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Recent unconventional feedstuffs for economic poultry production in India: A review

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Abstract
Poultry industry is the fastest growing sector in Indian agriculture. Poultry feed accounts-58% of total feed market in India. Current annual growth rate of poultry and agriculture sector are around 8 and 1.8% respectively in the country. Overall growth in human, livestock and poultry populations has outpaced the growth in cereals production leading to severe feed shortages and consequent rise in feed cost. Feed costs are primarily driven by the cost of protein sources. Maize and soybean meal are most commonly used conventional feed ingredients in poultry diets. Maize at the inclusion level of 55%-65% and soybean meal at the inclusion level of 25%-30% based diets mostly fed to poultry. Their cost and availability determines the cost of feed. As there is scarcity of conventional feed ingredients at reasonable price, there is need to utilize locally available alternate feed sources. Use of alternate feed ingredients or unconventional feeds based on their price, availability, incriminating factors and nutritive value. Thus, there is need for identifying, evaluating locally available alternative feed resources and augmenting their feeding values for economical and sustainable poultry production.

Keywords: Poultry, feed, unconventional, cost, incriminating factors

Introduction
Poultry feed accounts 65-75% of total recurring expenditure. Unconventional /Alternative /Non traditional feedstuffs are those which are not normally being used in feeding or commercial diet preparation. These are agricultural/ and industrial products/their by products not commonly used for their diet and are available at competitive lower price in market. They may be classified as energy and protein rich alternate feedstuffs. Cereal grains, grain by products and agro industrial by products are used as energy sources. Energy sources are used at 50-70% in the diet and also contribute to 5% - 30% of the total protein content of the diet. The protein quality of the cereals and agro-industrial by products is poor due to low content of limiting amino acids like lysine and methionine beside low calcium and high phosphorus contents. Although 60% of phosphorus is present in the form of bound phytate salt and which is not available to poultry.

However, the effective combinations (Cereal mixture, protein mixture and protein-cereal mixture) are required to be identified through biological trials. The alternate vegetable feed resources are generally deficient in one or more amino acids. However, the critical amino acids (lysine, methionine and threonine) are available commercially for supplementation to ensure improved utilization of protein and feed. Again, the cost of lysine generally fluctuates based on soybean meal prices, being rich in lysine. Some of the ingredients (sesame meal, maize gluten meal and rapeseed meal) are relatively rich in methionine, thus judicious use of these ingredients along with soybean meal may reduce some amount of methionine supplementation in diet saving national money as large amount of methionine is imported in India.

A. Protein resources
Guar meal (GM)/Cluster bean (*Cyamopsis tetragonoloba*)
Guar meal is a byproduct of guar gum industry. It is very rich source of protein (40-48%), yet its use as a protein supplement has been limited in poultry due to the presence of certain deleterious factors like gum (galactomannans), anti-trypsin factor, and anti-vitamin E factor. It contained CP 42.0%, EE 3.8%, CF 8.9%, ME 2200 kcal/kg, lysine 2.55%, methionine 0.67% and 0.49% tryptophan on an average. Deleterious effects associated with increased intestinal viscosity are more pronounced in younger birds mainly because of gum. Guar korma is can

safely be incorporated up to 7.5% level in poultry diet. Dinani *et al.* (2017) [9] envisaged that incorporation of 7.5% guar meal without enzyme supplementation and 15% guar meal with enzyme supplementation or 15% fermented guar meal proved beneficial.

Azolla meal *(Azolla pinnata)*

Azolla meal contained 24.50% crude protein, 3.70% ether extract, 14.90% crude fiber, 39.90%NFE, 17.00% total ash, 2.14% calcium, 0.44% phosphorus on dry matter basis. Bird fed with 75% level of the regular feed and 12.5% in the form of Azolla, weighed almost equal to the birds fed. The birds receiving normal feed with 5% extra in the form of Azolla, grew faster than the bird fed with 100% feed alone. Incorporation of Azolla meal up to 7.5% level in diet supplementation did not influence the growth performance of growing meat type Japanese quails during 0-5 weeks of age (Rathod *et al.*, 2013; Kumar *et al*., 2018) [14-16]

Cotton seed meal (*Gossypium* sp.)

Inclusion rate of around 5% is normal in commercial practice due in part to gossypol which can be neutralized with soluble iron compounds in the ratio of < 2:1. Studies showed that cotton seed meal (47.5% CP) when formulated on a digestible amino acid basis can be included in broiler diets at up to 200g and 300g/kg in broiler starter and finisher diets without a significant loss in broiler performance (Sajad *et.al.*2015) [26].

Experiments with cottonseed meal in the diets of brown egg and white egg hybrid layers from 18 to 57 weeks of age resulted in excellent production (90%) when cotton seed meal was included at 120g and 200 g/kg and with no effect on inclusion level. A concern was that when eggs were stored at 10ºC for six weeks, yolk discoloration was observed in almost 30% of eggs from hens on diets with 200 g cotton seed meal / kg and much higher than at 120 g/ kg. Also there was a suggestion that there were fishy flavours with a 'prawny' odour from some eggs. This suggests that cotton seed meal should be restricted to 100g/ kg in layer diets (Wani et. al., 2015) [34]. Thirumalaisamy *et al.* (2018) [27] reported that the overall performance based on body weight gain, feed intake and feed efficiency was better in the diet formulated with 4% level of cotton seed meal on total amino acids basis.

Linseed meal (*Linum usitatissimum*)

Linseed meal is the by-product of extracting the seed for oil. The meal contains 350-380 g/kg CP that is low in protein quality, being deficient in lysine. Linseed meal is toxic to poultry except in very small proportions (under 3 percent). The toxicity can largely be eliminated by soaking the meal in water for twenty-four hours or by adding pyridoxine (Vitamin B6) to the diet. Kumar *et al*. (2018) [15, 16] observed that feeding of 10% flaxseed meal to broiler chicken for three weeks duration (2–5 weeks of age) has no adverse effects of the growth performance, carcass characteristics and cost economics of broiler chicken production.

Sesame meal (*Sesame indicum*)

Sesame meal provides an adequate protein source for poultry, (351-470 g/kg CP), but it must be used rapidly to prevent it from becoming rancid and unpalatable. It is also valued as a source of protein in human diets, and so is less frequently used in animal rations. Sesame has similar protein content to that of cottonseed meal and is also high in calcium and phosphorus. It is low in lysine, so must be fortified with soya meal if fed to pigs or poultry. There can be a reduction in the availability of calcium, magnesium, and zinc, because sesame contains 50 g/kg phytic acid.

Maize (*Zea mays*) germ meal

Maize by-products result from both the dry and wet milling of maize. Maize meal, hominy and maize grits are produced by dry milling; the resultant by – products are maize hominy feed, maize bran maize germ cake and maize germ meal. Hominy feed, which contains – 10% CP, is a mixture of maize bran, maize germ, and part of the starchy portion of either white or yellow maize kernels as produced in the manufacture of pearl hominy. Maize germ meal (dry milled) is ground maize germ which consists of maize germ with other parts of the maize kernel from which part of the oil has been removed. Wet milled maize germ consists of ground maize germ from which most of the soluble have been removed by steaming and most of the oil removed by hydraulic expeller or solvent extraction procedures. Lakshmi *et al.* (2018) [18] reported maize germ meal could be included in diets of colored broilers up to 25% level keeping P at low level and by supplementing phytase enzyme without affecting bird's performance.

Distillers dried grains with soluble (DDGS)

Distillers dried grains with solubles (DDGS) is co-product of the ethanol industry produced during dry milling process. Its availability is increasing due to higher demand for ethanol as biofuel. DDGS contain 65% distillers grains and 35% distillers solubles on dry matter basis. DDGS contain all the nutrients from grain in a concentrated form except for the majority of the starch, which has been utilized in the fermentation process during ethanol production (AAFCO, 2005) [1]. Xue *et al.* (2012) [35] reported lysine (1.23%) is the first limiting amino acid in DDGS but it is richer in methionine content (1.19%). On chemical analysis, it was found that rice DDGS contained moisture 8.28%, DM 91.72%, CP 45%, EE 4.49%, CF 4.89%, TA 10.22%, NFE 27.12%, AIA 4.28%, ADF 15.20%, NDF 37.75%, Ca 0.73%, P 0.77% and GE 4097 kcal/kg (Gupta, 2016) [12].

Optimal inclusion rates are 12 to 15% in broilers (Lumpkins *et al.*, 2004) [19]. These levels can be increased to 20% and above for good quality (light) DDGS when the diet is nutritionally balanced with a particular care for the level of digestible lysine. Incorporation of 10% rice dry distiller grain with soluble (DDGS) in phase I & II feeding proved beneficial for egg production, egg quality traits & immune competence in laying hen. Protease enzyme supplementation with 10% rice DDGS can improve gut health and cost economics in layer (Gupta, 2016) [12]. However, rice DDGS can be safely incorporated in broiler chickens diets up to the inclusion level of 12.5% as alternate protein meal for economic broiler production (Dinani *et al.*,2018a) [7]

Rice gluten meal (RGM)

Rice gluten meal (RGM) is a by-product of wet-milling of rice obtained during starch extraction and syrup preparation. Metwally and Farahat (2015) [23] reported that RGM contained, on as such basis, (%) Moisture 7.6, DM 92.4, CP 57.6, EE 3.16, CF 1.45, NFE 28.95, Ash 1.24, Calcium 0.23, Phosphorus 0.40 and MEn (kcal/kg) 3330 where as Kumar *et al.* (2016) [17] observed that RGM (g/kg dry matter) contained organic matter 950, Crude protein 464, Ether extract 34.4, Ash 50, Neutral detergent fibre 404, Acid detergent fibre 173, Hemicellulose 231, Acid detergent lignin 38.4 and Metabolizable energy (MJ/kg) 13.2. In another study, it was observed that lysine is the first limiting amino acid (1.57%) in RGM through it is richer in methionine content (2.65%) on as such basis (Metwally and Farahat, 2015) [23]. However, RGM can safely can be incorporated in broiler diet at the inclusion level of 15% without any adverse effect on humoral immunity, gut health and intestinal histomorphometry (Dinani *et al*., 2018b) [8]

B. Energy sources

Maize (*Zea mays*)

As far as energy source is concerned, maize is the golden grain and undoubtedly an excellent source of energy in poultry and dairy rations. In poultry rations more than the protein the energy deficit is more common and this compels nutritionists to explore the usefulness of other carbohydrate rich feedstuffs as maize replacers in poultry diets. In ruminants although maize is the first choice for energy, because of its high cost and the ability of ruminants to utilize other cereal grains efficiently in comparison to poultry the importance of maize in ruminants is relatively less. In general, maize grain is low in protein content (9.1%), oil (4.4%) and ash (1.4%), but very high in starch content (73.4%) when considered on dry matter basis (Dei, 2017)

Sorghum (*Sorghum bicolor*)

Sorghum popularly called, as Jowar is the third largest cereal produced after rice and wheat in India. It is comparable to maize in nutrient composition except that it contains more (9-14%) protein (Mandal *et al*., 2002) [21]. Although the availability of these nutrients seems to depend upon the tannin content of the grains. The tannin content in sorghum ranges from 0.01 to 4.54%. However, due to high tannin content, it's incorporation in poultry feed may cause certain deleterious effects in poultry such as reduced feed intake, reduced weight gain and feed conversion efficiency along with decreased egg production in layers. High tannin in diets of growing broilers also hampered nutrient digestibility and found to increase the incidence of leg abnormality (Sannamani *et al*., 2010) [25]. Broilers can be fed up to 70% low-tannin sorghum in combination with soybean meal, minerals and vitamins (Batonon *et al*., 2015) [2].

Broken Rice (*Oryza sativa*)

During the milling of rough rice, several byproducts become available for use as animal feeds: polished rice, 50-66%; broken rice, 2-17%; polishing, 2-3%; bran, 6-85%; hulls, 20%;. Broken rice has a nutritive value somewhat similar to that maize and when prices are favorable, can be used as a substitute for all classes of poultry. Broken rice contained: DM 90%, CP 9.8% EE 1.2% ash 0.03% C.F. 0.7%, Ca 0.4%, P 0.2% and Gross energy 4060 kcal/kg (Casas *et al*., 2015) [4]. It is offered at graded levels up to 30% in the diet of broiler chicks showed no untoward effect. However, feeding of broken rice at high level appeared to increase carcass fat in broilers. In the laying hens broken rice can be substituted with yellow maize up to 13% levels without resulting economic loss to the producers but care should be taken to include some amount of yellow/red maize or some other kind of pigment source such as alfalfa meal such that the egg yolk color does not fade below an accepted level. Moreover, the broken rice being gritty does not necessitate grinding.

Pearl millet (*Pennisetum glaucum*)

Pearl millet is India's fourth most abundantly grown cereal, surpassed only by rice, wheat, and sorghum. The feeding of pearl millet in broiler diet at higher levels has been found to be associated with high abdominal fat content. It was also reported that pearl millet can effectively be used up to a dietary level of 32 per cent replacing about 50% of maize and 15% (a dietary level of 4.5%) of soybean meal to adjust protein level of broiler diet (Udeybir *et al*., 2009) [33] Feeding millet produced eggs that were higher in mono-unsaturated and omega-3 polyunsaturated fatty acids (PUFA), and lower in omega-6 fatty acids than when feeding any other common cereal. Since mono-unsaturated and especially omega-3 PUFA may offer health benefits to consumers suffering from cardiovascular disease, supplementation of pearl millet in laying hens diet may contribute in the development of healthy "designer" eggs.

Wheat (*Triticum aestivum*)

The nutritive value of wheat in terms of crude protein, metabolizable energy (ME), crude fat, crude fibre, calcium and available phosphorus were 13.0%, 3153 kcal/kg, 1:5%, 2.9%, 0.01% and 0.13%, respectively. Wheat contains relatively high levels of non-starch polysaccharides and appreciable levels of pentosans (50-80g/kg DM)). This fraction possesses anti-nutritive activity even when present in low levels in broiler diets. The performance of broilers in terms of growth and feed efficiency was better with diet having 50% damaged wheat replacing maize. Beside this wheat waste could be replaced by maize in broiler ration upto 40% without affecting growth performance. In India, wheat is commonly used to feed poultry at the inclusion level of 50-60% in surplus production area (Blair, 2008) [3].

Rye (*Secale cereal*)

Most of the existing research pertaining to the use of rye in poultry diets has concentrated on its growth-depressing properties in growing chicks rather than attempting to determine under what conditions rye might prove to be an acceptable energy feedstuff for poultry. Rye grain is very similar to wheat in amino acid composition although rye protein is higher in lysine and slightly lower in both sulphur amino acids and tryptophan than wheat protein. Nevertheless, the feeding value of rye for poultry remains poor due to the presence of various anti-nutritional factors. Moreover, rye is regarded as being the least palatable cereal grain. The growth depressing effect of rye when it replaced maize in poultry diets has been reported in several studies and was observed at levels as low as 25% (Maner, 1987) [22]

Grain and grain by products

During the milling process of paddy and wheat, by products like rice bran, rice broken, rice polishing, wheat middling's and wheat bran are obtained and they serve as good sources of energy, B complex vitamins and trace minerals. They can be included at 10-20% level depending on the nutritive value and still maintain optimum growth, egg production and feed conversion. Replacement of maize by par boiled rice bran at 20% level has not resulted in any adverse effects on the performance of chicks.

Although, there are several varieties of millets, pearl millet, finger millet, proso millet and fox tail millet and these millets are most commonly grown in India. They generally contain more crude protein, fiber and phosphorus than maize. High levels of millets at more than 50% in poultry diets have proved unsatisfactory because of their coarseness and presence of tannins. Maize byproducts like hominy feed, maize germ, maize cake and maize grit are also suitable to replace maize at certain levels.

Combining nutritious cereals

The combinations of maize, pearl millet and sorghum at the inclusion level of 33% each or maize, pearl millet, sorghum and finger millet at the inclusion level of 25% each could support the broiler growth and feed efficiency. Similarly, combination of maize (50%), sorghum (25%) and pearl millet (25%) or combinations of maize sorghum and pearl millet 33.3% each provided economical gains in commercial broilers (Elangovoan *et al*., 2004) [11]. Moreover, these nutritious cereals can safely be used as part or solely as dilutor of protein-mineral concentrates used in broiler feeding after 3 or 4 weeks of age. The combinations of maize sorghum and pearl millet 33.3% each provided gain and feed conversion efficiencies similar to maize based diet.

The recent findings on utilization of different cereals and oilseed residues have been encouraging. The combinations of maize, pearl millet and sorghum at the inclusion level of 33% each or maize, pearl millet, sorghum and finger millet at the inclusion level of 25% each could support the broiler growth and feed efficiency. Similarly, combination of maize (50%), sorghum (25%) and pearl millet (25%) or combinations of maize sorghum and pearl millet 33% each provided economical gains in commercial broilers. Moreover, these nutritious cereals can safely be used as part or solely as dilutor of protein-mineral concentrates used in broiler feeding after 3 or 4 weeks of age. The combinations of maize sorghum and pearl millet at 33.3% each provided gain and feed conversion efficiencies similar to that of maize based diet.

Combining oilseed residues

Inclusion of rapeseed meal and sunflower seed meal each at 10% level replacing soybean meal supported optimum growth and feed conversion efficiency and reduced cost of production of edible meat. Similarly combination of rapeseed meal and sunflower seed meal at 10% each replacing 67% of soybean meal resulted in similar growth and feed conversion efficiency as obtained in diet with soybean meal as sole source of vegetable protein. Combination of groundnut meal and niger seed meal in 75:25 ratio was found to be suitable for economic egg production (Mandal *et al*. 2004; Tyagi *et al*.2007) [20, 32].

Inclusion of rapeseed meal and sunflower seed meal each at 10% level replacing soybean meal supported optimum growth and feed conversion efficiency and reduced cost of production of edible meat. Similarly, combination of rapeseed meal and sunflower seed meal at 10% each replacing 67% of soybean meal resulted in similar growth and feed conversion efficiency as obtained in diet with soybean meal as sole source of vegetable protein. Combination of groundnut meal and niger meal in 75:25 ratio was found to be suitable for economic egg production. Solvent extracted rapeseed meal (RSM) and un-decorticated sunflower seed meal (SSM) could safely be included up to 10 and 5% level, respectively, replacing part of soybean meal in maize or maize-pearl millet based diet. However, combination of maize and pearl millet in a ratio of 1:1 and soybean meal alone or with RSM or SSM yield apparently better performance than maize with soybean meal

Combining nutritious cereals with oilseed residues

Solvent extracted rapeseed meal (RSM) and un-decorticated sunflower seed meal (SSM) could safely be included up to 10 and 5% level, respectively, replacing part of soybean meal in maize or maize-pearl millet based diet. However, combination of maize and pearl millet in a ratio of 1:1 and soybean meal alone or with RSM or SSM yield apparently better performance than maize with soybean meal. Use of RSM or SSM in broiler starting diets based on sorghum or finger millet may be restricted. However, these meals can be used at 5 or 10% levels in sorghum or finger millet based finisher diets (Mandal *et al.*, 2004) [20].

Replacement of 50% of dietary maize with pearl millet, and soybean meal with combination of rapeseed meal (solvent extracted) and sunflower seed meal undecordicated, (solvent extracted), each at 5 or 10% level of diet supported optimum growth, feed utilization efficiency and meat production in broiler chickens. Inclusion of 30% w/w pearl millet, 5% w/w rapeseed meal and 10% w/w sunflower seed meal or 30% pearl millet, 10% rapeseed meal (RSM) and 10% sunflower seed meal (SSM) replacing maize and soybean meal (SBM) partially rendered economic broiler production (Tyagi *et al.*, 2003) [28].

Use of sorghum replacing 75% of dietary maize and rapeseed meal (5% or 10% w/w) and sunflower meal (5% or 10% w/w) replacing soybean meal partly supported optimum gain and feed efficiency of broiler chickens similar to that of maize soy based control. Inclusion of sorghum (replacing 75% maize) along with 10% RSM and 5% SSM or 10% RSM and 10% SSM (w/w) resulted in economic broiler production (Sannamani *et al.*, 2010) [25].

The diets containing maize, sorghum and pearl millet (50:25:25 or 33:33:33) as source of cereals, SBM and 5% safflower cake was superior in terms of performance and economics of broiler production. Raising starting chickens on diets containing pearl millet and/or sorghum replacing maize partially (50 and 75%, respectively) or completely and sunflower seed meal and mustard meal replacing soybean meal partly was found to be economical (Tyagi *et al.*, 2004) [30].

Conclusion

Many studies have been conducted in India for locally available alternative feedstuffs regarding their nutritive values; presence of incrementing factors and many methods has been tried for augmenting their feeding values. Use of feed additives like exogenous enzymes supplementation, acidification, fermentation, toasting *etc.* are reported beneficial to increase their inclusion level. Further studies are needed regarding identifying, evaluating such locally available alternative feed resources and augmenting their feeding values for economical and sustainable poultry production.

Table 1: Percentage proximate composition of energy feedstuffs on dry matter basis (ICAR,2013)

Ingredient	Dry matter	Crude protein	Crude fibre	NFE	Ether extract	ME kcal/kg
Maize	89.9	9.3	2.5	70.3	1.6	3.440
Sorghum	88.4	10.5	5.6	65.3	3.5	2.593
Pearl millet	88.8	12.8	2.	63.2	4.5	2.655
Finger millet	86.3	8.8	4.6	67.5	1.3	
De-oiled rice bran		12.7	11.8	57.5	0.5	2.235
Tapioca tuber		3.0	2.0	93.2	1.0	3.197

Table 2: Maximum level of inclusion of feed ingredient in poultry diets (ICAR,2013)

Ingredient	Level of inclusion (%)	Ingredient	Level of inclusion (%)
Maize	60	Groundnut meal	40
wheat	50	Ground nut meal deoiled	20
Barley	20-40	Soybean meal	40
Oats	10-20	Seasame meal	20
Sorghum (Dark Variety)	10-20	Sunflower meal	20
Sorghum (white variety)	25-40	Sunflower meal	20
Pearl millet	50	Coconut meal	5
Rice	40	Cottonseed meal	5
Rice bran	10-20	Mustard meal	10
Rice polish	25-40	Maize gluten feed	15
Rice polish (deoiled)	10-20	Maize gluten meal	15
Wheat bran	10-15	Niger meal	15
Maize bran	10	Fishmeal	10
Hominy feed	10	Fish scrap	10
Salseed meal (deoiled)	3-5	Feather meal	2
Molasses	5-10	Meat meal	3
Animal and vegetable fats	10	Meat cum bone meal	10
Poultry manure meal	10	Blood meal	5
Tapioca flour	10-20	Poultry by product meal	3

Table 3: Anti-nutritional factors present in alternate feed sources (ICAR-CARI, 2015)

Alternate protein sources	ANFs
Guar meal (GM) or korma	Gum (Galactomannans), anti-trypsin factor etc.
Cotton seed cake (corticated/Decorticated)	High fiber and Gossypol
Linseed meal	Linamarin
Groundnut cake	Aflatoxin contamination
DDGS	High fiber
Rice gluten meal	High fiber
Sun flower cake	High fiber but rich in methionine
Rapeseed/canola	Glucosinolate
Palm kernel meal	High fiber
Coconut meal	Aflatoxin contamination
Sesame meal (Til cake)	High phytate but rich in methionine
Rubber seed meal	Glucosinolate
Azolla meal	Phenols, flavonoids, saponins, tannins
Blood meal	Poor palatability
Feather meal	High Keratin
Wheat	Non starch polysaccharides
Sorghum	Tannins
Millets	High fibers and tannins
Rice bran/Wheat bran	High fiber, rancidity, phytate
Cassava root meal	Cyanogenic glycosides
Cassava peel meal	Cyanogenic glycosides
Sweet potato meal	High fiber
Taro	Calcium oxalate
Mango seed kernel	Tannins

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