egg weight was 169.33 and 64.36 g, respectively (Bharali *et al.* 2020).

Indigenous ducks of Tamil Nadu: The indigenous ducks of Tamil Nadu mostly include Kollam, Arni, Sanyasi, and Keeri and there are wide phenotypic variations between them. In Tamil Nadu, most of the farmers prefer to maintain indigenous ducks as they are hardy, produce large size eggs and require minimum input management system. They lay up to 160-200 eggs per annum; but, the egg production is highly irregular. The duck housed egg production and duck day egg production is about 13.78-50.94% and 25.37-54.40%, respectively. The egg weight ranged from 49.50 g (24 weeks) to 69.95 g (72 weeks) with average egg weight of about 60-64 g (Gajendran and Karthickeyan 2009, 2011; Veeramani *et al.* 2014).

Indigenous ducks of Odisha: The indigenous ducks of Odisha have been well reviewed by Padhi (2014). The 4th week and 8th week body weight of Desi ducks of Odisha were 627.29 g and 1032.64-1120.15 g, respectively (Padhi *et al.* 2009, Padhi and Sahoo 2012, Padhi 2014). The egg production of the Desi (Kuzi) ducks of Odisha up to 40, 60, 72 and 80 weeks of age was 110.79, 181.62, 217.68 and 239.22, respectively (Padhi *et al*. 2021).

Local ducks of Andaman: Andaman local ducks are medium sized ducks with features of comparatively longer neck, yellowish bill with black tip, black skin, white band around neck and shorter shank as compared to the indigenous ducks (Sujatha *et al.* 2021a). The adult weight, age at sexual maturity, body weight at sexual maturity and annual egg production of local ducks of Andaman are 1100-1500 g, 183, 1257 g and 110, respectively (Senani *et al.* 2005).

Other ducks: In north-eastern India (Assam), the age (days) at sexual maturity of Rajhanh was 330-365; and the annual egg production per duck was 20-25, respectively (Islam *et al*. 2002). The adult male and female of Kashmir ducks weighs 1.79 kg and 1.62 kg, respectively (Bihaqi *et al.* 2014). In West Bengal, the age (days) at first egg production of Desi duck was 196; and the average annual egg production was 79 (Roy *et al*. 2017).

Crossbred ducks: The cross-breeding between two exotic pure breeds (KC, WP, etc.) or between exotic pure breed with the locally available non-descriptive Desi (D) breeds is made for the enhancement of the production and reproduction potential of the ducks. The 8th week BW was more in KC × WP (2053.35 g), KC × D (1182.25-1341.04 g) and D × WP (1841.26 g) than the WP × KC (1863.29 g), D × KC (1145.60-1220.87 g) and WP × D (1799.55 g) ducks, respectively (Padhi and Sahoo 2012, Padhi 2014). The age at sexual maturity, age at peak production and egg production up to 300 days were 179-187.5 days, 196.5-206.5 days and 110-166 in KC × D crossbred ducks (Rashid *et al.* 1995). The age at first egg production; 50% egg production; and duck day egg production in KC × D (131 days, 175 days and 61.9%) and D × KC (133 days, 179 days and 62.9%) crossbred ducks had been reported by the earlier workers (Nageswara *et al.* 2005).

Muscovy (Moti): The origin of Muscovy is South America or Brazil. It is not a descendant of wild Mallard; and technically is not a duck. It is also known as Barbary duck or quackless duck. Muscovy ducks are also available in India, particularly in the hilly tract of Odisha and Assam. It is a meat type breed and produces excellent quality lean meat having higher proportion of breast meat. Unlike ducks; they make hissing sound; have no sex specific voice; grazing and eating grasses habit; ability to flight; absence of curl feathers in the tail of males; a knob on the head of the drake; partly bare head and face with red rough and carunculated skin, bumpy, exaggerated red facial skin, with a knob on the top of the bill and lumps all over; presence of many red crests or spots around their eyes and above the beak; incubation period of 35 days instead of 28 days (ducks); no development of full feathers until 16 weeks of age instead of 12 weeks (others); long broad body with greater breadth and breast; long and sharp claws and roosters. They need less water and are still wild type. There are mainly two varieties of Muscovy ducks i.e. white variety and dark variety. The white variety has pure white plumage, pale orange or yellow legs and a pinkish fresh coloured beak. The dark variety has got a lustrous blue black broken with some white breast body and back. The wild type plumage of Muscovy is all black, glossy greenish on the back and with large white wing patches. The adult Muscovy drake and duck can attain about 4.5-6.4 kg and 2.2-3.1 kg, respectively. The crossbred of Muscovy drake and mallard ducks results in mule ducks or mulard ducks, which are sterile. On the contrary, the offspring produced from crossing of Mallard drakes with Muscovy ducks are not desirable for meat or egg production (Panda *et al.* 2005, Bais *et al.* 2014, Giri *et al.* 2014a). In north-eastern India (Assam), the age (days) at sexual maturity of Muscovy was 300- 315; and the annual egg production per duck was 50-60 (Islam *et al*. 2002).

Nutrition of ducks

Nutrient requirements: The nutrient requirements of White Pekin ducks have been provided by NRC (1994). Three types of diets has been suggested by NRC (1994) for White Pekin ducks, i.e. from 0-2 weeks (22% CP, 2900 kcal MEn/ kg), 2-7 weeks (16% CP, 3000 kcal MEn/ kg) and breeding (15% CP, 2900 kcal MEn/kg). Besides, the requirements for amino acids (arginine, isoleucine, leucine, lysine, methionine, methionine+cystine, tryptophan, and valine); macro-minerals (calcium, chloride, magnesium, nonphytate phosphorous and sodium); trace minerals (manganese, selenium and zinc); fat soluble vitamins (A, D_3, E and K) and water soluble vitamins (niacin, pantothenic acid, pyridoxine and riboflavin) have been provided.

However, five types of practical levels of nutrients and diets have been suggested by Singh and Panda (1996) for ducks i.e. starter (0-2 weeks), grower (3-8 weeks), grower (9-20 weeks), layer and breeder, separately. The suggested practical levels of different nutrients in feed for ducks are energy, protein, amino acids (arginine, glycine and/ or serine, histidine, isoleucine, leucine, lysine, methionine, methionine + cystine, phenyl alanine, phenyl alanine + tyrosine, threonine, tryptophan and valine), minerals (calcium, phosphrous, sodium, copper, iodine, iron, manganese and zinc) and vitamins (biotin, choline, folic acid, niacin, pantothenic acid, pyridoxine, riboflavin, thiamine, vitamin A, vitamin B_{12}, vitamin D, vitamin E and vitamin K). The suggested practical level of amino acids in feed for duck has been provided as percentage protein and percentage diet. Like chickens, the feed intake of ducks is related to the dietary metabolisable energy levels. Adeola (2006) reviewed research on duck nutrient utilization and suggested that there is need for more research to be done in the areas of amino acid nutrition in ducks and the evaluation of non-traditional feedstuffs. The role of vitamin E and Se in egg production, fertility and hatchability of native ducks has been studied and reported that dietary supplementation of vitamin E and selenium to the laying native ducks is beneficial for egg production, fertility and hatchability (Giri *et al.* 2012). Biyatmoko (2014) reported that the measurement of real needs of the protein in Alabio duck is 19%, while the metabolic energy requirement is 2650 kcal/kg. Joshi *et al.* (2015) studied effects of feeding different levels (18%, 20% and 22%) of proteins on the performance in Khaki Campbell ducks during starter stage and concluded that increase in the supplementation of protein in the Khaki Campbell ducks during the starter period significantly impact the health and productive traits of the birds and thereby the overall economic status of the farm. In duck feed, 16% CP is beneficial for Khaki Campbell ducks during growing stage for better reproductive organ growth as well as for early sexual maturity (Giri *et al*. 2015).

Feeds and feeding: Feed is the major factor in livestock and poultry production system as it accounts for 70-75% of the total cost of production. Like poultry, commercial duck feed is not available in most parts of the country; however, feeds can be prepared at home for ducks depending upon their physiological stages and level of production. A standard duck feed contain cereal, cereal by-products, vegetable proteins, animal proteins, minerals and vitamin supplements. The feeds of ducks can be of two forms, i.e. mash and pelleted. The pelleted diets are utilized more efficiently than the mash form due to reduced wastage and ease of consumption. The pellet size of the starter (0 to 2 weeks) and grower (after 2 weeks) diets are 3.18 mm and 4.76 mm diameter (NRC 1994). Generally, use of maize and groundnut is avoided in duck feed, as they are more prone to aflatoxins and ducks are very sensitive to it. Mishra *et al.* (2021) have concluded that the AFB1 content of juvenile WP ducks should be kept limited to the recommended safe levels (<10 ppb); exceeding a threshold of 200 ppb is sure to cause poor growth and FCR, with adverse blood biochemical changes, high mortality, morbidity and lameness.

To minimize the cost of production, many locally available alternate or unconventional feed ingredients are used for feeding of ducks. Azolla (*Azolla pinnata*) has been considered as a promising suitable feed substitute for backyard duck farming (Swain *et al*. 2022). There was increased hen day egg production (39.94 vs 38.88), 30.43% feed saved over control, increase in Roche fan colour score (7.41 vs 6.22) with the savings in feed cost of ₹ 1 per duck per day, when fresh azolla was supplemented in the feed of backyard ducks at the rate of 200 g per duck per day (Sujatha *et al.* 2013). Similarly, supplementation of fresh azolla @200 g/duck/day by substituting 20% of standard duck layer diet improved the egg production, egg weight, feed conversation ratio, performance efficiency index and shape index with enrichment of yolk colour (Swain *et al.* 2018). Further, feeding of dried azolla at 10% level in the diet of Khaki Campbell laying ducks was also beneficial in terms of improved egg quality and reduction in feed cost with enriched yolk colour without any adverse effect on the production performance (Swain *et al.* 2020). Water soaked cassava tuber meals can replace the maize up to 40% without affecting the growth and production potential of White Pekin ducks (Sahoo *et al.* 2014). The costly feed ingredient like wheat can be completely replaced by low cost broken rice to reduce the cost of production (Naik *et al.* 2020a, 2020b, 2021). Cassava (tuber crops) can be included in the starter feed of WP ducks, replacing wheat up to 50% level without affecting the performance of the ducks (Naik 2022).

The feed intakes of ducks are mainly dependent upon the breed, physiological stages and level of production. Daily feed intake of 110 g per bird has been reported by Nageswara *et al.* (2005) in Desi ducks. The cumulative feed intake (g) per duck during 0-4 weeks, 5-8 weeks and 0-8 weeks was 1650.94-1746.59, 2871.68-3096.34 and 4522.82-4792.75, respectively (Joshi *et al*. 2014). In KC ducks, the feed intake (g) at 1st week, 4th week and 8th week was 16.13-17.21, 99.93-105.56 and 101.21-114.00, respectively (Joshi *et al.* 2015). In WP ducks, the daily feed

intake was 117.61-136.38 g, 137.71-162.59 g and 142.97-160.31 g, at 4th week, 6th week and 8th week, respectively (Naik 2022).

The metabolisability (%) of dry matter, organic matter, crude protein, ether extract, crude fibre, gross energy, and balances (g/d) of nitrogen and energy were 72.99-79.38, 78.50-83.79, 68.20-79.16, 50.76-83.78, 41.57-62.05, 76.24-79.16, 3.76-4.38 and 448.1-530.1, respectively (Sahoo *et al.* 2014, Mohanty *et al.* 2015a, Joshi *et al.* 2015, Naik *et al.* 2021).

Blood biochemical profile

In ducks, the level of glucose (106.05-208.80 mg/dl), total protein (2.71-6.33 g/dl), albumen (1.62-4.01 g/dl), globulin (1.25-4.46 g/dl), albumen: globulin ratio (0.43-0.63), calcium (7.23-19.90 mg/dl), phosphorus (3.37-8.68 mg/dl), triglycerides (294.10-297.70 mg/dl), cholesterol (133.92-244.45 mg/dl), urea (6.09-10.20 mg/dl), uric acid (8.07-8.32 mg/dl), creatinine (0.77-1.05 mg/dl), SGOT (22.57-27.99 µ/l), SGOT (44.16-75.21 units/ml), GOT (76.90-127.43 U/L), SGPT (6.32-8.79 µ/l), SGPT (120.20-325.25 units/ml), alkaline phosphatise (17.52-32.24 KA units/100 ml) and total acid phosphatise (0.85-0.88 KA units/ 100 ml) were reported by the earlier workers (Mahanta *et al.* 1997, Giri *et al.* 2012, Joshi *et al.* 2015, Giri *et al.* 2015, Mohanty *et al.* 2015a, Naik *et al.* 2020b). For Andaman local ducks, the haematological profiles reported were total leucocytes counts (13300.10 $\times 10^6$/L), lymphocytes (8.51×10^9/L), heterophils (7.58×10^9/ L), heterophil/ lymphocyte ratio (0.89), total erythrocytes count (3.31×10^{12}/ L), haemoglobin (13.11 g/dl), PCV (56.78%), MCV (172.29 fl), MCH (59.88 pg) and MCHC (39.46 g/ dl); and the serum biochemical parameters were creatinine (2.4 mg/dl), alanine amino transferase (107.78 IU/l), alkaline phosphatase (52.44 IU/l), aspartate amino transferase (312.22 IU/l), cholesterol (202 mg/dl), HDL (119.22 g/dl), LDL (58.78 g/dl), calcium (13.67 mg/dl), total protein (5.56 g/dl) and albumen (2.21 g/ dl) (Sujatha *et al.* 2021b).

The liver lipid %, protein (g/100 ml), bilirubin (mg/100 ml), uric acid (mg/100 ml) and creatinine (mg/100 ml) in broiler chicken were 10.40, 8.875, 20.00, 9.655 and 0.280, respectively (Verma *et al*. 2012). The mean values of different haematological parameters viz. RBC (10^6/µl), WBC (10^3/µl), lymphocytes (10^3/µl), monocytes (10^3/µl), PLT (10^3/µl), Hb (g/dl), Ht (%), MCV (fl), MCH (pg), MCHC (g/dl) of poultry (broilers and indigenous breeds) were 2.49, 3.55, 80.33, 18.82, 70.83, 11.98, 5.13, 3.21, 36.78, 62.56, 7.69, 11.48, 31.53, 42.21, 126.75, 118.76, 31.71, 32.29, 25.02 and 27.19, respectively (Muneer *et al.* 2021).

Duck eggs

Egg quality: The egg quality parameters include both external and internal egg qualities. The external egg qualities are egg weight and egg shape index. Egg weight of 57.10-76.71 g and egg shape index of 67.85-78.09 had been reported in ducks by the earlier workers (Sharma *et al.* 2002, Nageswara *et al.* 2005, Senani *et al.* 2005, Harikrishnan and Ponnuvel 2012, Bihaqi *et al.* 2014, Mohanty *et al.* 2015b, Naik *et al*. 2020a, Naik *et al.* 2022b). The internal egg quality includes albumen index, yolk index, Haugh unit, % albumen weight, % yolk weight, % shell weight, shell thickness with and without membrane, yolk colour, etc. The albumen index, yolk index, Haugh unit, % albumen weight, % yolk weight, % shell weight, shell thickness (mm) with and without membrane and yolk colour in duck eggs were reported as 0.07-0.86, 0.40-0.76, 69.37-99.16, 51.09-60.88, 30.26-33.97, 8.30-15.03, 0.35-0.53, 0.34-0.44 and 1.60-4.9, respectively by the earlier workers (Sharma *et al.* 2002, Nageswara *et al.* 2005, Senani *et al.* 2005, Bihaqi *et al.* 2014, Harikrishnan and Ponnuvel 2012, Mohanty *et al.* 2015b, Naik *et al*. 2020a, Padhi *et al.* 2021, Naik *et al.* 2022b).

Etuk *et al.* (2012) reported egg weight (70.80-76.35 g), shell% (9.21-9.90 %), egg shell thickness (0.417-0.420 mm), shape index (0.74-0.76), albumen index (5.47-7.44), yolk index (40.60-41.40), albumen yolk ratio (0.133-0.185) and Haugh unit (69.97-7074) in Muscovy ducks reared under different management (semi-intensive, intensive with and without wallow) systems.

Nutritive value of duck eggs: The nutritive value of duck eggs was studied by Jalaludeen and Churchil (2006). It contains 185 calories, 13.8 g total fat, 3.7 g saturated fat, 884 mg cholesterol, 1.5 g carbohydrate, 12.8 g protein, 674 IU vitamin A, 64 mg calcium, 3.8 mg iron and 146 mg sodium. Aziz *et al.* (2012) reported that based on the average cholesterol content per gram of yolk in chicken, ducks and quail eggs (7.65 mg, 10.36 mg and 16.05 mg, respectively); the total cholesterol content is higher in duck eggs (186.46 mg) than chicken eggs (114.75 mg) and quail eggs (48.15 mg). Duck egg contains 9.70-10.50% saturated fatty acids (SFA), 76.51-77.99% unsaturated fatty acids (USFA), 7.66-8.14% polyunsaturated fatty acids (PUFA) (n-6), 4.60-5.10% PUFA (n-3), 1.60-1.72 n-6/n-3, 0.77-0.84 SFA/PUFA (Mohanty *et al.* 2015b).

Comparison of quality and nutritive value of duck and fowl eggs: The composition of eggs from different species of poultry had been documented by Swain (2010). The comparative (duck vs fowl) values for different egg quality and nutritive value parameters are egg weight (70 vs 50, g); albumen (52.5 vs 58.5, %); yolk (35.4 vs 31.9, %); shell (12 vs 12.3, %); water (69.7 vs 73.6, %); organic matter (29.3 vs 25.6, %); protein (13.7 vs 12.8, %); lipids (14.4 vs 11.8, %); carbohydrates (1.2 vs 1.0, %); inorganic matter (1.0 vs 0.8, %); energy (185 vs 149, kcal/100 g); calcium (64 vs 49, mg/100 g); phosphorus (220 vs 178, mg/100 g); iron (3.85 vs 1.44, mg/100 g); sodium (146 vs 126, mg/100 g); selenium (36.4 vs 30.8, µg/100 g); thiamin (0.156 vs 0.062, mg/100 g); riboflavin (0.404 vs 0.508, mg/ 100 g); niacin (0.200 vs 0.073, mg/100 g); pantothenic acid (1.862 vs 1.255, mg/100 g); vitamin B_6 (0.250 vs 0.139, mg/100 g); folate (80 vs 47, µg/100 g); vitamin B_{12} (5.40 vs 1.00, µg/100 g); vitamin A (1328 vs 635, IU/100 g) and

cholesterol (884 vs 423, mg/100 g).

Carcass characteristics and meat quality

The carcass characteristics of ducks had been studied by many researchers (Senani *et al.* 2005, Padhi *et al.* 2009, Mohanty *et al.* 2015a). The live weight during slaughter was 1010-1409 g. The percentage of blood loss, dress yield and evisceration was 2.22-7.15%, 58.48-78.99 and 60.54-67.04, respectively. The percentage of edible carcass and inedible viscera was 77.86-78.99 and 7.38-19.52, respectively. The percentage of giblet (4.37-11.88), neck (6.96-14.24), wings (7.15-16.43), back (14.73-24.22), breast (19.60-22.30), thigh (8.53-15.06), drumstick (8.79-9.23), head (5.15-6.43), skin (11.45-13.62), skin and feather (22.93-25.99), leg (3.0-7.15), gizzard (5.65-5.78), crop (7.15), liver (2.88-4.46), heart (1.49-7.15), intestine (3.30-9.71), feather (5.21-7.97) and shank and feet (2.90-3.06) had been reported by the above workers. The neck, wing, breast, back, leg, skin and breast as percentage of eviscerated weight were 12.91-15.88, 16.74-18.17, 12.10-21.47, 20.28-23.34, 13.47-25.23, 18.90-20.70 and 11.56-22.51, respectively. The cutting loss was 1.07-2.02%. Ali *et al.* (2007) reported that duck breast meat had significantly higher redness but lower lightness value compared to chicken breast. The fatty acids (%) C14:0, C16:0, C16: 1, C18:2, C18:3 were significantly higher, while C18:0 was significantly lower in duck breast compared to chicken. The SFA increased, while USFA and MUSFA decreased only in duck breast during the seven day storage time. In Odisha, the carcass characteristics of WP ducks in 8th week of age were studied (Naik 2022) and observed that the various body parts as percentage of body weight were blood (5.02-6.08), feather (11.65-13.30), head (5.23-5.85), shank (2.69-2.98), heart (0.56-0.67), liver (1.69-1.85), gizzard (2.84-3.20), giblet (5.16-5.45), intestine (3.51-3.92) and eviscerated weight (68.98-70.70). The cut off parts as percentage of eviscerated weight were neck (9.87-10.92), legs (19.89-21.91), breast (25.02-29.11), back (23.11-27.35), wings (13.84-17.08) and processing loss (0.25-1.95).

In broiler chickens, the eviscerated yield (%), and various cut up parts as percentage of eviscerated weight (breast, thigh, drumstick, back, wing, neck, abdominal fat and caecal weight) yields and different organ weights (liver, heart, gizzard, giblets, spleen, bursa of fabricius and thymus) were 63.97-66.97, 27.64-30.85, 16.12-17.77, 15.23-15.86, 17.33-19.27, 7.42-7.69, 4.26-4.53, 1.652-1.934, 0.917-1.044, 3.080-4.000, 0.752-0.853, 2.952-3.426, 7.257-7.920, 0.234-0.293, 0.283-0.337 and 1.689-1.749, respectively (Swain *et al*. 2012a). However, in Vanaraja chickens, the eviscerated yield (%), and various cut up parts as percentage of eviscerated weight (breast, thigh, drumstick, back, wing, neck, abdominal fat and caecal weight) yields and different organ weights (liver, heart, gizzard, spleen and thymus) were 63.9-66.3, 20.90-22.40, 15.23-16.03, 14.87-16.43, 20.60-22.40, 8.83-9.50, 4.00-5.07, 1.676-2.047, 1.563-1.963, 2.93-3.10, 0.787-0.834, 2.73-3.50, 0.261-0.278 and 0.628-0.830, respectively (Swain *et al*. 2012b).

Duck rearing systems

Ducks can be reared under intensive, semi-intensive and extensive rearing system. Under intensive rearing system, ducks are kept in closed house with or without provision of water channels. They are not allowed to scavenge outside. Provision for feed and water are made inside the closed house. They are mostly kept in deep litter system, in which paddy husk or chapped straw are used as bedding material. Under semi-intensive rearing system, the birds are kept in the house and are provided with some locally available or homemade supplementary feed besides allowing them to scavenge outside during day time. This semi-intensive rearing system is mostly practiced by the farmers. Under extensive rearing system, ducks are only provided with night shelter and are completely allowed to scavenge outside.

Rashid *et al.* (1995) reported that under rural condition, there was improvement in the performance of ducks with supplementary feeding than without supplementary feeding w.r.t. age at sexual maturity (179.1 vs 192.8 days); age at 50% egg production (191.1 vs 203.5 days); age at peak egg production (195.0 vs 209.3 days); and egg production up to 300 days (109.37 vs 72.67); body weight at sexual maturity (1548.3 vs 1421.6 g); body weight at peak egg production (1675.0 vs 1530.8 g); body weight at 465 days (2450.0 vs 2188 g/duck); hatchability % on total eggs (63.33 vs 61.00) and mortality % up to 465 days (7.33 vs 11.33). The duck day egg production (DDEP) %, feed intake (g/b/d) and feed intake (kg)/ kg eggs were lower in the extensive (53.3, 75 and 2.17) management system than the semi-intensive (59.3, 127 and 3.34) and intensive (60.0, 128 and 3.39) management system (Nageswara *et al.* 2005). Under extensive system of management in tribal districts of Odisha, both Khaki Campbell and native ducks performed well (Giri *et al.* 2014b). The socio-economic background of duck owners and status of duck rearing in different parts of the country had been reported by many researchers (Islam *et al.* 2002, Halder *et al.* 2007, Biswas *et al.* 2017, Sasikala *et al.* 2020). The duck farmers mostly belong to very poor, small or marginal income group and the ducks are reared as subsidiary source of income. They generally keep small flock size comprising of 6-200 ducks maintaining sex ratio 1: 5. The hatching of duck egg is made by broody ducks or hens. The ducks are mostly reared under semi-intensive rearing system. They are mostly fed home-made feed or supplementary feed in form of crushed snails, rice paste and kitchen refusals, etc. Some farmers also prefer to rear ducks under integrated duck-fish farming system.

Duck based integrated farming systems

In the integrated farming system (IFS), the different individual farming system complement each other for better production and more profit. The various duck based integrated farming systems are duck-fish, duck-rice,

duck-rice-fish, etc. (Jalaludeen and Churchil 2020). The percentages of N, P, K and C in duck droppings were 1.0, 1.4, 0.62 and 26.2, respectively (Paria *et al.* 2011). In duck-fish IFS, fish utilizes the spilled over duck feed and their droppings which save the need for pond fertilization and fish feeding; ducks keep aquatic plants in check; the cost on duck feeding is partially reduced as ducks forage in the pond; ducks loosen the pond bottom which increases the pond productivity; ducks uniformly distribute their droppings throughout the pond, which is in fact labour saving device; no additional space is required for duck rearing; fish, eggs and meat are produced in a single unit area and it ensures higher profit with fewer inputs (Subramanian *et al.* 1996). In duck-fish IFS, there was 61-70% egg production and 10.10-10.70 kg fish production per duck and there was no effect of different breeds of ducks (Indian Runner, Zending and Khaki Campbell) on the total income from egg, fish, spent duck and net profit per duck (Das *et al.* 2003). In duck-rice IFS, duck droppings are used as manure for rice and as a result no or less fertilizer is used; ducks perform inter-tillage as they search for food with their bills; they are good exterminators of beetles, grasshoppers, snails, slugs, mosquito pupae and larvae; and thus no or less pesticide are used; they are released on paddy fields after harvest to feed on leftover rice grains and in this process enhance soil fertility through their droppings (Akbar *et al.* 2014). In duck-rice-fish IFS, fishes also performed as biological pest control agents and the duck droppings are also used as natural feed for fishes, as a result no or less fertilizer or pesticide are required. Islam *et al.* (2004) evaluated duck-rice-fish IFS and concluded that the growth performances of three fish species (Rohu, Catla, Mirror carp) were better, the egg productions of the ducks were 61% and the ducks met up a portion of their feed requirement by grazing.

Constraints of ducks farming

The decreasing importance of duck farming is mainly due to unavailability of suitable germplasm, scarce in scavenging areas and natural feed resources, drying of natural water bodies, excessive use of chemicals in crop fields, unavailability of vaccines, poor marketing facilities, etc.

Future research

The future research must focus on breeding strategies to be developed for higher growth rate and egg production; to develop nutrient requirements for different types of ducks; need to explore and evaluate locally available feed ingredients and alternate feed resources to minimise the feed cost; different types of duck farming systems should be developed; protocols should be developed for prevention and cure of duck diseases; efforts should be made to increase the fertility and hatchability for easy supply of germplasms to the farmers; and duck based products should be developed through post-harvest technology.

Conclusion

In India, there is ample scope for duck production to meet the demand of egg and meat of the country. The research carried out on ducks is very limited and more attention should be given on various aspects of duck research. Suitable duck breeds or varieties need to be developed for rural backyard duck farming. Comprehensive feeding packages for different types of ducks should be formulated for economic production of ducks eggs and meat. Scientific management practices should be evolved for reduction in labour input and clean egg and meat production. There is a need for establishment of hatcheries and other infrastructures to promote duck farming at rural level for sustainable livelihood of the people.

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