TECH NOTES

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Alternative Feed Ingredients

Global Nutrition Team

SUMMARY

Depending on locations or regions of the world, poultry diets are commonly formulated with cereal grains such as corn or wheat, in combination with protein meals such as soymeal and sometimes with animal byproducts such as meat and bone meal. One or more fats such as soybean oil, poultry oil, palm oil or tallow may also be included as an additional energy source. However, at certain times, nutritionists are also looking for other so-called novel or alternative raw materials. These times include periods when common ingredients become scarce or limited in supply, or during volatile ingredient markets when there is increased pressure to reduce diet costs and increase efficiency.

This article provides information on alternative raw ingredients that could be used during periods of scarcity or market volatility to provide economic benefits, giving information on both their potential opportunities and potential limitations to maximize productive response.

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The remainder of this article provides more detail on the points summarized on page one.

INTRODUCTION

When reviewing raw material possibilities, alternative ingredients may become economically more attractive and viable for inclusion in poultry feeds. For example, in Western Europe where wheat is traditionally the economic cereal of choice, a dramatic increase in wheat price can result in corn or sorghum becoming viable alternative ingredients. And conversely, in some Asian countries where corn is the commonly used cereal, wheat has at times become a more economically viable alternative in broiler and broiler breeder diets.

Another consequence of increased feed ingredient prices is that it makes feed additives and micro-ingredients more attractive for diet optimization. An increase in the use of synthetic and crystalline amino acids and enzymes has occurred around the world. Price volatility of energy and protein sources has resulted in an increased use of exogenous enzymes such as phytase, carbohydrases and proteases.

The evolving feed ingredient marketplace demands a better understanding of the different ingredient alternatives, their potentials and their limitations for inclusion in poultry diets. This article provides information on the use of alternative feed ingredients, and the potential opportunities in their use and to further strengthen economic competitiveness.

ALTERNATIVE FEED INGREDIENTS

Wheat

Wheat is a major energy source in poultry feeds in certain parts of the world (e.g. Europe and Australia), where corn is not readily available or too costly to be used. It has a higher level of crude protein but a lower energy compared to corn. High in starch (over 65%), these grains are low in some specific nutrients, but because of the high starch gelatinization property, its inclusion in diets, even at 12-15% can result in good quality pellets.

When used in broiler diets, the following should be considered:

- **Xanthophylls:** The concentration is low compared to corn. Hence, it is ideal for white-skinned broilers but to produce yellow skin pigmentation either corn or pigments will need to be added.
- **Vitamins:** Wheat has lower levels of vitamin A and biotin compared to corn.
- **Enzymes:** When used at high levels in poultry diets, appropriate wheat-based xylanases should be used to breakdown the high levels of NSP (non-starch polysaccharides) and to minimize protein variations.
- **Pelleting:** recent research has found that pelleting temperature should be set lower for wheat than corn for optimal broiler performance.

Corn (maize)

Corn is the major energy source in poultry feeds in many parts of the world. It has the highest energy content of most cereals but is lower in protein than wheat. Harvesting conditions, processing, and storage will affect the nutritional value of corn, primarily its metabolizable energy (ME) content.

When used as a substitute for wheat, special attention must be paid to the following characteristics:

- **Xanthophylls:** The concentration is highly variable (5 to 20 ppm) depending on the origin and class of corn. The degree of yellow skin pigmentation will vary depending on the xanthophyll level. Using corn with lower levels of xanthophylls or restricting its inclusion levels is necessary in markets that demand white-skinned broilers.
- **Oil:** Corn has a highly digestible fat, with a high unsaturated fatty acids (linoleic acid) content. This must be taken into account when considering the source of any supplemental oil/fat used if effects on carcass fat composition are to be limited.
- **Amino acid profile:** Corn has low levels of limiting essential amino acids and, when compared to wheat, the lower protein content will increase the need to use high protein ingredients and supplemental amino acids.
- **Starch:** Corn is composed of over 60% starch which is of a highly digestible nature. Compared to wheat, a lower degree of gelatinization is achieved so pellet quality tends to be poorer.
- **Toxins:** Mold growth and mycotoxin(s) production can be of concern with corn. Aflatoxin, T-2, and zearalenone are the most common. Mycotoxin screening and monitoring is important, and in particular, visual assessment for broken and damaged kernels is key. Broiler breeders should be fed using corn sources low in mycotoxins.
- **Enzymes:** Research suggests there may be some benefit of using carbohydrases, like amylases and xylanases, to improve the nutritional value of corn and reduce energy variation due to various factors inherent in corn production.

Sorghum (milo, kaffir)
The world's fifth largest cereal crop, sorghum, is used in many regions as an alternative to corn or wheat as the main energy source in poultry diets. Sorghums cultivars are divided into various types based on genotype and tannin content. The negative effects of tannins in poultry feeding include depressed feed intake, reduction in amino acid digestibility, inhibition of digestive enzymes, and a possible impact on ME value.

The deleterious effect of sorghum is more pronounced with younger birds. When using sorghum in poultry diets the following must be considered:

- **Nutritional value:** The nutritional value of sorghum is approximately 95% of corn, and its energy content is higher and more consistent than wheat.
- **Protein:** The nutritional quality of protein and the variation in amino acid content and digestibility are of concern with sorghum and should be monitored.
- **Starch:** Sorghum typically has the lowest starch digestibility of all the cereals.
- **Processing:** Grain texture, particle size, and pelleting temperatures are factors that can affect pellet quality, and potentially impact broiler performance when feeding sorghum based diets. Achieving effective grinding is very important, to avoid the presence of whole seeds in the feed, which will consequently be found in the excreta.
- **Pigmentation:** In contrast to corn, xanthophylls are not present in sorghum so for markets that demand a pigmented carcass, the diet must be supplemented with corn or pigments.

Barley
Barley, normally grown for malting, is also grown for animal feeds in some areas, especially temperate countries. This grain has a varying protein level (between 6 and 13%) and its starch content approximates to 55-57%, hence barley has a lower energy content than both corn and wheat.

When used in poultry diets, a few things need be noted:

- **Nutritional value:** The nutritional value of barley is lower than that of corn and wheat. Its higher content of NSP and fiber (about 5%) and the presence of ß-glucans make it less digestible for chicks. Barley is also lower in lysine concentration, vitamins A, D, E and calcium levels. It should not be used solely as the energy source but mixed with other grains such as wheat or corn.
- **Enzymes:** ß-glucanases must be added to the diet to reduce the negative effects on gut viscosity and litter quality.

Oats
Oats are a cold tolerant cereal typically grown in colder areas of the world such as Northern Europe and Canada. Things to consider with oats are:

- **Energy:** Oats offer the lowest ME contribution of all the cereals due to the high fiber levels and lower starch content (40-42%).
- **Protein:** The protein composition and digestibility of oats is one of the best of all cereal grains, due to its higher globulin content.
- **Lipids:** The oil quality of oats is high due to a high concentration of unsaturated fatty acids (oleic and linoleic). However, if used at high levels, greasy carcasses can become an issue.
- **Soluble fiber:** Contains significant ß-glucan levels that can lead to digesta viscosity problems and thus ß-glucanases must be added.

Distillers Dried Grains with Solubles (DDGS)
DDGS has become increasingly abundant as a by-product from ethanol production. It is primarily used in ruminant feeds, particularly dairy, but some producers do include it in their poultry feeds.

- **Variability:** The DDGS drying process varies significantly from one plant to another, affecting the digestibility of protein (e.g. lysine digestibility can range from 59 to 84%). Energy values also vary (ME ranges from 2490 – 3190 kcal/kg), due to variation in final product fat and fiber concentrations, and because of the caramelization of starch during the drying process.
- **Quality:** DDGS samples that are darker in color have been found to have lower amino acid digestibility (especially lysine) than DDGS samples that are lighter in color. Color measurement (colorimetry) is a quick and reliable method of estimating the amino acid quality of DDGS when used as a feed ingredient.
- **Minerals:** Use of DDGS should account for the higher total and available phosphorus concentrations compared to corn. Also, sodium content should be checked, as salt is added during the process of DDGS desiccation.
- **Mycotoxins:** If mycotoxins are present in the corn prior to ethanol production, DDGS subsequently produced will contain 3 times the concentration of mycotoxins, therefore monitoring for these metabolites is critical.
- **Pellet quality:** The 'springiness' of DDGS fiber greatly reduces pellet quality.
- **Handling:** Bridging and flowability of DDGS can be a major problem in feedmills depending on DDGS particle size.

Corn Gluten Meal
This is a co-product of the corn wet milling process to primarily produce starch and syrup. During the process, the soluble fraction, "corn water", is centrifuged to separate the starch and gluten. The starch is then washed to remove the last traces of protein resulting in high purity (approximately 99.5%). The gluten fraction is dried (to approximately 10% moisture) to yield an approximately 60% protein product called corn gluten meal. Thus, it is a high protein ingredient (ranging from 60 to 70%), with high methionine levels but low levels of lysine and tryptophan. This relatively unbalanced amino acid profile limits its use. The high digestibility of its nutritional components gives corn gluten meal a high energetic value. Corn gluten meal also contains high concentrations of xanthophylls (200–500 ppm) especially when produced from yellow corn. Quality control points to be considered are the moisture of the product, which should not exceed 12%, and its coloration: yellow – orange color.

Corn Gluten Feed
Corn gluten feed is another co-product of the corn wet milling process, being the fraction that remains after the extraction of starch, gluten, and germ. Composed of a soluble fraction called "corn steep water or liquor" and corn bran. Sometimes it may also include corn germ meal which gives a darker color to the product. Chemical composition will vary greatly based on milling process and relative proportions of its components. Corn gluten feed has a high proportion of fiber (about 8.0%), resulting in a lower ME concentration, moderate protein content (around 22%) and nearly 2.5% crude fat. The amino acid profile is low in lysine and tryptophan, which makes the ingredient more suitable for breeder diets.

Rice Bran (rice pollards)
Rice bran is a by-product of rice production, being a mixture of bran and the germ layers of the rice grain after being polished. Its high oil and starch content make it a good energy source. Typically, there are 2 types of rice bran. Full-fat rice bran contains a high percentage of oil (10-18%). Defatted rice bran has had the oil extracted, so it has a higher concentration of protein and fiber. Defatted rice bran has been reported to have 75% of the ME value of the full-fat type.

- **Variation:** Processing method, the mixture of rice bran and polishing in the final product and moisture content generates variation in the nutritive value of this ingredient. Also, rice bran can be contaminated with rice husks, greatly affecting its quality; protein levels should be closely monitored for this reason.
- **Oil:** Rice bran has a high polyunsaturated fat content and is a good source of linoleic acid. However, the presence of a lipolytic enzyme in the bran, which becomes active during processing, makes rice bran prone to oxidative rancidity. The oxidative process could interfere with ME and vitamin stability and availability. This limitation can be overcome with the use of an appropriate antioxidant (e.g. ethoxyquin).
- **Fiber:** Rice bran is high in fiber, containing appreciable levels of insoluble and soluble oligosaccharides, especially arabinoxylans.
- **Anti-nutritional factors:** High levels of phytic acid can interfere with mineral absorption, and the presence of trypsin inhibitors can affect protein digestion.

Wheat Bran
A by-product of flour processing, wheat bran consists of skins and particles of wheat grains from which most parts of the endosperm have been removed. It is relatively high in protein (15-17%) and in phosphorus and magnesium, but low in calcium, energy and starch. Wheat bran has few anti-nutritional properties and is therefore a good alternative feed ingredient especially in diets low in protein such as pullet and breeder feeds. However its high fiber and low physical density may limit its inclusion rates.

Cassava (manioc, tapioca)
Cassava is an energy yielding crop produced in tropical regions, Thailand being the main exporter. Dried cassava chips and pellets are the products commonly used in animal feed.

With this ingredient the following factors should be considered:
- **Anti-nutritional factors:** Fresh cassava roots contain an anti-nutritional factor called cyanogenic-glucosides (linamarin), which is hydrolyzed into glucose and hydrocyanic acid (HCN) by the action of linamerase enzyme present in the root, and released in the processing stage. Good quality chips should contain less than 30 ppm of HCN.
- **Nutritional value:** Cassava is mainly a source of energy, with a high starch content (60-70%) that is highly digestible. Protein level is low (2.5%) and of poor balance. It lacks coloring carotenoids, so attention must be paid if pigmented birds are marketed.
- **Feed processing:** The dustiness and bulkiness of ground cassava needs to be considered with mash feeds. Pellet quality can be poor with cassava-based diets.

Rapeseed/Canola Meal
Rapeseed meal is an oilseed crop with the second largest worldwide production (including canola). It is a by-product of oil extraction from rapeseed and is a good source of protein for broiler feeds. Typically, its crude protein content ranges from 34-38%, with a favorable amino acid content compared to soybean meal. The presence of anti-nutritional factors (e.g. erucic acid, glucosinolates, tannins and sinapine) limits its inclusion rate. The improved rapeseed cultivars that are low in erucic acid and glucosinolates, named "canola", have become more available and their inclusion in broiler diets can be much higher than standard rapeseed meal. The maximum recommended level of glucosinolates in the diet is 4 µmol per gram.

Points to consider with rapeseed/canola meal:
- Good protein source, high in sulphur-containing amino acids but low in lysine.
- Anti-nutritional factors (erucic acid, glucosinolates, tannins and sinapine) limit its use at high levels.
- The nutritive value of rapeseed/canola meal can be improved with the use of carbohydrases (cellulase, glucanase, xylanase), and proteases.

Attention should be given to inclusion rates for rapeseed and canola meal in broilers and breeders as outlined in **Table 1**.

Cottonseed Meal
This by-product of cotton oil extraction is characterized by its high fiber content which reduces the nutrient density compared to soybean meal. Cottonseed meal is a protein source the use of which has been limited in poultry feeds due to its content of anti-nutritional factors - gossypol and cyclopropenoid fatty acids.

Points to consider with cottonseed meal:
- **Gossypol:** Polyphenolic pigment found in the seed. Gossypol binds dietary iron in the diet, in the bloodstream, and in egg yolks, causing iron deficiency problems and the formation of discolored yolks. Gossypol has also been found to inhibit pepsin and trypsin action in the gastrointestinal tract. High free-gossypol levels have been correlated with reduced performance and increased mortality. However, free-gossypol levels below 100 ppm in the diet have shown no detrimental effect. For breeders, cottonseed meal with free-gossypol levels below 50 ppm, and with low residual lipid content (to reduce to a minimum the presence of cyclopropenoid fatty acids) is recommended to avoid yolk mottling problems in eggs.
- **Protein:** Cottonseed meal has lower protein content than soybean meal (40-42%), and the first limiting amino acid is lysine. The oil extraction method used can impact lysine digestibility, primarily due to the binding of gossypol with lysine. However, lysine supplementation can overcome this limitation.
- **Fiber:** A highly variable component which should be closely monitored as it influences the nutritional value. The low nutritional density of this ingredient due to its fiber content could make it advantageous for use in pullet rearing diets.

Sunflower Meal
The fourth most important oilseed meal, sunflower meal, is derived from the extraction of oil from sunflower seeds. It is widely used in many regions as a protein source and acts as a partial substitute for soybean meal. Sunflower meal can be made from whole or decorticated seeds. The quality characteristics of the meal are affected by the seed and type of oil extraction process. Sunflower meal is free of anti-nutritional factors.

Points to consider with sunflower meal:
- Color of sunflower meal goes from grey to black and depends on the degree of de-hulling (meals with less hulls are lighter in color) and on the oil extraction process.
- Hipro (High Protein) meal is much more suitable for poultry and should be sourced in preference to standard meal. Its crude protein content varies from 36% to 40%.
- Distinction must be made between Hipro meal and standard meal, and formulation matrix values must reflect the difference.
- Good digestibility of the protein fraction. Rich in methionine, cystine, and tryptophan, but low in lysine.
- Valuable source of calcium, phosphorus and B vitamins.
- Inclusion in broiler diets usually limited to 5% as a result of its high fiber and low energy level.

Palm Kernel Meal

The oil extraction process used (solvent vs. expeller extraction) affects nutritional value. Its high fiber content severely limits its suitability for use in broiler feeds; however in breeder feeds the lower nutrient density of the ingredient may be beneficial. Palm kernel meal can be a useful source of protein, characterized by its low lysine level but well supplied with sulphur-containing amino acids; however its high fiber level impacts protein digestibility. Its inclusion levels in poultry feeds can be increased with the use of NSP enzyme mixtures (cellulase, glucanase, and xylanase).

Copra Meal (coconut oil meal)

Copra meal is a by-product of the extraction of coconut oil. Copra is the dry kernel of the mature nut of the coconut tree. Flakes or cake is obtained from copra after the removal of oil by either solvent or expeller extraction. The method of extraction used influences the residual oil content (ranging from 1.5% to 14%). Typical crude protein content is around 20%, with low essential amino acid levels. Digestibility of the protein fraction is low. It has high fiber content, varying from 8% to 16%. The use of enzymes (e.g. mannanase) has been shown to improve the nutritional value of copra meal. A general recommendation is to not use in pre-starter and starter diets due to low energy, high fiber content, and high water holding capacity which could hinder feed intake. It can be used at up to 10% for other poultry diets when enzymes are used. Quality control efforts should be focused on monitoring:

1. Rancidity (dependent on the residual oil content).
2. Mycotoxin levels.
3. Protein, fat, and fiber content, due to their high variability.

CONCLUSION

During periods of limited supply or volatile ingredient markets, the use of alternative feed ingredients in broiler and breeder diets could provide economic benefits and strengthen financial competitiveness in a poultry business. However, it is important to thoroughly investigate and characterize the ingredients to determine the opportunities and limitations of their inclusion, as it is essential to maximize productive response. The economic fundamentals must remain - maximize productivity at a more competitive production cost.

Table 1: Recommended maximum inclusion level of various alternative ingredients in diets for broilers and breeders.

Ingredient	Broilers		Breeders	
	<3 weeks	>3 weeks	Rearing	Production
Wheat (+ enzymes)	50%	70%	50%	70%
Corn	None	None	None	None
Sorghum (low tannin)	None	None	None	None
Barley (+ enzymes)	3%	15%	5%	20%
Oats (+ enzymes)	5%	15%	25%	20%
DDGS	6%	15%	15%	15%
Corn gluten meal	5%	10%	10%	10%
Corn gluten feed	3%	5%	10%	10%
Rice bran	5%	10%	15%	15%
Wheat bran	*Not recommended*	5%	10%	15-20%
Cassava (low HCN)	20%	30%	30%	30%
Rapeseed meal	5%	5%	5%	*Not recommended*
Canola Meal (solvent extracted)*	5%	10%	5%	5%
Cottonseed meal (low gossypol)	5%	10%	10%	*Not recommended*
Sunflower meal	5%	10%	10%	10%
Palm kernel meal (+ enzymes)	*Not recommended*	10%	15%	10%
Copra meal (+ enzymes)	*Not recommended*	10%	10%	10%

**Consider excluding during the last 5 days prior to processing to avoid potential meat processing plant issues.*

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