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S Durga
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

N Sri Balaji
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

V Kumaravel
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

P Senthil Kumar
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

S Senthilkumar
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

MR Purushothaman
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

Correspondence
S Durga
Department of Animal Nutrition, Veterinary College and Research Institute, Namakkal, Tamil Nadu, Tamil Nadu Veterinary and Animal Sciences University, Tamil Nadu, India

Potential by-products used in swine diets

S Durga, N Sri Balaji, V Kumaravel, P Senthil Kumar, S Senthilkumar and MR Purushothaman

Abstract
Largely due to the demand for grains for the bio-fuel industry, the cost of feed energy will increase worldwide. Therefore, alternative energy supplying pig feed ingredients should be explored. The inclusion of DDGS in diets is limited by the fiber concentration in DDGS and for finishing pigs, also by the concentration of unsaturated fatty acids. Diets fed to growing-finishing pigs, may contain up to 70% field peas and no soybean meal is needed in these diets. Wheat shorts have been available for use in swine diets for many years. The available energy content of wheat shorts is lower than that of corn, but it contains more digestible amino acids and phosphorus than corn. If diets are formulated carefully, growing-finishing pig diets may contain 40% wheat shorts without compromising pig performance. Liquid feeding allows the use of liquid co-products such as whey, whey permeate, corn distillers soluble, brewer's yeast, sugar syrup, and corn steep water. The nutritional value of these co-products has been characterized and recommendations for their use in pig diets are made. These co-products are generally more variable in nutritional value, which should be considered carefully when formulating and costing swine diets.

Keywords: By-products, grower and finisher pigs

Introduction
It is known that feed cost represents more than 60% of the total costs in pig production. Among the alternatives currently available to improve the efficiency of feed use are, on the one hand, a wide variety of food additives and, on the other hand, the presentation of feed in liquid form that, as well as the use of by-products from the agri-food industry, has been shown to reduce feed costs [1].
The use of by-products has increased significantly in recent decades, and it will continue to increase throughout the country because by-products are a source of nutrients at a much lower cost than conventional raw materials. However, the high demand for by-products is likely to lead to an increase in their cost [7], which could diminish the competitiveness they currently offer, with respect to raw materials.
Knowing the potential full value of a given by-product for animal feed is of great interest. Prior to using a particular by-product, it is desirable to consider, in addition to its potential nutritional value, both its logistical constraints-such as supply, seasonality of supply, variability in nutrient contents, water content, palatability, management, cost/benefit ratio- and the precautions associated with its use. Generally, when there is not too much information on by-products and only their estimated nutritional value from dry matter is available, it is assumed that the maximum level of inclusion in order not to compromise productive performance should not exceed 15% of the diet in fattening pigs [2]. However, animal trials are essential for evaluating their digestibility, palatability, animal performance, and potential risks associated with their use, as well as determining their maximum inclusion levels, which are derived from the results obtained for those factors and will provide, as a final result, the potential value of the by-product.

Potential by-products for swine diets
Potential by-products which may be considered for swine diets may be classified from their primary product origin as follows:

Grain
1. Distilling by-products/co-products
2. Brewing by-products
3. Milling by-products

II. Animal
1. Milk by-products
2. Meat by-products
3. Egg by-products

III. Vegetable
1. Potato by-products
2. Cull beans
3. Field peas

IV. Sugar and starch production
1. Cane, beet and corn molasses
2. Salvage candy

Grain by-products

Distillers dried grains

Distillers dried grains is the residue remaining after the removal of alcohol and water from a yeast fermented grain mash. Distillers co-products are primarily from corn but may also be from barley or other grains. Corn is 2/3 starch and during the fermentation and distillation processes, the starch is converted to ethanol [3]. This wet mash goes through a series of centrifuges, evaporators, and presses to produce solubles (liquid) and distiller's grains (Semi-dry).

Table 1: Composition of DDG

Moisture	Maximum 12%
Crude protein	Minimum 26.5%
Crude fat	Minimum 10%
Crude fiber	Maximum 7.5%
Color	Golden
Smell	Fresh, fermented, pleasant cereal odor
Bulk density	34 – 37 lb/cubic foot
Particle size	Coarse = 10% maximum on a 2000-mesh screen Fine = 15% maximum on a 600-mesh screen & pan

Table 2: Inclusion level of DDGs in pigs

Phase	Starting Point	Maximum Inclusion Rate
Nursery (>15 lbs)	5%	25%
Grow-Finish	10%	20%
Gestating sows	20%	50%
Lactating sows	5%	20%
Boars	20%	50%

Brewer's dried grains

Brewers dried grains is the dried residue of barley malting and often contains other grains in the brewing of beer. It is a low energy feed (ME=1,000 kcal/lb.) containing 13 to 16% crude fibre. Brewers dried grains has a fairly high protein level (25%), but the quality is low because of low levels of lysine (0.9%) and tryptophan [1] (0.3%). Because of its low energy value, this ingredient is not very useful in growing-finishing or lactation diets but could be used in gestation diets with grain to meet the lysine requirements.

Grain milling by-products

1. Maize bran is the outer coating of the maize kernel including the hull and small amounts of the underlying gluten. It contains 5 to 10% crude fibre, and consequently, is lower in energy than the whole corn grain. It is similar to whole maize grain in protein, lysine, calcium, and phosphorus, and its energy value is similar to that of oats and may be used like oats in swine diets.
2. Hominy feed is a mixture of maize bran, maize germ and part of the starchy portion of the kernel. Hominy feed is similar in analysis to corn, being higher in fat (7%) and fibre (6%) than corn but similar in energy, (protein-10%), lysine (0.3%), and tryptophan (0.1%) concentrations [2]. It can replace corn in swine diets on an equivalent basis.
3. Maize gluten meal may be either a 40% or a 60% protein by-product of wet milling. Its value as a replacement for soybean meal in swine diets is limited because of its low lysine (0.8%) and tryptophan (0.2%) values [7]. Because of its cryptoxanthine (yellow) content, corn gluten meal is used primarily for poultry in layer diets for egg yolk colour and in broiler diets for skin colour.
4. Rice bran is very palatable and readily consumed when fresh. However, because of its high unsaturated fat content (13%), rancidity occurs, causing objectionable odor and taste. The quality and value of rice bran (1,350 kcal ME/kg) also varies depending upon the amount of rice hulls included in the bran. The high fibre of hulls and poor digestibility rapidly reduces the energy value of rice bran. The phosphorus is largely unavailable. Fat extracted rice bran has a lower energy value (1,200 kcal ME /kg, but the problem of rancidity in storage is eliminated.
5. Rice polishing is the by-product of polished rice for human consumption. It does not vary as much in nutritional value as rice bran and can be a useful diet ingredient for swine. The combination of rice polishing and rice bran may be included in growing-finishing diets at levels of 20 to 30% with satisfactory performance [5]. The cost of transporting these rice by-products from the source of production and processing virtually eliminates them from consideration by swine producers.

Bakery by-products

Dried bakery product is a mixture of bread, cookies, cake, crackers, and dough. It is similar to corn in protein and amino acid composition (10% protein, 0.3% lysine, and 0.1% tryptophan) but higher in fat (10%) and energy (1,650 kcal ME /lb). Dried bakery product may replace up to one-half of the maize in maize soybean meal growing-finishing and sow diets and up to 20% in starter diets [2]. The salt content may be fairly high, and the standard salt supplementation could be deleted. Keep water available for the pigs at all times.

Animal by-products

Milk By-products

Milk by-products have a concentration and balance of nutrients that make them desirable as swine feeds. They are palatable and highly digestible but usually are not economical for extensive use in swine feeds. Liquid by-products like sweet or acid whey and salvaged whole or skim milk are less costly than dried by-products, but their high water content limits the distance that these materials may be transported economically.

a) Dried skim milk (DSM) produced from roller-drying or spray-drying of low fat milk, contain about 50% lactose and 33% of a very high quality protein. This by-product is very palatable and highly digestible, and on an available lysine basis, it is equal to soybean meal (44%). Because dried skim milk is usually expensive compared to other feed ingredients [8], its use should be limited to pre-starter diets fed during the first 2 weeks after early

weaning (less than 3 weeks of age). Dried skim milk is commonly included at 10 to 20% of pre-starter diets. However, if economics change, such as reduction of cost of diet, it can be fed in all phases of swine production.

b) Liquid sweet whey is the by-product from making hard cheeses (Cheddar, Munster, and Monterey Jack). When the cheese curds are separated, the liquid whey has a temperature of about 100°F, is slightly acidic (pH 6.0 to 6.5), and contains about 5% lactose, 1% high quality protein, and 0.05% high available phosphorus. Liquid sweet whey is best suited for pigs from 20kg to market weight. While it may be fed to gestating sows, it should not be fed to lactating sows because consumption of a large volume of liquid during lactation may reduce total energy intake.

c) Dried whey can be included at 20 to 30% of the starter diet and should be substituted on a lysine equivalent basis. The greatest benefit from dried whey occurs the first week after weaning. The benefit may last for only the first week for pigs weighing over 5 kg at weaning, while pigs weighing less than 5 kg may benefit from dried whey in the diet for 2 to 3 weeks post weaning [2]. These benefits in starter diets will be consistently observed only when "edible" grade of whey is used. When the cost of dried whey exceeds that of conventional ingredients, judgment should be used as to how long whey-fortified diets are fed.

Meat By-products

a) Animal fat is obtained from the tissues of harvested animals by commercial processes of rendering or extracting. Animal fat consists primarily of true fats (triglycerides) and can be classified into four types: choice white grease, tallow, yellow grease, and hydrolyzed animal fat. Lard is rendered from swine, and tallow is rendered from cattle, sheep, and goats. Yellow grease is predominantly tallow but may also include restaurant greases. Hydrolyzed animal fat is obtained from fat processing procedures commonly used in edible fat processing or soap making. It consists predominantly of fatty acids. All of these fats have a metabolizable energy (ME) value of about 3,550 kcal/kg. They contain virtually no nutrients other than fat. Fat quality can be an issue. If there is a quality concern for a certain fat source, it should be analyzed for moisture, impurities, and unsaponifiable matter (MIU-million international unit), as well as free fatty acids [3]. Moisture should not exceed 1%, free fatty acids 15%, impurities 0.5%, unsaponifiable material 1%, and total MIU of 2.5%. Full-fed growing-finishing pigs will generally consume a fairly constant daily ME caloric intake regardless of the energy density of the diet. Thus, as fat is incorporated into the diet, the energy density (kcal/kg) increases, and the pig consumes fewer kgs daily to maintain an equal intake of ME (calories). Rate of gain in growing-finishing pigs is maximized by incorporating 5 to 8% of animal fat into a maize-soybean meal diet. Consequently, feed efficiency is considerably improved as animal fat is incorporated into the diet. The relative cost of ME from fat vs. grain essentially determines its use in growing-finishing diets. However, fat additions greater than 6% can cause feed to bridge in feeders or storage bins.

b) Meat meal and meat and bone meal are made from the trimmings at harvest. These include bone, tendons, ligaments, inedible organs, cleaned entrails and some carcass trimmings. These differ from tankage in that they do not include dried blood and are produced by a different cooking method. If the meat meal contains more than 4.0% phosphorus, it is designated meat and bone meal. Meat meal typically contains about 8% calcium (Ca) and 4% phosphorus (P) and meat and bone meal contains about 10% Ca and 5% P. In both meat meal and meat and bone meal, the Ca shall not exceed 2.2 times the actual P level. Both Ca and P of these products are highly available. Meat meal contains about 55% protein, 3.0% lysine, and 0.35% tryptophan. Meat and bone meal contains about 50% protein, 2.5% lysine, and 0.28% tryptophan [4]. The digestibility of protein and availability of amino acids in these products are not as high as that of soybean meal [8]. In a maize-meat and bone meal diet, tryptophan is the first limiting amino acid. Because of this, the high ash content and palatability, it is advisable to limit these products to 5% of the diet.

c) Blood meal is produced by drying the blood collected at slaughter by one of several drying processes. The old drying procedure was by a vat cooker process. This was a slow drying process, and much of the lysine in blood meal was poorly available. Blood meals contain 80 to 90% protein and 8 to 9% lysine. However, with the cooker drying process, less than 20% of the lysine is available to the pig.

d) Feather meal is a by-product resulting from the hydrolysis under pressure of cleaned feathers from slaughtered poultry [6]. The lysine level in feather meal is quite low (about 1.5% available lysine). Most of this product is used in feeding poultry. Its use in swine diets should be limited to 3% for growing-finishing pigs and sows.

e) Poultry by-product meal consists of the viscera, head and feet from poultry harvest. These are dry or wet rendered, dried, and ground into a meal. The meal is 93% dry matter, 1% crude fiber, 12% crude fat, 55% crude protein, 3.7% lysine, 0.45% tryptophan, 4.4% calcium, 2.5% phosphorus, and has an ME value of 1,300 kcal/kg. Poultry by-product meal may be utilized similarly to meat meal in swine rations.

Egg By-products

a) **Bloodspot eggs** from egg candling stations are often available at little or no cost. Eggs, including the shell, contain 60% moisture, 10% protein, 9% fat, 6% calcium, 0.2% phosphorus and 0.7% lysine [9]. Finishing pig studies in which one-third of the dietary energy was from eggs showed satisfactory performance. This would indicate that growing-finishing pigs could safely consume a dozen eggs in the shell daily, eliminating the need for supplemental calcium and reduce the supplemental protein need.

b) **Hatchery by-product meal** is hatchery waste consisting of a mixture of egg shells, infertile and unhatched eggs, and cull chicks. This is cooked, dried, and ground with or without removal of part of the fat. Hatchery by-product meal from layer type chick hatcheries has a higher protein level than that from broiler chick hatcheries because males are culled from layer type chicks and go into the by-product. Because of the high calcium content, hatchery by-product meal should be limited to not more than 3% of the diet of growing-finishing pigs and sows

[1]. At this level it will replace the lysine in 2% of soybean meal and also replace the supplemental calcium.

Vegetable By-products

1. Cull potatoes are available in large quantities each fall after harvest and in lesser amounts at other times of the year. Raw potatoes have 22% dry matter, which is primarily starch. Raw potatoes are unpalatable to the pig and poorly digested, but cooking improves both the palatability and digestibility. Cooking can be accomplished by boiling in water or by steaming [5]. Potatoes contain 2% protein and have an ME value of 370 kcal/lb on a freshly cooked basis. Because of the energy value, cooked potatoes may replace about one-half of the maize in growing-finishing diets.
2. Cull beans from the dry navy bean (*Phaseolus vulgaris*) crop are available in considerable quantities at the fall harvest, and lesser amounts are available at other times during the year. Navy beans, like potatoes, must be cooked to obtain good performance of growing-finishing pigs [6]. Navy beans contain factors such as trypsin inhibitor and haemaglutinin, which reduce digestibility and palatability. These factors are inactivated in the cooking process (Steam cooking for 30 min.). Cooking also improves the utilization of the complex carbohydrates in beans. If the cull beans are not cooked, they will be better utilized by ruminants than by swine.
3. Field peas are used for human consumption, but can also be used both an amino acid and energy source for pigs. A major benefit of field peas is that they can be fed raw. Since most varieties contain no anti nutritional factors, they do not have to be heat-treated. Field pea's amino acid content is intermediate between maize and soybeans, and depending on variety, can have an energy concentration similar to that found in corn. They are low in the sulfur amino acids methionine and cysteine, and marginal in tryptophan, but supplementation of synthetic amino acids alleviates this problem.

When formulating diets containing field peas, they should first be balanced on lysine concentration, and then analyzed for concentrations of methionine, tryptophan, and threonine. Nursery pigs can be fed diets containing up to 18% peas, while growing-finishing diets can contain up to 40% field peas [7]. Gestating and lactating sows can be fed 16 and 24% field peas, respectively [8].

Sugar and starch by-products

1. Cane molasses and bagasse are by-products of cane sugar refining. Bagasse is the material left after the juice has been squeezed from the plant [9]. Molasses is that portion of the juice remaining after further refining in the production of sugar. These by-products are economically utilized only in areas producing and refining sugar cane. Cane molasses and bagasse in a 4:1 ratio can be incorporated into growing-finishing diets at 10 to 30% if the diet is properly balanced with soybean meal, minerals and vitamins; near maximal growth rate can still be attained. Excessive use of molasses can induce scouring. Adding bagasse at one-fourth of the molasses level will aid in reducing this problem. However, because of the high fiber concentration (45%) of bagasse, growth rate of growing-finishing pigs will not be optimum. Molasses and bagasse may be used as a laxative much as wheat bran to prevent constipation of sows.
2. Beet molasses and beet pulp are by-products of the production and refining of beet sugar [10]. The high fiber content of beet pulp, much like that of bagasse in sugar cane, limits its use to that of lactating sows as a laxative feed. Dried beet molasses may be used to a level of 10% (Replacing maize) in the growing-finishing diet for good performance.
3. Corn molasses is a by-product of corn sugar (dextrose) manufacture from maize starch. Corn, cane and beet molasses all have similar nutrient analyses, except that maize molasses contains practically no protein or calcium.

Conclusion

Pork producers have many different feedstuffs available, and by-products/co-products are typically used to provide amino acids, one of the most expensive components of a swine diet. Many by-products are available from the industries of grain milling, baking, brewing and distilling, fruit and vegetable processing and meat, milk and egg processing. Many of these by-products are utilized regularly in manufactured feeds and supplements because of least cost formula. Other by-products may be major ingredients in unique swine diets because of their abundant supply from nearby source.

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