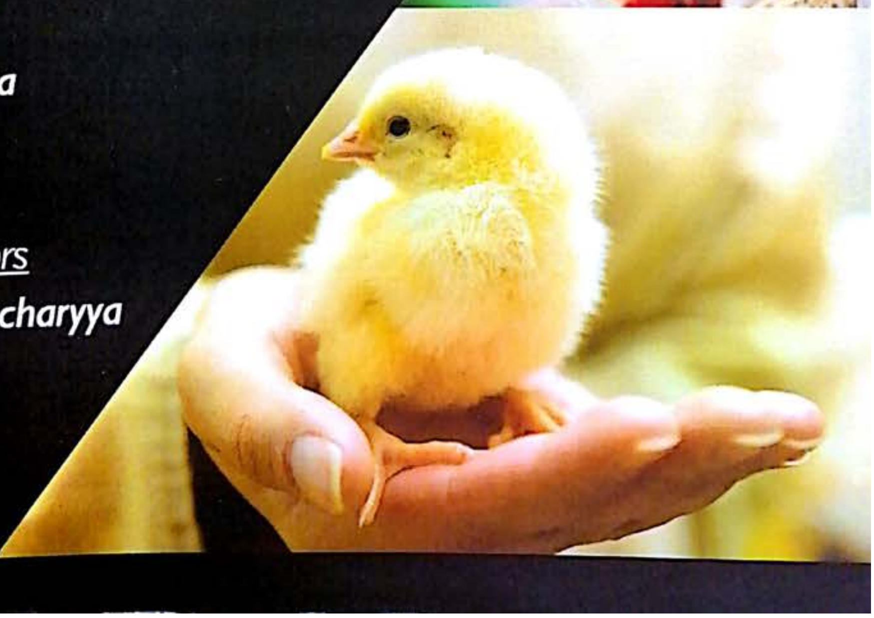
Recent Trends in Sustainable Poultry Production



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SATISH SERIAL PUBLISHING HOUSE
403, Express Tower, Commercial Complex
Azadpur, Delhi-110033 (India)
Phone : 011-27672852, Fax : 91-11-27672046
e-mail : info@satishserial.com, hkjain1975@yahoo.com
Website : www.satishserial.com

Published by :

SATISH SERIAL PUBLISHING HOUSE

403, Express Tower, Commercial Complex, Azadpur, Delhi-110033 (INDIA)
Phone : 011-47073040 Fax : 91-11-27672046
E-mail : info@satishserial.com, hkjain1975@yahoo.com

ISBN : 978-93-95700-03-0
E-ISBN : 978-93-95700-02-3

Composed, Designed & Printed in India

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Chapter 12

Alternate Feed Resources for Sustainable Poultry Production

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Introduction

There is need to improve the scientific knowledge for utilizing low cost locally available agro-industrial by-products in poultry feed in order to reduce the feed cost. As feed constitutes 60-70% of the total cost of production, any attempt to reduce the feed cost may lead to a significant reduction in the total cost of production. Poultry being the monogastric animal lack fibre degrading enzyme for breakdown of complex carbohydrates like cellulose, hemicellulose and lignin. Since, the complex carbohydrate is a major component of fibrous by-products like cashew apple waste, brewery waste, rice bran, wheat bran and sunflower cake, etc. there is need to find ways and means for improvement in the utilization of these fibrous materials so as to incorporate these materials in the poultry feed without any adverse effect on their health and production. There is an opportunity to utilize locally available by-products as alternate feed resources for economic production of broilers, backyard poultry, japanese quails and ducks. Hence, it was felt to evaluate these by-products for economic feeding of poultry to produce more meat and egg. Considering the demand for egg and meat in the coming years, low cost poultry rearing is a boon for marginal farmers and landless poor in the coastal ecosystem. There is ever increasing demand for conventional feed ingredients for feeding of poultry. Incorporation of these feed ingredients in poultry feed has increased the cost of production enormously. Attempts to utilize locally available cheap by-products may benefit the end users in reducing the feed cost which in turn can reduce the total cost of production of meat and egg and making them easily available at cheaper cost in rural India for sustainable production and better livelihood and nutritional security. The traditional sources of vitamins and proteins used in poultry rations, such as fish meal, meat and bone meal, soybean meal, groundnut cake, etc. are becoming expensive in developing countries. The availability of such feed ingredients is not adequate because of the spiraling cost of raw materials and ever increasing competition with the human beings for the same food items. Hence, the search for alternative feed sources has become inevitable to reduce the feed cost.

The chemical composition of agro-industrial by-products i.e. brewers' dried grain, cashew apple waste, cashew nut shell, broken rice and other unconventional feed ingredients like cereals (bajra and ragi), protein sources like sunflower cake, earthworm meal, maggot meal and poultry hatchery waste, and legume green fodder (cowpea leaf meal) , algae like azolla and green leaf sources like moringa leaf meal along with their feeding value in broilers, backyard poultry, japanese quails and ducks are described here in brief for the benefit of students, professionals and ultimately poultry farmers to economize the cost for sustainable production.

Agro-industrial by-products

Brewers' dried grains

Brewer's dried grain is a valuable by-product of brewery which has a potential to be used as supplementary alternate feed resource for livestock and poultry. It is a safe feed when it is used as fresh or properly dried form. These materials are considered to be good sources of un-degradable protein, energy and water-soluble vitamins. They have been used in feeding of both ruminant and monogastric animals (monogastrics using predominantly the dried forms). Brewer's grain is the material that remain after grains have been fermented during the beer making process. These materials can be fed as wet brewer's grains or dried brewer's grains. Brewers' dried grain (BDG) is a by-product of barley malt, corn or rice that is treated to remove most of the readily soluble carbohydrates, protein, fibre, linoleic acid, vitamins and minerals. Some breweries dry the brewer's grain and sell it as dried brewer's grain, while others sell it as wet brewer's grain. Both types have similar feeding characteristics if the wet brewer's grain is fed shortly after it is produced. Fermented local and industrial by-products of brewing have been used as non-conventional feedstuffs in broiler rations (Flores and Ganzalez, 1994) mainly as protein and energy supplements (Samanta and Mandal, 1988). Brewery by-products like brewery waste grains and yeast's are worthy of consideration as potential non-conventional feeds to promote use of locally available feed ingredients. Since the brewers' dried grain is rich in fibre, addition of fibre degrading enzyme may be useful in improving its feed value.

Chemical Composition

Brewery waste after collection from the local breweries has to be sundried before inclusion in the poultry feed. Brewery waste when collected from the brewery contains about 75% moisture which is a major constraint for storing and because of high moisture content, it is not possible to feed poultry as it is and need complete drying without much loss of nutrients. After complete drying, the brewery waste is designated as brewers' dried grain (BDG). The nutritional content of the material may vary from plant to plant and depending upon the type of grain used (barley, wheat, corn, etc.) in the initial brewing process as well as proportions being fermented and fermentative process being used. The range values for different chemical constituents of BDG are given here in Table 1.

Table 1: Chemical composition of Brewers' dried grain.

Chemical Constituents	% Composition
Dry matter	90.10-93.00
Crude protein	11.00-30.89
Ether extract	7.00-11.05
Crude fibre	9.55-20.00
Total ash	3.09-11.04
Acid insoluble ash	1.37-1.96
Calcium	0.28-0.60
Total Phosphorus Lignin	0.43-1.0012-28
Cellulose	12-25
Arabinoxylans	28

Anonymous (2012); Fasuyi, 2005; Ironkwe and Bamgbose, 2012; Isikwenu, 2011; Swain *et al.* (2005a); Mussato and Roberto, 2005;Swain *et al.*, 2012; Lynch *et al.*, 2016

Feeding value

High fibre content in BDG limits its inclusion in poultry rations at higher level. Higher level of BDG in the diet reduces the performance of chickens due to its high fibre content. Brewery waste protein can replace 20% soya protein in the diet of chickens without causing significant differences in the growth and feed intake. The data pertaining to previous studies indicated that brewery waste could be used as a complementary protein source in broiler chicken diets. Studies on the evaluation of BDG in commercial broilers are limited. With enzyme feed supplementation, it can be used at a certain level. BDG with Kemzyme-HF @ 0.75 g/kg diet can be incorporated in broiler ration at a level of 5% for economic production (Swain *et al.*, 2005a). A study in Rhode Island Red chicks indicated that BDG could be incorporated at a level of 20% in RIR chick ration without any adverse effect on their growth and feed efficiency. BDG can be incorporated upto 20% in the diet of Vanaraja chicks for better carcass yield and higher profit margin without affecting the growth performance (Swain *et al.*, 2012). Incorporation of sorghum-barley brewer's spent grain (SBBSG) had no adverse effect on the performance and health of broilers with improved feed conversion efficiency (Nortey *et al.*, 2018).

Cashew apple waste

The cashew is native to northeast Brazil in the 16th Century; Portuguese traders introduced it to Mozambique and coastal India, but only as a soil retainer to stop erosion on the coasts. In India, vast tonnages of cashew apples have largely gone to waste while it pioneered in the utilization and promotion of the nut. Cashew apple (*Anacardium occidentale L*) is a promising feed source, which could be used for dairy cows and monogastric animals to some extent. In 1995, the whole country had 200,000 ha of cashew trees. From this area, about 500,000 tons of cashew apple produced per year. There is commercial interest in processing the fresh apple as a source of sugar-rich juice for human consumption. The waste product from processing, after drying, has been fed to pigs and poultry with promising results. Cashew apple waste (CAW) is available in plenty in the coastal states with an annual production of about 3, 82,000 metric tons. The average weight of fresh apple is about 74.33 grams having dry matter content of 10.22 per cent. CAW is obtained after extraction of fenny which can be used as a cheaper source feed ingredient for poultry by partially replacing costly energy source maize. The waste is usually sundried and ground before incorporation in the feed. Similarly, cashew nut shell is the outer covering of cashew nuts which is not usually used for human consumption but can be used as a cheaper source feed ingredient for poultry.

Chemical Composition

The chemical composition of cashew apple waste (CAW) varies according to the location and species from which the apple wastes are prepared. The range values (%) for the different chemical constituents of CAW and per cent composition of cashew nut shell (CNS) are given below in tabular form (Table 2).

Table 2: Chemical composition of cashew apple waste

Chemical constituent's	% Composition	
	CAW	CNS
Dry matter	18.40-22.50	-
Crude protein	6.45-11.40	5.00
Ether extract	3.35-11.04	11.7
Crude fibre	8.50-11.85	27.3
Total ash	3.51-6.15	1.39
Acid insoluble ash	1.26-1.42	0.20

Lakshmipathi *et al.*, 1990; Sundaram, 1986; Swain *et al.*, 2007a; Swain and Barbuddhe, 2007

Feeding value

Cashew apple waste can be used in layer chick ration by replacing up to 25% maize in their diet without any adverse effect on growth, digestibility of dry matter and retention of protein and fat. However, Cashew apple waste can replace 10% of commercial layer diet by weight basis without any adverse effect on the egg production and egg weight with reduction on the feed cost. Economics analysis revealed that inclusion of CAW at a level of 20% replacing maize reduced the feed cost by Rs. 1.43/- for production of 1 Kg body weight gain of Vanaraja dual purpose bird. It is suggested that inclusion of cashew apple waste in the diet of broilers adversely affected the performance but the carcass traits were similar to the control diet (Swain *et al.*, 2007a). It is suggested from another experiment that CAW could replace upto 20% maize in the diet of Vanaraja chicks without any adverse effect on their performance. Enrichment of CAW was done through biodegradation by *Pleurotus florida* and both untreated and treated CAW (TCAW) was analyzed for the chemical composition. The crude protein and ether extract values were increased from 11 to 17% and 3.65 to 4.10%, whereas the Crude fibre and total ash values were decreased from 10.10 to 7.88% and 13.96 to 9.82%, respectively. The treated CAW replacing maize could not improve the egg production and feed efficiency but the egg weight was improved. Replacing maize with CAW at 5 and 10% level had no significant influence on body weight gain, feed intake and feed efficiency of Japanese quail chicks. CAW and CNS can replace 10 and 5% maize, respectively in Japanese quail layer diet without any adverse effect on their production with reduced cost of egg production (Swain and Barbuddhe, 2007).

Unconventional Alternative Energy Sources

Broken Rice

Rice (*Oryza sativa*) is a staple food of most of the Indian states. Rice is a staple crop in tropical cereal crop is Asia, accounts nearly 90% of the World's total production of 480 million tons). During the milling of rough rice or paddy, several by-products become available and include polished rice (50-60%), broken rice (1-17%), polishings (2-3%), bran (6-8%) and hulls (20%). Broken rice a by-product obtained through milling of rough rice or paddy is a potential unconventional alternate energy source for poultry feeding. Therefore, there is tremendous scope for using broken rice as a substitute for high energy feed ingredient like maize and wheat in chicken and duck feed in order to reduce the feed cost as well as the competition with human beings for conventional energy source i.e. maize and wheat. Another additional advantage is that broken rice is very less associated with aflatoxin which pose threat to the survivability of chicken, duck and other livestock.

Chemical Composition

The chemical composition of broken rice varies as per the sources from where it is collected, processing conditions and storage period. The range values for the chemical constituents of broken rice are given below in tabular form (Table 3).

Table 3: Chemical composition of Broken Rice

Attributes	% Composition
Dry matter	87.90-95.50
Crude protein	7.19-11.41
Ether extract	1.4-1.5
Crude fibre	0.7-2.52
Total ash	0.3-3.30

Rama Rao *et al.*, 2000; Swain *et al.* (2005b; 2006)

Feeding value

The broken rice is comparable to maize in crude protein and energy contents and has been exploited for its feeding value to poultry. Broken rice may be a potential alternative feed ingredient for poultry to substitute maize as an energy source due to its continuous availability and low price. The apparent metabolizable energy (AME) content of broken rice is comparable to that of maize. Broken rice can be used at a level of 15% in the diet of Vanaraja growing chickens in order to reduce the feed cost and economize the cost of production. In Japanese quails chicks, rice kani (broken rice) can replace maize upto a level of 20% in the diet without any adverse effect on their performance with appreciable reduction in the feed cost. Similarly, rice kani (broken rice) can be used at a level of 7.2% by replacing 15% maize in the diet of Japanese quail layers to economize the feed cost without any adverse effect on egg production and efficiency of feed utilization. It is suggested that rice kani could replace 30% of maize in the diet of growing vanaraja chicks for better economics of production in coastal climate (Swain *et al.*, 2005 b). Broken rice can be included at 2.4% level in the diet of Japanese quail layers by substituting 5% maize for better economics of production in terms of better egg production and feed conversion ratio (Swain *et al.*, 2006). Complete replacement of wheat by broken rice had no effect on blood biochemical profile of White Pekin laying ducks during second year of egg production (Naik *et al.*, 2021a). Further, broken rice can replace wheat completely in the diets of white pekin ducks during second year of laying without affecting the metabolizability of various nutrients (Naik *et al.*, 2021b). White pekin ducks can be raised on wheat and/or broken rice based diets under intensive rearing system; however, mixture of wheat and broken in equal ratio increased the performance and was economical during mid-phase of laying (41-52 weeks) (Naik *et al.*, 2022a). Broken rice could replace 100% wheat in the diet of white pekin ducks in the second year of laying without any adverse effect on egg production performance, however, mixture of wheat and broken rice in equal ratio increased the metabolizability of nutrients (Naik *et al.*, 2022b).

Unconventional cereals as alternative energy source

Bajra (*Pennisetum typhoides*) and Ragi (*Eleusine coracana*)

Coarse cereals like bajra ((*Pennisetum typhoides*) and ragi (*Eleusine coracana*) are abundantly available in most parts of India. The demand for maize has increased tremendously for use as human and other industrial use making it less available for animal feed. Millets grossly resemble maize in proximate composition except variation in protein and minerals. Replacement of maize with coarse cereals, reduces feed cost and pressure in use of maize. The chemical composition of Bajra and Ragi is given in Table 4.

Table 4: Chemical composition of Bajra (*Pennisetum typhoides*) and Ragi (*Eleusine coracana*)

Attributes	Bajra (*Pennisetum typhoides*)	Ragi (*Eleusine coracana*)
DM	90.09-91.3	90.54-91.0
CP	8.36-10.89	8.34-8.36
EE	3.86-5.24	1.16-3.38
CF	1.97-2.80	3.28-3.66
Total ash	1.68-6.39	3.16-6.73
Acid insoluble ash	0.19-2.08	0.26-2.73
Calcium	0.020	1.7
Phosphorous	0.031-0.296	0.13-0.25

Ramarao *et al.*, 2004; Amadou *et al.*, 2013

Feeding Value in Poultry

Unground bajra and ragi could replace maize completely in the diet of laying hens without affecting the egg production, egg weight, feed efficiency and other quality parameters in addition to production of stronger shell. ragi could replace upto 50% maize in the diet of laying Gramapriya white chicks without any adverse effect on their body weight gain and feed efficiency. Bajra is a satisfactory feed ingredient for laying hens that can be included in unground form at moderate levels as per the results of research work conducted by earlier workers (Rama Rao *et al.*, 2000). Bajra and jowar can be effective alternatives to maize while ragi in whole form is not suitable for inclusion in broiler diets because the body weight, feed efficiency and dry matter metabolizability in broilers fed bajra and jowar are similar to those fed maize diet, whereas inclusion of ragi in broiler diet adversely affected the body weight and feed efficiency. However, weights of gizzard and length of small intestine are significantly more in ragi fed broilers (Raju *et al.*, 2004). Corn can be completely replaced by bajra (Pearl millet) in broiler diet with improved productive efficiency of broilers without affecting the natural physiological function of broilers (Hatim *et al.*, 2019). Pearl millet can totally replace maize on weight basis without affecting growth, feed efficiency, carcass traits and immunity. Reddy *et al.*, 1991 and Rama Rao *et al.*, 2004). Incorporation of pearl millet at higher level on nutrient basis increased growth and feed efficiency (Sharma *et al.*, 1979; Asha Rajni *et al.*, 1986; Thakur and Prasad, 1992; Prasad *et al.*, 1997; Rama Rao *et al.*, 2004a). The concentration of LDL and cholesterol in serum decreased while abdominal fat and serum triglyceride increased with inclusion of pearl millet in broiler diet (Rama Rao *et al.*, 2001; 2004a). Finger millet can be used at a level of 15% w/w replacing 25% maize in the diet of broilers in the starter (0-4 wk) and finisher (5-7 wk) phases without any adverse effect on their performance (Tyagi *et al.*, 2004).The performance of broilers was reduced with feeding of pearl millet and finger millet with total replacement of maize in the diet. Poor performance of broilers may be due to the low ME content in pearl millet and finger millet (Rama Rao *et al.*, 2004b). Egg production (kgs) and feed efficiency (kg feed/kg eggs) of Gramapriya white laying hens fed bajra and ragi rplacing maize completely were similar to those fed control diet with maize as sole energy source(Swain *et al.*, 2009).

Cowpea leaves

Cowpea (*Vigna unguiculata [L.] Walp.*) is an important grain and fodder legume crop grown in many parts of the world. Cow pea is used at all stages of its growth including as vegetables (Ofori and Stern, 1986). Harvested tender green cow pea leaves constitute an important leafy vegetable often prepared as salad like spinach, lettuce, amaranthus and cabbage for direct consumption. Because of the high nutritional value of tender leaves, it can be expoilted as a part of feed in poultry. Chemical composition of cow pea leaveis given in Table 5.

Table 5: Chemical Composition

Attributes	% Composition
DM	12.00
CP	19.07-22.00
EE	1.24-11
CF	15.02
Total ash	11.72
Acid insoluble ash	0.92

Chander Datt *et al.*, 2009; Mamiro, 2011; Chikwendu *et al.*, 2014; Swain *et al.*, 2018a

Feeding value

Cow pea leaves (fresh) were fed to Vanaraja laying hens at an inclusion level of 75 g and 125g per day, respectively by replacing part of whole standard layer ration. First group was given standard layer ration @ 75g/hen/day and fresh cowpea leaves 75g/hen/day and second group was given standard layer ration @ 62.5 g/hen/day and fresh cow pea leaves @ 125/hen/day. Results indicated that significant ($P<0.05$) reduction in egg production (dozen) was observed in group fed 125g cowpea leaves and pod/hen/day. However, laying hens fed 75g of fresh cowpea leaves and pods/hen/day produced eggs similar to that of control group. This study indicated that fresh cow pea leaves can be fed to Vanaraja laying hens @75g/hen/d for more income generation due to significant reduction in feed cost without affecting the performance (Swain *et al.*, 2018a). Inclusion of cowpea at levels of 10-30 % in broiler diet significantly increased the FCR (Eljack *et al.*, 2010).

Moringa oleifera leaf Meal (MOLM)

Moringa (*Moringa oleifera Lam*) leaf meal is rich in Carotene, ascorbic acid, Vitamin A and B-vitamins, minerals i.e. Ca, Iron, Copper, Sulphur, etc., crude protein and amino acids. It is free of heavy metals such as mercury, arsenic and cadmium. It is a perennial crop and can be harvested throughout the year. *Moringa oleifera* leaf has 7 times more Vitamin C than oranges, 10 times more Vitamin A than Carrots, 17 times more calcium than Milk,9 times more protein than Yoghurt, 15 times more potassium than banana and 25 times more iron than Spinach. Chemical composition of cow pea leaves is given in Table 6.

Table 6: Chemical Composition

Attributes	% Composition
Crude Protein	27.27
Ether Extract	3.76
Crude Fibre	18.53
Total Ash	11.50
Acid insoluble Ash	0.37
Ca	2.003
NFE	38.94

Feeding Value

Dietary supplementation of 5% *Moringa oleifera* leaf meal (MOLM) improves yolk colour and protein absorption without adverse effect on laying performance and egg quality (Wei *et al.*, 2016). Supplementation of MOLM @ 0.50 kg/100 kg diet in Vanaraja laying hens was beneficial in terms of improved egg production, better FCR and reduced cost of production of eggs. Its use in Vanaraja laying hens reduced the feed cost per dozen egg from Rs. 27.98 to Rs. 22.33 (Reduction of Rs. 5.65/dozen egg) (Swain *et al.*, 2017). MOLM can be supplemented at 3% level in diet of Japanese quails for economic growth and production without any adverse effects (Varalaksmi *et al.*, 2021). Inclusion of 5% MOLM in broiler diets improved body weight, FCR, hot and cold eviscerated carcass weight, dressing percentage, breast and drumstick percentages and tenderness and juiciness scores of both breast and thigh meat (El Tazi, 2014). Laying hens with dietary supplementation of 5% MOLM had similar egg production compared to control diet fed hens but with yellow-orange yolk colour without any adverse effect on feed intake, live weight gain and egg weight (Gakuya *et al.*, 2014). Kumar *et al.* (2017) suggested inclusion of 10% MOLM in the ration of Vanaraja backyard poultry for better growth performance, FCR and quality meat with low cholesterol and good fatty acid contents.

Azolla (*Azolla pinnata*)

Nutritive Value of Azolla

Azolla is very rich in proteins, essential amino acids, vitamins (vitamin A, vitamin B12, Beta Carotene), growth promoter intermediaries and minerals including calcium, phosphorus, potassium, ferrous, copper, magnesium. *Azolla* contains 4.70-6.60% dry matter; 20.45-28.54% crude protein; 11.20-15.91% crude fiber; 2.37-4.60% ether extract; 12.30-19.91% total ash; 30.08-47.0% nitrogen free extract; 0.80-2.22% calcium; and 0.35-1.29% total phosphorus (Bacerra *et al.*, 1995; Basak *et al.*, 2002; Parthasarathy *et al.*, 2002; Alalade and Iyayi, 2006; Sujatha *et al.*, 2013; Rathod *et al.*, 2013; Saikia *et al.*, 2014; Acharya *et al.*, 2015; Ashraf *et al.*, 2015; Anitha *et al.*, 2016; Swain *et al.*, 2018 and Shukla *et al.*, 2018). *Azolla* is also rich in iron (283.30–1569 ppm dry weight), copper (7.33–16.74 ppm dry weight) manganese (83.92–2418 ppm dry weight), zinc (46.77-325 ppm dry weight) and carotenes (206-632 ppm dry weight) (Bacerra *et al.*, 1995; Lejune *et al.*, 2000; Alalade and Iyayi, 2006; Mandal *et al.*, 2012; Sujatha *et al.*, 2013; Acharya *et al.*, 2015 and Anitha *et al.*, 2016). Chemical composition of Azolla is given in Table 7.

Table 7: Chemical Composition of Azolla on DM basis

S.No.	Attributes	Range Values (%)
1.	Crude Protein	20.45-28.54
2.	Ether extract	2.37-6.70
3.	Crude fibre	12.60-17.52
4.	Total ash	15.76-19.91
5.	NFE	30.08-47.00
6.	Calcium	0.80-2.22
7.	Total Phosphorus	0.35-1.29
8.	Carotene	206-632 mg/kg

Querubin *et al.*, 1986; Bacerra *et al.*, 1995; Lejune *et al.*, 2000; Srinivas *et al.*, 2012; Sujatha *et al.*, 2013; Rathod *et al.*, 2013; Saikia *et al.*, 2014; Acharya *et al.*, 2015; Ashraf *et al.*, 2015; Swain *et al.*, 2015; Yadav and Chhipa, 2016; Rana *et al.*, 2017; Swain *et al.*, 2018b and Shukla *et al.*, 2018

Feeding Value

Subudhi & Singh (1978) concluded that fresh *Azolla* can replace about 20% of commercial feed in the diet of young chickens that require about 9 kg fresh *Azolla* for 100 chickens daily. White Leghorn female chicks receiving the diet with 5% azolla grew faster than the control group and those given the diet with 12.5% azolla grew slightly slower (Singh and Subudhi, 1978). Ali and Lesson (1995) reported that 10% dried azolla can replace maize and soybean meal on an equal digestible protein basis in broiler diets (1-14 days). *Azolla* at 10-20% level depressed growth and protein efficiency ratio but had no effect on survivability (Parthasarathy *et al.*, 2002). Further, Basak *et al.* (2002) reported that azolla included in the diet of broilers (from 7 to 42 days) at 5% level improved live weight, feed conversion ratio, protein and energy efficiency, dressing percentage and profitability. Chick's diet can be formulated with inclusion of azolla meal (AZM) upto 10% with best performance (Alalade and Iyayi, 2006). Earlier workers (Balaji *et al.*, 2009; 2010) reported that inclusion of 4.5% azolla in the diet of broilers reduced the cholesterol content in serum and meat and did not have any adverse effect on performance. Replacement of soybean meal by dried azolla upto 5% had no deleterious effect on palatability, efficiency of feed utilization, carcass quality of broilers (at 6 weeks of age) and was profitable (Dhumal *et al.*, 2009). Naghshi *et al.* (2014) conducted experiment in Cobb broilers (1-42d) using 0-15% azolla in powder form in corn-soybean meal diet and observed that 5% azolla dietary group had lowest feed intake, highest weight gain and best feed conversion ratio. The carcass efficiency percentage was significantly higher in broilers belonging to azolla dietary group. Lowest feed cost per kg body weight was recorded on 5% azolla group.There is a general consensus that dried azolla in broiler diets should be limited to 5% as higher levels tend to depress nutrient utilization and performance (Parthasarathy *et al.*, 2002; Basak *et al.*, 2002). In pullet chicks, azolla could be included the diet safely upto 10% (Alalade *et al.*, 2007). Fresh azolla could replace 20% or more of a commercial broiler diet (Subudhi and Singh, 1978). Inclusion of dried azolla at a level of 15% in the diet of commercial layers in a 16 week study could not affect the egg production performance of the laying hens (Khatun *et al.*, 2008). Boitai *et al.* (2018) reported that Vanaraja laying hens fed diets incorporated with 10% azolla meal during a period of 8 weeks did not show any adverse effect egg production and egg quality.

Alejar and Aragones (1989) conducted experiment in Mallard ducks by partial replacement (20%) of a rice grain-snail-shrimp diet and observed similar egg production and intensified yolk colour. Fresh azolla can partially replace whole soybeans up to a level of 20% of the total crude protein in diets of fattening ducks based on sugarcane juice, without any problems and with no adverse effect on growth rate or health; cost of feed per kg gain was lowest and net profit per bird highest; however, at levels of replacement higher than the above, rate of growth and feed conversion efficiency were significantly poorer (Bacerra *et al.*, 1995). Liu Xiang *et al.* (1998) supplemented fresh azolla to a formulated feed and observed that duckling (2-8 weeks) fed with azolla had greater growth rates than birds fed the control diet. Sujatha *et al.* (2013) conducted experiment in indigenous layer ducks and observed comparable performance by replacing 0-20% commercial layer feed with 200g fresh azolla per duck per day along with daily saving of approximately Rs. 1/- per duck. Feeding fresh azolla as partial replacement to traditional paddy rice-snail-shrimp (PSS) based diet for laying Mallard and growing Muscovy ducks howed no significant difference among the various dietary treatments containing 0, 20, 30 and 40% azolla replacing corresponding levels of PSS, both for Mallard (egg production) and Muscovy (meat production) in terms of production efficiency (Escobin, 1987). A study conducted by Sujatha *et al.* (2013) revealed that a backyard duck farm having 50 ducks will require about 10 kg of fresh azolla per day (200g fresh azolla/duck) to replace 30 percent of commercial feed. Approximately, Rs. 50/- can be saved on feed cost daily. The eggs in the control group of ducks had a yolk colour score of 6.0 that increased to 7.4 with azolla diet. The pigmenting ability of azolla clearly demonstrated by its high Roche fan colour score which could be due to the presence of high amount of â-carotene pigment in azolla. The change in yolk colour due to azolla supplementation of diet has also been demonstrated by Bastian (1987). Feeding of dried azolla at 10 % level in the diet of Khaki Campbell laying ducks was 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).

High levels of ADF and lignin have been indicated as the main factor limiting the efficient utilization of azolla meal (AZM) by monogastric animals (Bukingham *et al.*, 1978; Tamany *et al.*, 1992; Basak *et al.*, 2002). There are contradictory reports regarding the feed consumption in poultry fed on azolla incorporated diets. Feed intake was significantly affected in chicks fed on 10 and 15% AZM diets (Cambel, 1984 and Bhuyan *et al.*, 1998). Castillo (1983) and Basak *et al* (2002) observed that inclusion of AZM in broiler diet did not affect feed consumption. However, Bacerra *et al.* (1995) explained the decrease in dry matter intake as the inability of the birds to eat more of the bulky AZM based diets. The feed consumption was considerably low in laying ducks (153 g/duck) with azolla supplementation (200g fresh azolla/duck/day) as against control group (219 g/duck) (Sujatha *et al.*, 2013).

Unconventional alternative protein sources

Protein is the main limiting factor and the second most expensive feed component of poultry ration after energy. In developing countries, poultry feed prices are consistently increasing because of the dependency on imported soybean meal. In order to decrease the dependency on soybean meal, it is essential to find sustainable alternative protein sources like sunflower oil cake, earthworm meal, poultry hatchery waste, etc. to reduce the feed cost without compromising the production performance of poultry.

Sunflower oilcake

It is the residual cake remain after the expression of oil from sunflower seed and used chiefly as a livestock feed. It is a concentrated feed rich in protein and fats. In amino acid content and biochemical value oil cake, proteins are superior to those of cereals; they contain more lysine, methionine, cystine, and tryptophan. The calcium and phosphorus contents are also higher. Like cereal feeds, oil cakes are poor in carotene but rich in vitamins of the B complex. Sunflower oil cake (SOC) is deficient in amino acid lysine but rich sulphur containing amino acid methionine. The chemical composition of SOC is given in Table 8.

Table 8: Proximate Composition

Chemical Constituents	% Composition
Dry matter	98.60
Crude protein	26.95-49.1
Ether extract	0.39-12
Crude fibre	11.6-23.89
Total ash	6.54
Acid insoluble ash	1.2

Shrivastav,1977; Singh and Prasad, 1979; Panda *et al.*,1981; Srivastav and Johri, 2002; 2005.

Feeding Value

Sunflower oil cake can be incorporated in a high fibre diet at a level of 10% replacing soybean meal with supplementation of kemzyme at a level of 1.5g/kg diet without any adverse effect on feed efficiency with significant reduction in serum cholesterol level (Swain *et al.*, 1996). Sunflower cake could be incorporated at a level of 6.4 per cent in the diet of laying hens by replacing 20% soybean meal on iso-nitrogenous basis for better egg production, feed efficiency and economics of production without affecting the overall performance. White leghorn can be fed sunflower seed meal (SSM) upto 18.7% without any adverse effect on egg production, egg weight and feed efficiency (Shrivastav, 1977). Sunflower cake can be supplemented in the broiler starter and finisher diets at a level of 28% and 20%, respectively without any marked change in body weight gain, feed intake and feed efficiency (Paradis *et al.*, 2002). Solvent extracted and expeller processed SSM can be used up to a level of 15% and 7.5%, respectively for supporting higher weight gain, better feed efficiency and protein utilization in broiler quails (Shrivastav and Johri, 2002). Expeller processed and solvent extracted SSM can be incorporated in laying quail diets upto a level of 22.5% replacing soybean meal protein without any undesirable effect on egg production and egg quality characteristics. Further, the serum cholesterol concentration decreased proportionately with increase in the level of SSM in the diet of laying quails (Shrivastav and Johri, 2005). Combination of GNC and Sunflower cake can replace 20% soybean meal protein in the diet of Vanaraja growing chicks for better performance, immunity and lower cost of production (Swain *et al.*, 2007b). Deoiled sunflower oil cake can replace 50% groundnut cake (GNC) in the diet of broiler chickens with significant improvement in body weight gain and FCR. The cost of production per kg meat was reduced from Rs. 27.43 to Rs. 24.29 due to inclusion of sunflower cake in the diet (Dangi *et al.*, 2011). Sunflower oil cake can be included in the broiler chicken diet upto 10 % without any adverse effect on the performance (Berwanger *et al.*, 2017). Sunflower oil cake can replace soybean meal at 20% level in an isonitrogenous diet for better egg production with cheaper cost of egg production (Swain *et al.*, 2008).

Earthworm meal

Earthworm meal consists of processed worms reared for vermicomposting. The protein rich earthworms are by-products of vermicomposting. The earthworms are thoroughly rinsed in water in a bowl and killed in putting them in warm water for 3-5 minutes. Then they are oven dried at 80°C for overnight in hot air oven. After drying the earthworms are milled with hammer mill or ground in laboratory grinder into powder and packed in air tight containers and stored below 20°C for further use as poultry feed. The chemical composition of earthworm meal is given in Table 9.

Table 9: Chemical composition of earthworm meal

Chemical Constituents	% Composition
Crude protein	51-70
Ether extract	7.76-10.00
Crude fibre	0.90-8.06
Total ash	14.00-19.74
Calcium	0.53-5.03
Total Phosphorus	0.14-1.21
ME (Kcal/Kg)	3530

Mekada *et al.*, 1979; Ignacio *et al.*, 1993; Ghatnekar *et al.*, 1995; Bernard *et al.*, 1997; Sogbesan and Ugwumba, 2008; Rezaeipour *et al.*, 2014; Gunya *et al.*, 2019;

Feeding value

Earthworm meal produced from species *Eisenia foetida* can be used at a level of 10% in the diet of broilers with better body weight gain without deleterious effect on carcass characteristics and meat quality attributes (Gunya *et al.*, 2019). Earthworm (*Eisenia foetida)* had no anti-nutritional factors which declines growth performance which is equal to the growth performance obtained in those fed fish meal diet in broilers (Reinecke *et al.*, 1991). Supplementation of 0.4% earthworm meal to broiler ration improved feed consumption, live weight and digestibility of nutrients (Son and Joe, 2013). In Japanese quails, 10% earthworm meal can be used replacing fish meal with improvement in body weight gain and feed conversion ratio (Prayogi, 2011).

Housefly maggot meal

House fly larvae grown on poultry litter can be used with great benefit as a potential alternate protein source in poultry (Pretorius, 2011). Sometimes fly-attractant like animal offal and rotton fruit can be used to support pupae and larvae production (Odesanya *et al.*, 2011). A moisture range of 60-70% and temperature range of 25-30°C are suitable for larvae development (Miller *et al.*, 1974). Chemical composition of housefly maggot meal is given in Table 10.

Table 10: Chemical Composition of Housefly maggot meal (on DM basis)

Chemical Constituents	% Composition
Moisture	5.22-8.66
Crude protein	39.16-63.99
Ether extract	9.0-26.0
Crude fibre	1.6-8.60
Total ash	5.16-17.3
Calcium	2.01-8.0
Total Phosphorous	1.32-24.0
ME (Kcal/kg)	3393.8-4278

Atteh and Ologbenia, 1993; Zuidhof *et al.*, 2003; Aniebo *et al.*, 2008; Hwangbo *et al.*, 2009; Aneibo and Owen, 2010; Adewolu *et al.*, 2010; Pretorius, 2011; Adesina *et al.*, 2011

Feeding Value

Live maggots can be a valuable supplement to the diet of rural poultry. In Ghana, the supplementation of 30-50g/day/bird of live maggots to scavenging backyard chicken resulted in higher growth rate, higher clutch size, egg weight, number of eggs hatched and chick weight (Dankwa *et al.*, 2002). Feeding diet containing 10 or 15% maggot meal to broilers significantly increases the body weight, protein digestibility, lysine and tryptophan content of breast muscle, profitability and reduces the cost of production(Hwangbo *et al.*, 2009). Maggot meal can replace 75% of soybean meal in the diet of laying hens without any adverse on egg production performance and egg quality (Saha, 2020). Further, it is suggested that maggot meal can be included in the diet of broilers upto a maximum level of 10% replacing fish meal of the diet. Higher rate of inclusion results in lower feed intake performance probably due to darker colour of the meal which is not appealing to broilers (Atteh and Ologbenia, 1993; Bamgbose, 1999). Other reason can be imbalance of amino acids which generally becomes apparent at higher level of inclusion. Methionine supplementation might enhance performance. Maggot meal can replace meat cum meal with increased egg yield and hatchability in a 7 month feeding trial in laying hens (Ernst *et al.*, 1984). Maggot meal can replace 50% fish meal (5% in diet) in 50 weeks old laying hens without any adverse effect on egg production and shell strength. However, 100% replacement had deleterious effect on egg production (Agunbiade *et al.*, 2007).

Poultry hatchery waste

The Poultry hatchery waste (PHW) is the product left over in the poultry hatchery after the hatching process is completed. Poultry hatchery waste is primarily composed of dead chicks, infertile whole eggs and shells from hatched eggs (Hamm and Whitehead, 1982). This material is usually incinerated, rendered, or taken to sanitary landfills and used for composting. Each of these disposal methods has particular regulatory or operational requirements or economic characteristics that may enhance or limit its use within a particular farm. Since, the moisture content of the fresh hatchery waste is high, it makes the disposal and incineration costly to the producer and it may be unsafe environmentally (Vandepopuliere *et al.*, 1977, Miller 1984). Chemical composition of processed poultry hatchery waste is given in Table 11.

Table 11: Chemical composition of processed poultry hatchery waste

Chemical Constituents	% Composition
Crude protein	22.80-44.25
Ether extract	14.40-30.00
Crude fibre	0.90-8.06
Total ash	14.00-40.00
Calcium	7.26-22.60
Total Phosphorus	0.39-0.84

Ilian and Salman, 1986; Khan and Bhatti, 2001; Rasool *et al.*, 1999; Swain *et al.*, 2011; Wisman, 1964; Abiola *et al.*, 2012

Feeding value in Poultry

Results on performance study indicated significant ($P<0.01$) increase in body weight gain due to incorporation of processed hatchery waste at all the levels in the diet of chicks at 7 week of age by replacing fish meal at 0, 25, 50 and 100% levels. Significant ($P<0.01$) improvements in feed conversion ratio (FCR), protein efficiency ratio (PER) and performance index (PI) in chicks were observed due to feeding of PHW at all the levels. Maximum net profit was recorded due to feeding of 8% PHW (Swain *et al.*, 2011).

Conclusion

The agro-industrial by-products like brewery waste, cashew apple waste, cashew nut shell, rice kani (broken rice), alternative cereals like ragi, bajra and green fodder like cowpea leaves, are available in plenty locally. Presently, these by-products are not exploited to full extent for inclusion in the poultry feed. These by-products and fodder leaves have good nutrient composition and reported to contribute to the productive value for egg and meat with reduction in cost of production. Hence, keeping their chemical composition and potential feeding value in consideration, these by-products can be incorporated to some level in the poultry feed formulations to economise the feed cost and to increase the profit margin for the poultry farmers.

References

On request from the authors