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Characterization and Classification of Potential Poultry Feeds in Ethiopia Using Cluster Analyses

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Abstract

The purpose of this work is to characterize and classify locally available poultry feeds, currently in use or potentially relevant but so far unutilized, based on literature data and to provide poultry farmers and local feed manufacturers with alternatives of feed stuffs that can potentially substitute each other.

The feeds were originally categorized according to the conventional classification scheme of the NRC. The feed stuffs under each general category were clustered into similar groups based on the nutrients more commonly considered in poultry feed formulations. Metabolizable energy, crude protein and fiber, and lysine, methionine and tryptophan were selected to characterize the crude nutrients and critical amino acid contents, respectively. Agglomerative Clustering of feeds (observations) was performed to classify the feeds into separate groups (clusters). Hierarchical Cluster Analysis of Observations was employed using a Squared Euclidean Distance matrix and a Complete Linkage method.

In the first category, eight cereal grains and five tubers clustered into seven groups: barley, finger millet, oats and carrot in cluster 1 and maize, sorghum and wheat in cluster 2 making the largest group. The cereal grain processing by-products clustered into four groups at 90% level of similarity, the first two clusters containing 75% of the observations. In the other category, close to 50% of the pulse grains formed a homogenous group at about 80% level of similarity. Oil seed cakes clustered into five distinct classes, about 40% of which grouped together containing feeds having average level of nutrients. The by-products of animal origin produced six clusters at 81% level of similarity with most of the feeds standing separately. Meat and fishmeal have the highest levels of energy and protein and a very good assortment of critical amino acids in this category.

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In conclusion, the cluster analyses produced different groups of alternative feed stuffs with reasonably high degree of homogeneity. The anti-nutritional factors limiting utilization of some of these feed stuffs in poultry rations were also presented along with the cautions needed.

Key words: Cluster analysis, grains, food processing by products, nutrient contents

Introduction

The contribution of intensive commercial poultry industry to the supply of poultry meat and egg in Ethiopia has been very small. The contribution of this sector doesn't exceed 2-3% of the total out put estimated at about 79,120 MT eggs and 76,560 MT of chicken meat produced annually (Alemu Yami, 1995), though there is a trend of expansion. Its staggering progress is attributed to a range of factors including arrays of policy issues, socioeconomic limitations and technical constraints. One of the most frequently cited and the foremost challenge facing the sector is inadequate supply and poor quality of poultry feeds and lack of systematically documented information in the value of the available feed resource base. The significance of feed availability and quality and information on alternative feed sources in poultry production can not be overemphasized since, especially under commercial systems, feed is the principal determinant of the economics of production.

Feeding alternatives should be explored adequately in countries like Ethiopia where poultry compete with an increasing human population for the limited food/feed resources available. Although the country has a diverse range of agro-ecologies enabling production of varieties of crops offering wide options of resources for poultry feeding, their utilization is still limited. So far most of the feed processing plants and poultry farmers in Ethiopia depend on very few and similar feed ingredients in formulating rations for different classes of chicken. Crops currently less popular locally are also included in the analyses taking into account the current, changing scenario in crop production in different parts of the country. In this respect, there is a growing prospect related to the emerging investments in the production of introduced species/varieties of crops that are relatively new in the existing production environment. Systematic presentation of available information on the quality of local feed stuffs would enable optimum and efficient use of these resources in the rapidly developing poultry industry.

Reasonably large quantity of information is available on the nutrient contents of major feed stuffs, currently in use or potentially relevant to poultry feeding in Ethiopia. A large portion of the data used to cluster the feed stuffs was drawn from local sources (Evaldson, 1970; Beyene Chichaibelu *et al*., 1977; Alemu Yami, 1981; Seyoum Bediye and Zinash Sileshi, 1989; Alemu Yami and Guenther, 1992). Reference was also made to nutrient compositions of tropical feeds practically relevant to poultry feeding in Ethiopia (Oyenuga, 1959; Göhl, 1981; Close and Menke, 1986; SLU, 1986, Leeson and John, 2001) to complement the available information.

The purpose of this paper is to characterize and classify the major feed stuffs grown in most parts of Ethiopia that are relevant for poultry feeding in to different groups based on literature data of their nutrient contents. The outputs would enable poultry farmers and feed manufacturing/processing industries to look for suitable substitutes of individual feeds during formulation of different rations, and identify appropriate combinations for optimum quality and cost. Such information is also expected to give users the opportunity to take advantage of the seasonal abundance of certain feeds in times of scarcity of the others. Feeds with promising potential, such as tubers, that have currently very little or no role as poultry feed in Ethiopia, were considered in the analyses to encourage use of these resources in the future.

Methodology

The feed items were originally grouped according to the conventional classification scheme of the NRC (NRC, 1984) and analyzed based on the nutrients commonly considered in poultry feed formulations. Data on feed composition were collected from local sources complemented by information from nutrient composition tables of tropical feeds. Metabolizable energy (ME), crude protein (CP) and crude fiber (CF) were selected to reflect the crude nutrient contents of the feeds and lysine, methionine and tryptophan were considered to reflect the amino acids critical in poultry nutrition (McDonald *et al.*, 1995; Kellems and Church, 1998; Leeson and John, 2001).

Clustering methods were selected after repeated examination of cluster outputs of data subjected to different methods (Minitab Inc., 1996). Agglomerative clustering of feeds (observations) was performed by joining two clusters at each amalgamation step to classify the feeds into separate groups (clusters). Hierarchical Cluster Analysis of Observations was employed using a Squared Euclidean Distance matrix. A Complete Linkage method, where the distance between two clusters is defined as the maximum distance between a variable in one cluster and a variable in the other cluster, was applied (Minitab, 1996). Variables were standardized before processing the data. Similarity levels were reported under each cluster analysis. Dendrograms of observations were not presented in order to reduce the size of the paper.

Results

Cluster analyses of energy source feeds

Cereal grains and tubers. Table 1 presents the composition and cluster groups of eight cereal grains and five tubers. The feeds were grouped into 7 clusters at 85% level of similarity. Observations in each cluster displayed very little variability. Clusters 1 and 2 contained 62% of the feeds high in critical amino acid and ME contents. All the cereal grains and tubers considered have comparable levels of CP (8.0-12.7%) except cassava (3.9% CP, cluster 4) and sweet potato tubers (5.3% CP, cluster 6). Oats whole seed (cluster 3) and all the tubers (clusters 4,5,6, and 7) except carrot clustered into separate groups with considerable level of variability in all measurements compared to clusters 1 and 2, and each other. Oats whole seed is the lowest in ME (2380 kcal/kg) but contains the highest level of CF (13%) (Table 1)

Cereal grain processing by-products. Eight feeds of cereal grain processing by-products were considered for clustering in this category. Four clusters were identified at about 90% level of similarity. Except rice polishings (cluster 3) and brewer's dried yeast (cluster 4), all the by-products belonged to either cluster 1 or 2 (Table 2). Feeds in cluster 1 are high in CP and CF, but low in ME. Feeds in cluster 2 are characterized by moderate levels of ME, CP and CF (except rice bran, which is high in CF). Rice polishings is especially characterized by its rich assortment of the amino acids lysine, methionine and tryptophan. Brewer's dried yeast (cluster 4) is a unique item, least fibrous and exceptionally rich in ME, CP and lysine compared to all the rest in the category.

Cluster analyses of protein source feeds

Pulse grains and oil seeds. The most common types of pulse grains and oilseeds available in Ethiopia considered in this category. The feeds were clustered into 4 groups at 80% level of similarity. Cluster 1 includes 50% of the feeds containing high levels of CP and ME next to Soya bean. Soya bean, clustered separately (cluster 3), is the best in all measurements with a very good assortment of critical amino acids. Pea (cluster 2) is exceptionally high in lysine. Sunflower and pigeon pea (cluster 4) contain moderate levels of amino acids and low levels of CP relative to the other groups. Sunflower seed has the most fibrous in the category (Table 3).

Oilseed cakes. Five groups were identified at 84% level of similarity for 10 types of oilseed cakes common in Ethiopia. The nutrient composition and cluster classes were presented in Table 4. Feeds in this category have comparable levels of ME. Cottonseed and Soya bean cakes were grouped under cluster 1 with high levels of CP and critical amino acids. About 40% of the oil seed cakes were grouped in to cluster 2 containing moderate levels of CP, CF and amino acids. Peanut and safflower cakes were clustered separately, high CP content and very low levels of methionine and tryptophan, and the lowest levels of ME and CP and very high CF content characterizing each, respectively. Noug seed cake, cluster 3, is also high in CF but relatively lower in protein content compared to the rest in the category.

By-products of animal origin. Feeds in this category clustered into six classes at 81% level of similarity (Table 5). Crude fiber was excluded from the analysis since it was not a relevant measure of quality in feeds of animal origin.

Although cluster 1, consisting of blood meal and poultry offal meal, shares similar features in most measurements, very high level of CP and ME characterize each feed, respectively. Meat meal and fishmeal (cluster 4) contain the best levels and assortments of nutrients compared to all the rest in the category. Raw and steamed bone meal, both very low in ME and CP, and hydrolyzed feather meal, each formed separate groups with different features. Hydrolyzed feather meal (cluster 6) is comparable to blood meal (cluster 1) in ME and CP contents.

Table 1. Cluster groups of cereal grains and tubers based on metabolizable energy, crude protein and crude fiber (on DM basis), and lysine, methionine and tryptophan (as % protein, on DM basis)

Cluster	Feed	N	Energy (k cal/kg)	Crude Protein (%)	Crude Fiber (%)	Lysine (% protein)	Methionine (% protein)	Tryptophan (% protein)
1	Barley (*Hordeum vulgare)* seed, dehulled	5	3284	9.8	5.3	3.3	1.3	1.5
1	Finger millet (*Eleusine* spp.) whole seed	4	3002	11.0	6.3	3.0	1.3	1.2
1	Oats (*Avena sativa*, dehulled) seed	4	3107	11.8	7.0	3.8	1.5	1.4
1	Carrot (*Daucus carota*) tuber	3	2870	12.7	10.4	3.2	1.2	1.9
2	Maize (*Zea mays*) white seed	6	3679	10.8	2.0	3.0	1.1	0.6
2	Maize (*Zea mays)* yellow seed	6	3654	12.0	2.0	2.4	0.6	0.6
2	Sorghum (*Sorghum vulgare*) seed	6	3800	11.9	1.9	2.9	0.4	1.0
2	Wheat (*Triticum aestivum*) seed	6	3416	12.7	3.0	2.6	1.3	1.1
3	Oats (*Avena sativa*) whole seed	5	2380	11.3	13.0	2.7	1.1	0.9
4	Cassava (*Manihot esculenta)*	2	3510	3.9	4.9	6.2	0.6	0.5
5	Potato (*Solanum tuber.*) tuber, fresh	2	3730	11.0	2.9	5.6	0.0	2.0
6	Sweet potato (*Ipomoea batatas)* tuber	2	3100	5.3	0.2	4.1	1.1	1.8
7	Yam, trifoliate (*Dioscorea* spp) tuber.	2	2900	8.0	3.5	3.5	0.9	0.0

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Table 2. Cluster groups of cereal grain processing by-products based on metabolizable energy, crude protein and crude fiber (on DM basis), and lysine, methionine and tryptophan (as % protein, on DM basis)

Cluster	**Feed**	**N**	**Energy (k cal/kg)**	**Crude Protein (%)**	**Crude Fiber (%)**	**Lysine (% protein)**	**Methionine (% protein)**	**Tryptophan (% protein)**
1	Barley, Brewer's dried grain	4	1890	23.4	17.6	3.3	1.2	1.3
1	Maize, gluten feed	6	2046	26.2	13.2	2.3	2.2	0.9
1	Wheat, bran	6	1656	16.2	11.4	3.8	1.5	1.5
2	Rice bran	3	2710	11	13	4.1	1.8	1.6
2	Wheat shorts, dry milled	6	2596	18.2	6.5	4.1	1.1	0.9
2	wheat, middlings	6	2425	17.8	9.3	4.1	1.6	1.3
3	Rice polishings	3	2735	10.8	1.1	6.3	4.4	3.5
4	Barley, Brewer's dried yeast	4	3210	44.3	0.2	7	1.3	1.4

Table 3. Cluster groups of pulse grains and oil seeds based on metabolizable energy, crude protein and crude fiber (on DM basis), and lysine, methionine and tryptophan (as % protein, on DM basis)

Cluster	**Feed**	**N**	**Energy (k cal/kg)**	**Crude Protein (%)**	**Crude Fiber (%)**	**Lysine (% protein)**	**Methionine (% protein)**	**Tryptophan (% protein)**
1	Cow pea (*Vigna sinensis)*	4	2930	25.9	5.6	6.5	0.9	1.3
1	Harricot bean (*Phaseolus vulg.)*	3	2916	25.6	5.3	6.9	0.3	1.9
1	Grass pea (*Lathyrus sativa, L.)*	3	3450	24.4	7.1	9.7	0.6	0.0
1	Lentil (*Lens culinaris)*	4	3660	26.2	3.1	8.0	0.7	1.2
2	Pea (*Pissum sativum)*	3	2860	26.4	6.7	13.4	2.2	0.8
3	Soybean (*Glycine max)*	5	3815	39.0	4.3	9.4	2.1	2.1
4	Sunflower (*Helianthus annus L.)*	5	2840	19.3	21.6	3.6	1.5	0.0
4	Pigeon pea (*Cajanas cajan)*	3	2942	21.8	8.8	7.0	1.5	0.3

Table 4. Cluster groups of oil seed cakes based on metabolizable energy, crude protein and crude fiber (on DM basis), and lysine, methionine and tryptophan (as % protein, on DM basis)

Cluster	Feed	N	Energy (k cal/kg)	Crude Protein (%)	Crude Fiber (%)	Lysine (% protein)	Methionine (% protein)	Tryptophan (% protein)
1	Cottonseed (*Gosypium spp.*), cake	5	2363	51.5	8.8	4.1	1.4	1.1
1	Soybean (*Glycine max)*, toasted, cake	3	2601	51.4	6.7	5.5	1.5	1.1
2	Linseed (*Linum usitatisimum*, cake	3	2096	37.3	10.8	3.5	2.4	1.5
2	Rapeseed (*Brassica napus)*, cake	3	2666	37.5	13	3.8	1.7	1.3
2	Sesame (*Sesamium indicum)*, cake	3	2632	45.7	8.6	2.9	3.1	1.4
2	Sunflower (*Helianthus annus)*, cake	5	2156	42.9	15.1	3.5	2.2	1.4
3	Mustard (*Brassica spp.)*, cake	3	2373	38.2	8.4	4.4	1.5	0.0
3	Noug (*Guizotia abyssinica)*, cake	5	2647	32.4	21.5	3.5	2.0	0.0
4	Peanut (*Arachis hypogae)*,cake	4	2895	48.5	5.4	3.6	0.4	0.0
5	Safflower (*Carthamus tinctorius)*,cake	4	1870	22.8	34.9	2.7	1.5	1.2

Table 5. Cluster groups of feeds of animal origin based on metabolizable energy, crude protein and crude fiber (on DM basis), and lysine, methionine and tryptophan (as % protein, on DM basis)

Cluster	Feed	N	Energy (k cal/kg)	Crude Protein (%)	Lysine (% protein)	Methionine (% protein)	Tryptophan (% protein)
1	Blood meal	6	2566	92.4	8.0	1.5	1.3
1	Poultry offal meal	4	4248	64.2	5.7	1.4	1.1
2	Bone meal, raw	3	1371	39.3	4.7	0.7	0.0
3	Bone meal, steamed	4	1219	29.6	13.5	2.8	0.8
4	Meat meal	6	4000	85.0	5.2	4.3	1.0
4	Fish meal	4	3175	70.0	7.7	3.1	1.1
5	Meat and bone meal	6	2388	55.3	5.0	1.4	1.1
5	Hatchery by-product meal	4	1840	37.0	4.1	1.9	1.3
6	Hydrolysed feather meal	3	2960	91.0	4.3	1.0	0.0

Discussions

Cluster analyses of energy source feeds

Cereal grains and tubers. Cereal grains and tubers are mainly used as sources of energy in poultry feeding. Theoretically the ME contents of most of these feeds are comparable to the levels specified for different classes of chicken; ranging from 2890, for 6-12 weeks old chicks and pullets, to 3345 kcal required per kg of dry matter (DM) (on 90% DM basis) for broiler starters and finishers (NRC, 1984; McDonald *et al*., 1995). The cereal grains maize, sorghum and wheat (cluster 2) are the best sources of ME satisfying the requirements for energy of growers and pullets as well as laying and breeding hens; followed by the cereals (barley, millet and dehulled oats in cluster 1. Feeds in the latter class meet even the higher level required by starter chicks.

All the tubers, except carrot, are sufficient to meet the specifications for broilers. The tubers, when considered on fresh basis, are extremely deficient in energy due to their high water content, which often ranged from 70-80%. Their succulent nature renders them bulky and less convenient for poultry feeding. Thus, use of tubers should essentially involve adequate drying to a moisture content of not more than 10-15% (Göhl, 1981). Generally, subjecting tubers to simple processing, such as drying, would render them to be good sources of energy complementing grains. For instance, dried sweet potato meal could constitute up to 50% of the ration of poultry (Göhl, 1981).

The cereals are fairly comparable to each other but much better than tubers in CP content. But neither of the feeds in this category could supply the quantity of CP required by any class of chickens. Cassava and sweet potato tubers are exceptionally poor in CP and thus should be used with feeds very high in CP content. The level of CF is within the desirable range for both cereals and tubers, except oat whole seed. However, dehulling substantially reduced the fiber content of oats from 13 to 7.0% improving its ME content from 2380 to 3170 kcal/kg (Table 1).

Cereal grain processing by products. Cereal grains and their processing by products could often constitute up to 90% of poultry rations (McDonald *et al*., 1995). In a country like Ethiopia, where there is a critical shortage of grains it is rather mandatory to increase/optimize the utilization of by products of grain processing. As expected, feeds in this class generally do not meet the nutrient requirements of chickens (Leeson and John, 2001) except brewer’s dried yeast, which has the most desirable qualities in all measures considered.

The ME contents of brewers' dried grain, maize gluten feed and wheat bran are potentially equivalent to 40 to 50% of the amount in maize grain. This is expected to meet between 50 to 60 % of the energy demand of chickens (NRC, 1984) the utilization of which, however, would probably be limited by their high fiber content. The CP content of these feeds is equivalent to about 40% of the proportion in soybean meal or 53% of that in noug seed meal. Hence these by-products should be used with ingredients moderate to high in energy and protein. On the other hand, feeds in cluster 2, consisting of rice bran, wheat shorts and wheat middling are quite high in energy, containing 60 to 70% of the level potentially supplied by maize. This suggests that such feeds could be included in poultry diets along with ingredients less than average in energy, adjusting the level of CF. Brewer’s dried yeast is exceptionally rich in ME and CP which make it a very good source of energy and protein to compliment poor quality feeds.

On the other hand, all feed stuffs in the different clusters of this category are generally poor in their content of critical amino acids. However, brewer’s dried yeast and rice polishings could supply all the critical amino acids in sufficient quantity. Rice polishings are exceptionally rich in methionine and tryptophan containing about 200% of the level required by all classes of chicken (Banerjee, 1982; Leeson and John, 2001), expressed as percent of CP.

Cluster analysis of protein source feeds

Pulse grains and oil seeds. Observations within each of the four clusters in this category displayed very low variation. Feeds in cluster 1 constituting the common pulses (cow pea, haricot bean, grasspea and lentil) are low in CF and average in CP and ME compared to the rest in the category. Fifty percent of the feeds belong to this class potentially substituting each other at 80% level of similarity. It appears that they could be used to supplement feeds low to average in ME and moderate in CP and CF. However, the role of especially grass pea in replacing others is quite limited due to its content of a toxic factor, B-aminopropionitrile, causing paralyses (Close and Menke, 1986; McDonald *et al*., 1995) (Table 6). Pea is exceptionally high in lysine and methionine but comparable in other terms to feeds in cluster 1. Sunflower seed is remarkably high in CF (>18%) and marginal in CP (<20%) and, thus, could hardly be regarded as a protein supplement as such (Kellems and Church, 1998) although pigeon pea in the cluster appears to be slightly better. Soya bean obviously bears the most remarkable qualities as poultry feed in all aspects and thus, highly recommended for use in cereal based diets to balance especially their CP and critical amino acid contents. However, it should be processed prior to inclusion into rations because the seeds contain a number of toxic, stimulatory and inhibitory factors (McDonald *et al.*, 1995; Gohl, 1981) (Table 7).

The level of lysine is sufficient to excess in all of the feeds considered except in sunflower seeds. However, only soya bean and peas could meet the requirements of all the three amino acids specified for chicken. The amino acid composition of these feeds is characterized by high lysine content similar to that of fishmeal protein. While literature on the deleterious effects caused by high levels of this amino acid are scarce, according to Sinurat and Balnave (1995), higher proportions of lysine to metabolizable energy (ME) in the ration would decrease feed intake and growth of chickens under conditions of high housing temperature (25-35 ^{o}C).

Oilseed cakes. The 10 feeds in this category clustered in to five classes with a very high level of homogeneity. The second cluster in this category contained the largest set of observations, about 40%, with highly homogenous members (Table 4). Cottonseed and soya bean cakes in the first cluster are comparatively low in CF and contain very high level of CP, equivalent to about 70% of the amount in fishmeal. The ME value of these feeds is comparable to about 60% of the proportion in maize grain. Thus, feeds in this cluster have the most desirable qualities and could be considered as suitable alternative sources of CP and ME to supplement diets poor to average in CP and moderate to high in ME. Feeds in clusters 2 and 3 have average and comparable levels of ME and CP. However, inclusion of noug cake (cluster 2) in poultry diets would be limited by its high CF content (Smith, 1990). Safflower cake (cluster 5) appears to be the least suitable to poultry feeding due to its remarkably high CF and very low ME content.

Oil seed cakes are poor in critical amino acid profiles although soybean cake is slightly better in lysine. However, the overall assortment of critical amino acids in oil seed cakes is only comparable to that of cereal grains, grain processing by-products and tubers and far worse compared to pulse grains and oil seeds. As suggested elsewhere (Close and Menke, 1986; McDonald *et* *al*., 1995), considerable variations could exist in nutrient compositions of oil seed cakes of the same feed subjected to different oil extraction and processing techniques. Pre processing treatments such as decorticating and toasting, and oil extraction methods could result in large variability in the qualities of cotton seed, rapeseed and soybean cakes.

Feeds of animal origin. The 9 feed stuffs of animal origin produced using the complete linkage method displayed the 6 cluster groups with a very little variation within each cluster. Bone meal, raw or steamed, (clusters 2 and 3) and hatchery by-products meal (cluster 5) are obviously unsatisfactory as sources of both energy and protein. This is a reasonable classification since these feeds are considered rather as sources of minerals. Meat meal and fishmeal are the best sources of ME and CP. The quality of hydrolyzed poultry feather meal, on the other hand, is largely unpredictable since it is highly dependent upon the efficiency of hydrolysis. It could replace only 5-6% of an equivalent amount of soybean meal (Göhl, 1981).

As stated in most classical text books of animal nutrition (McDonald, *et al*., 1995; Kellems and Church, 1998), over view of the foregoing analyses shows that plant proteins of all sources except probably soybean seeds (to a certain extent) are unsatisfactory as sole sources of amino acids critical to poultry. Protein sources of animal origin are, therefore, necessary ingredients to correct the discrepancies unless the rations composed entirely of plant materials are fortified by addition of synthetic amino acids.

Most of the feeds in the category contain adequate level of lysine. However, feeds grouped in to cluster 4 (table 5) containing meat meal and fish meal have the best assortment of high levels of critical amino acids. These feeds could, thus, be used to balance rations based on plant protein sources severely limiting in critical amino acids. The levels of methionine and tryptophan in most of the other feeds are not large enough to overcome the deficiencies of these amino acids in high cereal diets of poultry (McDonald *et al*., 1995).

Conclusions and Recommendations

Most of the cereal grains and their processing by products, comprising the largest proportion of poultry rations, complemented with the different plant protein sources presented in the current paper appear to meet the crude nutrient requirements of different classes of chicken. However, such combinations usually fail to supply the required levels of critical amino acids.

Optimum utilization of these rations is achieved through inclusion of protein sources of animal origin such as fishmeal.

Table 6. Major factors limiting utilization of some poultry feeds and measures to overcome them-cereal grains and tubers

Feed	Limiting factor (s)	Precautions suggested	Reference
Millet	Some varieties have tannins which reduce palatability and protein digestibility	Limiting level of inclusion	Sreenivas, 1997
Sorghum	May contain tannins reducing palatability and protein digestibility	Limiting level of inclusion Treatment with ash	Sreenivas, 1997
Oats	High fiber, low energy	Using up to 30 (growing chicks) & 50% (laying hens)	Göhl, 1981
Barley	The owns would cause digestive upsets	Remove owns before feeding	Göhl, 1981
Wheat	High gluten contents may result in accumulation of a doughy mass in the crop (of the bird), upsetting digestion	Use of wheat stored for some time reduces the risk	McDonald *et al.*, 1995
Potatoes	The alkaloid solanidine and its derivatives causing gastroenterites	Avoiding green potatoes exposed to light, Steam/cook	McDonald *et al.*, 1995
Sweet potato	Trypsin inhibitors	Restricting the levels	"
Cassava	Cyanogenic glycosides (linamarin & lotaustralin) which are hydrolyzed into the toxin hydrogen cyanide (HCN)	Boiling, grating and squeezing, grinding, pelleting Sweet varieties have lower toxicity	Daghir, 1995 Close and Menke, 1986

The user of the present cluster classifications should mainly focus on identifying the deficiencies and excesses of nutrients of each feed in the cluster group and work out the combinations giving the best assortment of nutrients meeting his/her specific needs. On the other hand, even if the feeds belonged to the same cluster group with high degree of similarity this alone does not guarantee total replacement of one feed by the other due to the presence of potential anti nutritional factors limiting inclusion in the diet. The economic implications of alternative formulations should also be assessed critically by analyzing the economic benefit of each alternative.

Finally, standardizing the definition, quality, handling and processing procedures for animal feeds used in Ethiopia is the most critical issue deserving immediate action if future developments in the poultry industry in particular and the livestock sector in general are to be realized. Feed standards and quality control procedures should be formulated and enacted nationally and the regulations adopted strictly by feed manufacturers, suppliers and users as soon as is possible.

Table 7. Major factors limiting utilization of some poultry feeds and measures to overcome them: protein source feeds

Feedstuffs	**Limiting factor (s)**	**Precautions suggested**	**Reference**
Linseed oil cake	The toxic compound HCN which combines with cytochrome oxidase leading to immediate cessation of cellular respiration & even death; Has unidentified Anti Pyridoxine Factor; High levels of mucilage which is almost indigestible by poultry	Boiling, grating and squeezing, Grinding to a powder and then pressing, pelleting Restricting inclusion, 3-5%	Daghir, 1995; Göhl, 1981; Daghir, 1995
Soybean cake	Contains a number of toxic, stimulatory and inhibitory factors (problems mainly occur if whole seeds are used)	Toasting/ heating, less risk when meals produced by the expeller method are used	Göhl, 1981 Leeson and John, 2001
Cotton seed cake	Gossypol toxicity resulting in depressed appetite, loss of weight, haemolytic effects on the erythrocytes, cardiac irregularities and death	Restrict gossypol content in diet to not more than 100 mg kg^{-1}, Treat with ferrous sulphate /in a 1:1 molar ratio	McDonald *et al.*, 1995; Göhl, 1981; Daghir, 1995
Rape seed cake, Mustard cake	Glucosinolates resulting in goiter, kidney and liver poisoning	Limiting inclusions based on results from animal trials Not recommended for starters	Göhl,1981; Daghir, 1995
Peanut meal	Easily contaminated by Aspergillus flavus which produces aflatoxin, a potent liver toxin & very active carcinogen	Quick drying, proper storage to prevent mould growth	Daghir, 1995; Göhl, 1981
Sunflower seed cake	Fast oxidation and rancidity	Using up to 10% in diets of adult birds,	McDonald *et al.*, 1995
Sesame seed cake	*High content of phytic acid rendering the P in the meal unavailable,* The hulls contain oxalates	Decortication avoids oxalate toxicities, Limiting inclusion to about 5% for adult birds	Daghir, 1995; McDonald *et al.*, 1995
Grass pea, *Lathyrus* sp.	Contains a toxic ingredient, β-aminopropionitrile, causing paralysis	Restricting inclusion	McDonald *et al.*, 1995
Meat meal/ Meat and bone meal	Could easily be infected by pathogens, e.g. salmonella bacteria; Rancidity & loss of vitamin potency	Ensuring the final sterilization by heating to 100°C for 1hour, care in storing	Kellems and Church, 1998
Fish meal	Results tainting of products when used for grown/ adult animals	Remove from the diets in the finishing stage (broiler), Use lower levels for layers	Kellems and Church, 1998
Hydrolyzed feather meal	Risk of contamination of base material with Salmonella	Strict control of processing conditions	McDonald *et al.*, 1995

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