PURDUE EXTENSION

pork industry handbook

# By-Products in Swine Diets

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## Introduction

Feed costs comprise approximately 65-70% of the cost of pork production. While most US producers think of strictly corn and soybean meal (SBM) when feeding pigs, they need to realize that pigs require amino acids, energy, vitamins and minerals, and not any particular feedstuff for normal growth. In most regions of the US, a corn–SBM combination is usually the least expensive ingredient combination that meets the pig's nutrient requirements. However, in times of higher corn and SBM prices or in regions of the US that are removed from the Corn Belt, producers need to look at alternative feedstuffs in order to keep diet costs down.

## Objectives

- To identify by-products that are useful in swine diets
- To describe how these by-products result from processing
- Present nutrient value of by-products
- Show how they may be utilized in swine feeding

## Questions to Consider Before Utilizing By-Products

A number of questions should be asked and answered satisfactorily before by-products are incorporated into swine diets.

**1. Are there animal and human health hazards associated with the by-products?** The presence of toxic substances, disease organisms, molds, mycotoxins, and growth inhibiting factors in a by-product should be checked. If present, the by-product should not be considered unless these deleterious factors can be inexpensively eliminated or neutralized.

**2. Is the nutrient composition suited to swine feeding?** Check the nutrient composition from feed composition tables and laboratory analyses. The by-product must be an effective source of available nutrients or energy to be considered as a substitute for conventional ingredients. Even if a by-product has an acceptable total nutrient concentration, if that nutrient is poorly digested or absorbed, it's not available for growth and therefore of little benefit to the pig. Therefore, by-products with low nutrient density and/or availability should generally be avoided, except, perhaps for gestating or open sows. Also, palatability of feedstuffs is an issue to consider. If a feedstuff is not palatable, feed consumption and subsequently growth performance/production, will be reduced. Special caution must be taken when considering using by-products in nursery and lactation diets, where feed/energy intake is a critical issue.

**3. Are there added costs of utilizing the by-product?** By-products can directly increase costs because of added transportation, storage, processing equipment, facility modifications, or labor required for their use. Additional costs can result indirectly from reduced facility and equipment life, extra management time, feed wastage, manure disposal complications, increased risk of animal health problems, and reduced performance caused from by-product variability.

Total feed consumption can be affected by ingredients utilized, and would therefore impact the economic benefit of a by-product. If a product is high in fiber, animals will consume more of that diet than they would of a corn-SBM diet, so total feed consumption would be higher. Also, certain by-products may have a short shelf life (ex. high fat products) so they must be purchased in smaller amounts, thereby reducing the potential cost savings of buying in bulk. The other option would be to add a preservative or antioxidant to increase shelf life. Another cost of a by-product would be the potential for a nutrient imbalance. If a product contains a high concentration of one nutrient, it may cause a deficiency in another nutrient (ex. Ca-P or Ca-Zn) that normally would not occur. Therefore, experience of others and accurate "cost of production" records for the existing feeding program are valuable tools when projecting real costs.

**4. Who is in charge of quality control, and how much will that cost in time and money?** By-product composition can vary greatly depending on raw ingredients, processing method, drying temperature, etc; and for producers to properly incorporate a by-product into swine diets, they need to know the actual nutrient content of the product purchased. Values from reference tables provide a good starting point, but by-products should be routinely analyzed for nutrient content for the producer to get the maximum nutritional value of the product without affecting pig performance. It takes time and money to sample and analyze ingredients, and those costs must be incorporated into the actual cost of the ingredient for the producer.

**5. Do by-products reduce the cost of production most of the time?** The financial commitment necessary to feed by-products requires a cost-benefit advantage a high percentage of the time, not just during periods of high prices of conventional ingredients. A study of conventional ingredients' pricing history and cycles is necessary for making any long term decisions.

**6. Is by-product availability and quality sufficiently consistent to support longtime use?** A steady supply of the byproduct, a reliable price, and uniform quality are essential to consistent cost savings. If a by-product is produced nearby and at a price that will be competitive long-term, it may be feasible to build equipment to specifically handle it. Examples may be dairy processing facilities, hatcheries, or corn processing plants.

## 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:

1. Grain
    a. Distilling by-products/co-products
    b. Brewing by-products
    c. Milling by-products
    d. Baking by-products
2. Animal
    a. Milk by-products
    b. Meat by-products
    c. Egg by-products
3. Vegetable
    a. Potato by-products
    b. Cull beans
    c. Field peas
4. Sugar and starch production
    a. Cane, beet and corn molasses
    b. Salvage candy

In the following pages, each of the by-products in this classification system will be discussed. The discussion will provide information on the by-product including definition, how it is produced, nutritive value, palatability, availability, how it may be used, level of use in swine diets, management considerations, effect of level of use on pig performance, and problems related to its usage.

## Grain Fermentation By-Products

The principal by-products/co-products of the brewing and distilling industries that are useful in swine diets are brewers dried grains from the beer brewing industry, distillers dried grains from the commercial ethanol industry, and stillage from on-the-farm alcohol production.

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. One bushel of corn produces approximately 2.6 gallons of ethanol, 17 lbs of $CO_2$, and a wet spent-mash. This wet mash goes through a series of centrifuges, evaporators, and presses to produce Solubles (liquid) and Distillers Grains (semi-dry). The Solubles and Distillers Grains are then blended and dried to produce 17 lbs of Distillers Dried Grains with Solubles (DDGS) from the same bushel of corn.

DDGS provides lysine, phosphorus, and energy, and replaces soybean meal, dicalcium phosphate, and corn in swine diets. It is approximately equal to corn as an energy source, and although DDGS is quite high in protein (27%) it retains the poor amino acid balance of grains and is particularly limiting in lysine (0.7%). Also, it appears that the amino acids in DDGS are less available than those from SBM. However, by supplementing swine diets with synthetic amino acids, DDGS can work well in swine diets. Also, DDGS does contain a relatively large amount of available phosphorus (.71%) so inorganic phosphorus supplementation can be reduced. Therefore, diets need to be balanced on available amino acids and available phosphorus to ensure proper performance.

In general, there are 2 broad categories of DDGS: DDGS from "Old Generation" plants and DDGS from "New Generation" plants. The "New Generation" plants are relatively new (less than 10 years old) and utilize new technologies such as batch fermentation and improved quality control procedures to produce a higher quality DDGS compared to some older, larger ethanol plants.

Research at the University of Minnesota has shown that DDGS from the new generation ethanol plants has higher nutrient concentrations than traditional ethanol plants. Again, this is due to, in part, better fermentation, distilling, and drying processes in the new generation plants. Therefore, producers must know the source of DDGS they are buying before they incorporate it into their swine diets. Table 1 provides a set of standards to be used when purchasing DDGS for swine diets and Table 3 demonstrates the differences in nutrient concentrations between DDGS from Old and New Generation ethanol plants.

The economic projections shown in Table 4 are based on using the Old Generation DDGS. If New Generation DDGS is being used, the economic value needs to be calculated in a different manner. Since DDGS provides lysine, phosphorus, and energy, and replaces portions of soybean meal, dicalcium phosphate, and corn, all these factors must be included when considering the economics of using New Generation DDGS,. As a "Rule of Thumb", 200 lbs of DDGS and 3 lbs of limestone can replace 178 lbs of corn, 19 lbs of 46% protein soybean meal, and 6 lbs of dicalcium phosphate in a ton of complete feed. Therefore, if 200 lbs of DDGS and 3 lbs of limestone are less expensive than 178 lbs of corn, 19 lbs of 46% protein soybean meal, and 6 lbs of dicalcium phosphate, it is economical to use DDGS.

| | |
|---|---|
| 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<br>Fine = 15% maximum on a 600-mesh screen & pan |

**Table 1. Specifications for DDGS to be used in swine diets.**

Traditionally, DDGS has been included in swine diets up to 10%. However, the higher quality, New Generation DDGS can be added at higher amounts (Table 2). Occasionally, there may be an initial reduction in feed intake if DDGS is added to diets at a higher level. Therefore it is recommended to start at a lower level and then increase DDGS additions up to the maximum inclusion level to avoid this problem.

| 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% |

**Table 2. Recommended inclusion rates of DDGS in swine diets.**

Grow-finish pigs can perform normally on diets containing 30% DDGS. However, at this level, the bellies become "soft" due to the increase in unsaturated fats coming from the DDGS. Therefore, grow-finish diets should not exceed 20% DDGS if pork quality is a concern.

There have been numerous field reports and observations that 10-20% DDGS in growing-finishing diets reduces the incidence/severity of ileitis and Hemorrhagic Bowel Syndrome (HBS). However, controlled research trials have not been able to consistently demonstrate this effect. Therefore, caution should be used when applying any economic value to DDGS' health effects unless it is known to work in a specific operation. For more information on DDGS, go to http://www.ddgs.umn.edu/.

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 fiber. 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 (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.

Stillage is the wet mash resulting from either on-farm alcohol production from corn or from the New Generation plants. It is usually fed wet, which limits the pig's ability to consume large quantities. On an air-dried basis (90% dry matter), protein level ranges from 11 to 27% and lysine from 0.2 to 0.6%. Dry matter content of the wet product varies from 7 to 20% depending upon the thoroughness of separation of liquids from solids. Liquid stillage may be offered free choice along with a typical growing diet to growing-finishing pigs. A management concern for stillage when feeding to swine is that it must be picked up daily and can not be used in a "dry" feeding system. Stillage is better utilized by ruminants than by swine because of the poor protein quality and the high fiber and water content.

## Grain Milling By-Products

Corn dry milling is the method of producing cornmeal, hominy, and corn grits for human consumption, and by-products such as hominy feed and corn bran for consumption by animals.

Corn bran is the outer coating of the corn kernel including the hull and small amounts of the underlying gluten. It contains 5 to 10% crude fiber, and consequently, is lower in energy (1,200 kcal ME/lb) than the whole corn grain. It is similar to whole corn 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.

Hominy feed is a mixture of corn bran, corn germ and part of the starchy portion of the kernel. Hominy feed is similar in analysis to corn, being higher in fat (7%) and fiber (6%) than corn but similar in energy (1,400 kcal ME/lb), (protein ~10%), lysine (0.3%), and tryptophan (0.1%) concentrations. It can replace corn in swine diets on an equivalent basis.

Corn wet milling is the process of producing cornstarch and corn oil for human consumption. In the wet milling process a bushel (56 lbs) of No. 2 yellow corn yields 31.5 lbs of starch, 3.5 lbs of germ, 9.2 lbs of gluten feed, and 2.7 lbs of gluten meal. Corn oil is extracted from the germ, and the residue is added to the gluten feed.

Corn gluten feed is a mixture of gluten meal and bran and may contain some solubles and part of the germ. On an air-dried basis corn gluten feed contains about 22% protein but is low in lysine (0.6%), tryptophan (0.1%), and energy (1,100 kcal ME/lb). On an energy basis corn gluten feed is worth about 70% of that of corn. Because of its high fiber (10%) and low energy value for swine, corn gluten feed is better utilized by cattle.

Corn 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. Because of its cryptoxanthine (yellow) content, corn gluten meal is used primarily for poultry in layer diets for egg yolk color and in broiler diets for skin color.

By-products of milling wheat for flour consist primarily of the bran and aleurone layers of the kernel and the germ. Wheat flour by-products are generally identified by their fiber level. A wheat milling by-product with more than 9.5% fiber is wheat bran; that with less than 9.5% fiber may be classified as wheat middlings; if fiber is less than 7%, it's wheat shorts; and that with less than 4% fiber is red dog.

Wheat bran typically contains about 15% protein, 0.6% lysine, 0.18% tryptophan, and 1.15% phosphorus. The phosphorus in bran is poorly available, and because of the high fiber content (11%) the energy value (890 kcal ME/ lb) is low. Wheat bran may be used as a laxative agent in sow diets around farrowing, but because of its low ME value, it is not recommended for growing pig or lactation diets.

Wheat middlings and wheat shorts are similar in nutritional value. They both consist of portions of flour, bran, aleurone layer, and germ from the flour milling process. Both are considerably higher in energy value (1,300 to 1,400 kcal ME/lb) than bran. They contain about 16% protein, 0.6% lysine, and 0.18% tryptophan. They have about 0.9% phosphorus, which is poorly available. Middlings and shorts may constitute up to 10% of corn-soybean meal growing-finishing pig diets if in the meal form, and up to 30% of the diet if it is pelleted. Middlings and shorts replace portions of the corn and soybean meal on an equal lysine basis. These by-products have good pellet binding properties and are used extensively in commercially-pelleted swine feeds.

There are three by-products of processing rice grain for human consumption. These are rice bran, fat extracted rice bran, and rice polishings.

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/lb) also varies depending upon the amount of rice hulls included in the bran. The high fiber 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 /lb., but the problem of rancidity in storage is eliminated.

Rice polishings 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 polishings and rice bran may be included in growing-finishing diets at levels of 20 to 30% with satisfactory performance. The cost of transporting these rice by-products from the source of production and processing (Arkansas, Texas, and Louisiana in the U.S.A.) virtually eliminates them from consideration by swine producers in the upper Midwest.

## 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 corn in corn-soybean meal growing-finishing and sow diets and up to 20% in starter diets. The salt content may be fairly high, and the standard salt supplementation could be deleted. Keep water available for the pigs at all times.

## Milk By-Products

Milk by-products have a concentration and balance of nutrients that make them desirable as swine feeds (Table 3). They are very 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.

Liquid milk from surplus production or that which has not been sold within a prescribed time after processing may be available for swine feeding. Whole milk contains about twice the energy density but about the same lysine level as skim milk (Table 3). Milk may be fed to all classes of swine but is best suited for pigs from weaning through market weight. About 9.5 lbs of liquid skim milk is equivalent to 1 lb of soybean meal (44%) on an energy and lysine basis.

Milk that has soured under sanitary conditions may be fed. However, fresh milk is best for young pigs. Care should be taken to feed either sweet (fresh) or sour milk rather than changing from one to another since such changes may cause scouring. Avoid storing unprocessed milk under unsanitary conditions to reduce the growth of organisms that could threaten swine health. Milk packaged for human consumption may require special equipment or additional labor to remove it from cartons.

Liquid buttermilk is produced from the manufacture of butter and has about the same feeding value as skim milk if it has not been diluted by churn washings. Condensed buttermilk (semi-solid) is made by evaporating buttermilk to about one-third of its original weight. Thus, 1 lb of condensed buttermilk is equivalent to 3 lb of liquid buttermilk.

Dried buttermilk contains less than 8% moisture, 32 to 35% crude protein, and 6% fat. One pound of dried buttermilk is equivalent to about 10 lbs of liquid buttermilk or 3 lbs of condensed buttermilk. Dried buttermilk is an excellent feed but is generally too expensive to be used in swine diets except for starter diets. Feeding guidelines that apply to dried skim milk also apply to dried buttermilk.

Dried skim milk (DSM), produced from roller-drying or spray-drying of low fat milk, contains about 50% lactose and 33% of a very high quality protein (Table 3). 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, 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 (ex: reduced cost due to government programs) it can be fed in all phases of swine production.

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 .05% high available phosphorus.

Liquid sweet whey is best suited for pigs from 50 lbs 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.

The greatest economic benefit occurs when liquid sweet whey replaces soybean meal or other supplemental protein ingredients used in growing-finishing pig diets. To achieve these savings, liquid sweet whey should be available continuously and be provided free choice with ground corn (or sorghum, wheat, or barley) fortified with vitamins and minerals. Drinking water should be withheld so that pigs consume ample whey to meet their need for supplemental lysine, the first limiting amino acid.

Daily whey intake will increase until pigs reach 130 lbs when it will average 3.5 gallons per head per day. When fed in this manner, liquid sweet whey can replace 100 lbs of soybean meal (44% crude protein) per pig from 40 lbs to market weight. Nipple drinkers with strainers removed or troughs have been used in free choice feeding. To assure adequate access of pigs to liquid whey, the amount of drinking space or nipple drinkers should be doubled over that used for water. Although liquid sweet whey has the greatest economic benefit when substituted for supplemental protein, it can be partially substituted for complete feed by mixing the dry diet in a 5:1 ratio with whey to form a slurry. This method will reduce dry feed use 25 to 30%. The slurry distribution system should have main lines that continuously recycle the slurry back to the mixing tank and add new feed and whey as needed. Dry feed must be finely ground so that it will pass through a 0.1 in. opening to prevent blockage of distribution lines. Lines should be dropped from the main line to each pen and should be fitted with a valve to control feed delivery to coincide with the pig's needs. The entire system should be cleaned frequently to prevent yeast growth and reduced palatability.

Fresh liquid sweet whey must be delivered daily. Up to 40% of the nutrients can be lost during a 48-hour storage period, and the acid produced will decrease intake. High quality sweet whey that has a consistent pH and temperature is important to minimize digestive upsets.

Liquid whey is corrosive and reduces the life of facilities and equipment. Storage tanks, troughs and distribution equipment should be made of plastic, porcelain, or stainless steel. Storage tanks should be cleaned at least once a week to inhibit yeast growth that causes off-flavor and reduces palatability. Liquid whey, especially acid whey, corrodes concrete slats and solid floors. Feeding liquid whey will increase manure volume by twofold to threefold and can produce a wet environment. Manure handling systems should be designed to handle liquid manure and have sufficient capacity to store manure during periods when spreading on the field is not possible.

Liquid acid whey is the by-product from cottage cheese production. Acid whey nutrient composition is similar to that of sweet whey (Table 3). The principle difference is the greater acidity (pH 4.0) of acid whey. Acid whey is not as palatable as sweet whey, and voluntary intake is not sufficient to adequately supply the lysine needed to supplement a ground corn diet fortified with vitamins and minerals.

Management of liquid acid whey is similar to that for sweet liquid whey except that acid whey can be stored up to a week without deterioration, while sweet whey must be freshly supplied and consumed daily. Dried whey is produced by spray-drying or roller-drying liquid whey. The dried product contains 65 to 70% lactose, 13% crude protein, 0.8% lysine, 0.9% calcium, 0.7% phosphorus, and about 5% salts of sodium and potassium.

Dried whey contains high quality protein and nutrients that are readily digested by the young pig. Since dried whey is much less expensive than dried skim milk and has many of the benefits of milk, it is an attractive substitute for DSM in starter feeds.

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 13 lbs at weaning, while pigs weighing under 13 lbs may benefit from dried whey in the diet for 2 to 3 weeks postweaning. 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.

Dried whey may be included in diets of growing-finishing pigs and breeding animals when substitution is economical. Dried whey should be limited to 10% of the diet of older pigs, even when it enters the least-cost formula at greater levels, because lactase activity diminishes with age, and older pigs are unable to properly digest higher levels. Dried whey does not increase feed intake of either growing-finishing pigs or sows in lactation.

Dried whey can cause pelleting difficulty and can increase pellet hardness which reduces palatability. Dried whey diets may also attract moisture, causing feeds to bridge in feeders.

Dried whey should be free of brown or tan color which indicates overheating. This may cause decreased amino acid availability. Food grade (edible) dried whey contains less ash and has less variation in protein content and greater lysine content than feed grade whey. Food grade whey tends to support better performance of weanling pigs than feed grade whey.

Dried whey product or low lactose dried whey is produced by removing some of the lactose prior to drying. Dried whey product contains 40 to 50% lactose, 16% protein, 1.4% lysine, 1.7% calcium, and 1.0% phosphorus. It can be used in starter feeds with performance similar to that of dried whole whey. Up to 20% may be included in starter diets when substituted on a lysine equivalent basis.

## Meat By-Products

Animal harvesting and processing generally have three main by-products: animal fat (tallow and lard), blood meal (cooker-dried or flash-dried), and meat meal or meat and bone meal. Currently, while ruminant diets can not legally contain beef or poultry by-products, there is no such restriction for swine diets. Pigs can be fed diets containing meat by-products from pigs, cattle, poultry, etc.

**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/lb. 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), as well as free fatty acids. 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/lb.) increases, and the pig consumes fewer pounds 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 corn-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.

Animal fat may be added to the diet by melting and then dripping or spraying into the feed mixer when the diet is being prepared. Some dry-fat products on the market have good mixing and flow characteristics but are quite expensive.

There are several commercially available fat "blends" that contain one or more of the following: pork choice white grease, beef tallow, poultry fat, soybean oil, corn oil, and restaurant grease. Some are formulated on a "least cost" blend while others are a standard blend tailored to a specific market. Most often they are sold for less than straight choice white grease or vegetable oils and claim to have higher caloric content. From a production perspective, the ability of these blends to replace other energy sources appears to depend upon the ingredient quality, the blend of the particular load, and the type of diet being fed. For example, some blends perform well with finishing swine but are refused by lactating sows. If two fat sources are being blended together, moisture should not exceed 1%, free fatty acids 30%, impurities 0.5%, unsaponifiable material 3.5%, and total MIU 5% (moisture, impurities & unsaponifiable materials).

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 official specifications state that 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 (Table 3). The digestibility of protein and availability of amino acids in these products are not as high as that of soybean meal. In a corn-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.

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.

The newer drying processes include spray drying, ring drying, or steam drum drying. All of them are rapid drying procedures and result in a product called 'flash dried" blood meal. The lysine of flash dried blood meals is about 80% available. The first limiting amino acid in flash dried blood meal is isoleucine and limits the use of flash dried blood meals to 5% of the diet of growing pigs. A value of 7% lysine assigned to flash dried blood meal is a safe, conservative value to use in least cost formulation of swine rations. However, there is still variation in blood meal content between plants as well as between different batches at the same plant. Color can be used as a general indicator of blood meal quality. Light or tan-colored blood meal has a much higher feeding value than black or dark blood meal (over-heating in the drying process can decrease nutrient availability).

Hydolyzed hog hair is prepared from cleaned hair of slaughtered animals by heat and pressure to produce a byproduct suitable for animal feeding. It contains 94% crude protein (which is about 75% digestible) and 3.5% lysine (Table 3) of lower availability than the lysine of soybean meal. Its use should be limited to 2% or 3% in diets of growing-finishing pigs and sows and may replace an equal amount of soybean meal.

Feather meal is a by-product resulting from the hydrolysis under pressure of cleaned feathers from slaughtered poultry. 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.

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/lb (Table 3). Poultry by-product meal may be utilized similarly to meat meal in swine rations.

## Egg By-Products

Discarded eggs from candling stations and cull eggs and chicks from hatcheries are by-products of the egg industry.

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 (Table 3). 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.

Raw eggs in the shell are best utilized by growing-finishing pigs and are not recommended for young weanling pigs or sows. Raw egg white contains a protein (avidin) which binds the vitamin biotin, making it unavailable. Biotin deficiency has been observed in weanling pigs and sows but is seldom seen in growing-finishing pigs. Nevertheless, pigs fed raw eggs should be observed for signs of biotin deficiency, including cracked hoof pads and poor growth. This may be prevented by incorporating biotin into the vitamin-trace mineral premix to supply 100 mg to 200 mg of biotin per ton of feed.

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 (Table 3) 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 no more than 3% of the diet of growing-finishing pigs and sows. At this level it will replace the lysine in 2% of soybean meal and also replace the supplemental calcium.

## Vegetable By-Products

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. 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 corn in growing-finishing diets.

Several dried processed potato products are sometimes available for feeding to swine or other livestock. These include potato meal, potato flakes, potato slices, and potato pulp.

Potato meal is from cull potatoes that are sliced, dried, and then ground to a meal consistency. This dried raw potato meal is not well-digested by the pig and even when limited to 30% of the diet, there is often diarrhea and reduced performance. This product is uncooked, and both starch and protein are poorly digested. This product is better utilized by cattle than by pigs.

Potato flakes are prepared by steaming clean washed potatoes for 30 minutes in a tank in which pressure rises to 10 to 15 lbs/in$^2$. After they are steam-cooked, they are mashed, passed over drying rollers, and finally removed as thin flakes. Digestibility is good. Best performance is obtained when potato flakes are limited to 30 to 40% of the diet, but satisfactory performance has been obtained when potato flakes replace up to 50 to 60% of the cereals in the diets of starting, growing, and finishing pigs. Potato flakes contain 8 to 9% protein, 2 to 3% fiber, and about 75% starch. Metabolizable energy (about 1,600 kcal/lb) is equal to or higher than that of corn.

Potato slices are prepared by passing raw potato slices through a hot air rotating drier at 175° F for about 2 hours. This allows for both cooking and drying. Inadequate cooking could reduce their nutritive value. Potato slices may replace barley and corn in growing-finishing diets. Use up to 20% cooked-dried potato slices in the grower-diet and 40% in the finisher diet.

Potato pulp is a by-product of the starch industry and is the residue obtained after starch is extracted. Since potato pulp is uncooked, its palatability and digestibility are poor. It is better utilized by cattle.

Potato chips and French fries contain considerable vegetable fat taken up in deep frying. They consist of about 50% starch, 35% fat, 5% protein, and 3% minerals, mainly potassium and sodium salts. They have a high energy value (2,000 kcal ME/lb.) but little else of nutritional value.

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. Navy beans contain factors such as trypsin inhibitor and hemaglutinin, 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.

Cooked, air-dried (90% dry matter) cull navy beans are 57% digestible carbohydrates, 23% protein, 4% fiber, 4% minerals, and 1% fat. They contain about 1.5% lysine.

Field peas are used for human consumption, but can be also 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 peas' amino acid content is intermediate between corn 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 cystein, 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. Gestating and lactating sows can be fed 16 and 24% field peas, respectively.

## Sugar and Starch By-Products

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. 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.

Beet molasses and beet pulp are by-products of the production and refining of beet sugar. 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. However, this practice is not commonly recommended. Dried beet molasses may be used to a level of 10% (replacing corn) in the growing-finishing diet for good performance.

Corn molasses is a by-product of corn sugar (dextrose) manufacture from corn starch. Corn, cane, and beet molasses all have similar nutrient analyses, except that corn molasses contains practically no protein or calcium.

Salvage candy is any candy that is not marketable for human consumption including excess production, out-of-season, misshapen, or stale candy. Stale candy that never reaches the retailers shelf and outdated holiday candy are two major sources. The nutritive value of salvage candy varies greatly. If it contains peanuts or almonds it may contain a fairly high level of protein and would be more valuable than jellybeans, for example, which supply principally energy. Unless protein analyses are performed it would be best to assume no protein value and more soybean meal will need to be used in the diet when candy is substituted for corn. Depending on price, the cost of additional protein may more than offset the value of corn saved. Salvage candy could probably replace up to one-half of the corn in growing-finishing diets if amino acids are properly balanced.

## By-Product Nutrient Composition

The metabolizable energy density (kcal/lb, as fed) and analyses (%, as fed) of dry matter, fiber, protein, lysine, tryptophan, calcium, and phosphorus of by-products are summarized in Table 3. By-products vary greatly in their nutrient content and also in the availability of the nutrients to swine! Average values are listed. If a by-product is to make up a substantial part of the diet, it would be well to get one or more analyses of dry matter, crude protein, lysine, calcium, and phosphorus. Many of the state Departments of Agriculture have laboratories capable of analyzing feeds or feed ingredients for these components. In addition, there are feed company, university, and independent laboratories. However, make sure any laboratory you use is AOAC certified, or the results may be incorrect.

## Calculating the Value of By-Products

Formulas have been developed and are presented in Table 4 to enable you to determine the value of air-dried by-products that may be incorporated into grower diets. The system of by-product evaluation presented is based upon the value of the ingredients in a standard corn-soybean meal grower diet which are replaced by the by-product. For example, the value (¢/lb) of dried whey product is 0.98 (100C + 96S + 4P) / 200, in which 200 lbs of this by-product will replace 100 lbs of corn, 96 lbs of soybean meal, and 4 lbs of dicalcium phosphate. If the current price of corn (C) is 4.5¢/lb ($2.52/bu), soybean meal (S) is 9¢/ lb, and dicalcium phosphate is 14¢/lb., then the value of dried whey product is:

**0.98 (100 x 4.5 + 96 x 9 + 4 x 14) / 200 = 6.7¢/lb.**

Therefore, any time dried whey is less than 6.7¢/lb, it is economical to be used in the diet at the 200 lb/ton inclusion rate, but if it's more than 6.7¢/lb, it's too expensive to be used. For example, if dried whey is 6.8¢/lb, it would be too expensive to include in the diet with the corn-SBM-dicalcium phosphate prices used.

It should be noted that these economics are based on the assumption of using high quality by-products. If the by-products used do not meet or exceed the nutrient concentrations listed in Table 3, or are of poor quality due to processing (over-heating, etc), these economic estimates are not valid.

The formulas were developed by balancing the grower diet on lysine and phosphorus, two of the crucial and costly nutrients and developing a coefficient to account for metabolizable energy (ME) density. This was accomplished by dividing the ME of the diet containing dried whey product (1436 kcal/lb) by the ME of the standard corn-soybean meal grower diet (1,458 kcal/lb). Thus, 1,436/1,458 = 0.98. G Growing-finishing pigs that are full-fed will consume diets to equal ME intake. Therefore, it will take slightly more of the diet with dried whey product (2% more) to equal the kilocalories of ME of an equal amount of the standard corn-soy grower diet. Consequently, the value of the diet containing this product is only 98% of the value of the standard diet.

| By-Product | Metabolizable Energy | Dry Matter | Crude Fiber | Protein | Lys | Trp | Ca | P |
|---|---|---|---|---|---|---|---|---|
| **Milk By-Products** | kcal/lb. | | | % | | | | |
| Liquid whole milk | 290 | 12.8 | 0.0 | 3.4 | 0.25 | 0.05 | 0.12 | 0.09 |
| Dried whole milk | 2,200 | 97.0 | 0.1 | 26.0 | 2.09 | 0.37 | 0.91 | 0.75 |
| Liquid skim milk | 160 | 9.5 | 0.0 | 3.4 | 0.30 | 0.05 | 0.12 | 0.10 |
| Dried skim milk | 1,520 | 94.0 | 0.3 | 33.5 | 2.50 | 0.45 | 1.25 | 1.00 |
| Liquid buttermilk | 155 | 9.7 | 0.0 | 3.3 | 0.26 | 0.04 | 0.13 | 0.09 |
| Condensed buttermilk | 493 | 29.1 | 0.1 | 10.8 | 0.78 | 0.12 | 0.44 | 0.26 |
| Dried buttermilk | 1,380 | 93.0 | 0.4 | 32.0 | 2.20 | 0.47 | 1.32 | 0.93 |
| Liquid sweet whey | 103 | 7.1 | 0.0 | 0.9 | 0.07 | 0.01 | 0.05 | 0.05 |
| Liquid acid whey | 95 | 6.6 | 0.0 | 0.8 | 0.07 | 0.02 | 0.10 | 0.08 |
| Dried whey | 1,445 | 94.5 | 0.2 | 12.0 | 0.80 | 0.13 | 0.90 | 0.70 |
| Dried whey product | 1,240 | 92.0 | 0.2 | 16.0 | 1.40 | 0.22 | 1.69 | 1.13 |
| **Meat By-Products** | | | | | | | | |
| Animal fat | 3,550 | 95.0 | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Meat meal | 1,200 | 92.0 | 0.4 | 55.0 | 3.00 | 0.35 | 8.20 | 4.10 |
| Meat and bone meal | 1,100 | 93.0 | 0.4 | 50.0 | 2.50 | 0.28 | 10.10 | 5.05 |
| Flash dried blood meal | 1,300 | 90.0 | 0.6 | 85.0 | 7.00 | 1.00 | 0.30 | 0.25 |
| Hydrolyzed hog hair | 1,000 | 95.0 | 1.0 | 94.0 | 3.50 | 0.50 | 0.20 | 0.80 |
| Hydrolyzed feather meal | 1,000 | 94.6 | 1.0 | 85.0 | 1.94 | 0.50 | 0.20 | 0.80 |
| Poultry by-product meal | 1,300 | 93.0 | 1.0 | 55.0 | 3.70 | 0.45 | 4.40 | 2.50 |
| **Egg By-Products** | | | | | | | | |
| Bloodspot eggs | 500 | 40.0 | 0.0 | 10.0 | 0.50 | 0.10 | 6.00 | 0.20 |
| Hatchery by-product meal-broiler chick | 800 | 90.0 | 0.0 | 22.2 | 1.16 | 0.22 | 24.60 | 0.33 |
| Hatchery by-product meal-egg chick | 1,000 | 90.0 | 0.0 | 32.3 | 1.83 | 0.30 | 17.20 | 0.60 |
| **Grain By-Products** | | | | | | | | |
| Corn bran | 1,200 | 89.0 | 8.5 | 8.0 | 0.20 | 0.10 | 0.03 | 0.20 |
| Hominy feed | 1,400 | 90.0 | 5.5 | 10.4 | 0.30 | 0.10 | 0.05 | 0.40 |
| Corn gluten feed | 1,100 | 90.0 | 10.0 | 22.0 | 0.60 | 0.12 | 0.30 | 0.70 |
| Corn gluten meal | 1,400 | 91.0 | 2.0 | 42.0 | 0.80 | 0.23 | 0.03 | 0.45 |
| Wheat bran | 890 | 90.0 | 11.0 | 15.0 | 0.56 | 0.18 | 0.10 | 1.15 |
| Wheat middlings | 1,300 | 88.0 | 7.0 | 16.0 | 0.64 | 0.18 | 0.10 | 0.90 |
| Rice bran | 1,350 | 91.0 | 12.0 | 13.0 | 0.60 | 0.10 | 0.10 | 1.30 |
| Rice bran, fat extracted | 1,200 | 91.0 | 11.4 | 16.0 | 0.60 | 0.18 | 0.13 | 1.32 |
| Rice polishings | 1,500 | 90.0 | 4.0 | 12.0 | 0.50 | 0.10 | 0.05 | 1.20 |
| Brewers dried grains | 1,000 | 92.0 | 13.0 | 25.0 | 0.90 | 0.30 | 0.25 | 0.50 |
| Distillers dried grains | 1,300 | 93.0 | 11.0 | 25.0 | 0.60 | 0.20 | 0.10 | 0.35 |
| Distillers dried grains w/solubles, Old Generation | 1,540 | 91.0 | 10.0 | 27.0 | 0.70 | 0.20 | 0.15 | 0.70 |
| “” New Generation | 1,633 | 91.0 | 7.8 | 27.0 | 0.70 | 0.20 | 0.06 | 0.79 |
| Stillage | 150 | 10.0 | 1.0 | 3.0 | 0.08 | 0.02 | 0.02 | 0.10 |
| Dried bakery by-product | 1,650 | 92.0 | 1.0 | 10.0 | 0.30 | 0.10 | 0.06 | 0.47 |
| **Starch and Sugar By-Products** | | | | | | | | |
| Cane molasses | 1,060 | 77.0 | 0.0 | 4.5 | 0.20 | 0.10 | 0.81 | 0.08 |
| Dried cane bagasse | 500 | 91.5 | 44.5 | 2.0 | 0.10 | 0.05 | 0.60 | 0.20 |
| Beet molasses | 1,060 | 77.5 | 0.0 | 6.6 | 0.15 | 0.05 | 0.12 | 0.03 |
| Dried beet pulp | 1,020 | 90.6 | 18.2 | 8.7 | 0.65 | 0.09 | 0.68 | 0.09 |
| Corn molasses | 1,200 | 73.0 | 0.0 | 0.4 | 0.00 | 0.00 | 0.04 | 0.04 |
| Salvage candy | 1,600 | 93.5 | 0.0 | 3.0 | 0.00 | 0.00 | 0.06 | 0.06 |
| **Vegetable and Fruit By-Products** | | | | | | | | |
| Cooked cull potatoes | 370 | 22.0 | 0.7 | 2.2 | 0.06 | 0.02 | 0.02 | 0.06 |
| Potato meal | 1,100 | 90.0 | 2.0 | 9.0 | 0.25 | 0.10 | 0.10 | 0.30 |
| Potato flakes | 1,600 | 90.0 | 2.0 | 9.0 | 0.25 | 0.10 | 0.10 | 0.30 |
| Potato slices | 1,500 | 90.0 | 2.0 | 9.0 | 0.25 | 0.10 | 0.10 | 0.30 |
| Potato pulp | 1,000 | 90.0 | 6.0 | 7.7 | 0.20 | 0.10 | 0.10 | 0.30 |
| Potato chips and fries | 2,000 | 90.0 | 2.0 | 5.0 | 0.20 | 0.10 | 0.10 | 0.30 |
| Cooked cull dry beans | 1,400 | 90.0 | 4.0 | 23.0 | 1.50 | 0.20 | 0.20 | 0.40 |

**Table 3. By-product nutrient composition (as fed).**

## Summary

US 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 sources.

| By-Product | Max Use % | Formula Calculating Value of By-Product (cents/lb)[a] |
|---|---|---|
| Dry milk by-products | | |
| Dried whole milk | 10 | 1.05[b](50C+148S+2P)*÷200 |
| Dried skim milk | 10 | 1.01(20C+178S+2P)÷200 |
| Dried buttermilk | 10 | 0.99(40C+158S+2P)÷200 |
| Dried whey | 10 | 1.00(146C+52S+2P)÷200 |
| Dried whey product | 10 | 0.98(100C+96S+4P)÷200 |
| **Dry Meat By-Products** | | |
| Animal fat | 6 | 1.08(132C–10S–2P)÷120 |
| Meat meal | 5 | 1.00(-32C+115S+17P)÷100 |
| Meat and bonemeal | 5 | 1.00(-21C+97S+24P)÷100 |
| Flash dried blood meal | 5 | 0.99(-161C+265S-4P)÷100 |
| Hydrolyzed hog hair | 3 | 0.99(-23C+83S)÷60 |
| Hydrolyzed feather meal | 3 | 0.99(12C+48S)÷60 |
| Poultry by-product meal | 3 | 1.00(-32C+88S+4P)÷60 |
| **Dry Hatchery By-Products** | | |
| Hatchery by-product meal, broiler type chick | 3 | 0.99(30C+30S)÷60 |
| Hatchery by-product meal, egg chick type | 3 | 0.99(15C+45S)÷60 |
| **Grain By-Products** | | |
| Corn bran | 10 | 0.98(194C+6S)÷200 |
| Hominy feed | 60 | 0.96(1,164C+36S)÷1,200 |
| Corn gluten feed | 20 | 0.95(336C+64S)÷400 |
| Corn gluten meal | 20 | 0.98(306C+94S)÷400 |
| Wheat bran | 10 | 0.96(142C+58S)÷200 |
| Wheat middlings | 30 | 0.96(500C+100S)÷600 |
| Rice bran | 20 | 0.98(336C+64S)÷400 |
| Rice bran, fat extracted | 10 | 0.98(164C+36S)÷200 |
| Rice polishings | 20 | 1.05(352C+48S)÷400 |
| Brewers dried grains | 10 | 0.97(141C+59S)÷200 |
| Distillers dried grains | 10 | 0.98(164C+36S)÷200 |
| Distillers dried grains, w/solubles (Old generation) | 10 | 1.00(156C+44S)÷200 |
| “ “ (New generation) | See DDGS section of text | |
| Bakery and sugar by-products | | |
| Dried bakery by-product | 40 | 1.04(773C+27S)÷800 |
| Cane molasses | 10 | 0.97(194C+6S)÷200 |
| Dried cane bagassse | 5 | 0.97(96C+4S)÷100 |
| Beet molasses | 10 | 0.97(198C+2S)÷200 |
| Dried beet pulp | 5 | 0.98(76C+24S)÷100 |
| Corn molasses | 10 | 0.98(209C-9S)÷200 |
| Salvage candy | 20 | 1.01(427C-27S)÷400 |
| **Dry Potato and Bean By-Products** | | |
| Potato meal | 20 | 0.95(389C+11S)÷400 |
| Potato flakes | 40 | 1.03(788C+12S)÷800 |
| Potato slices | 40 | 1.00(788C+12S)÷800 |
| Potato pulp | 10 | 0.97(194C+6S)÷200 |
| Potato chips and fries | 30 | 1.10C |
| Cooked cull dry beans | 15 | 0.99(160C+140S)÷300 |

**Table 4. Formulas for calculating the value of dry by-products in a corn-soybean meal (44) grower diet. [a] To calculate value of by-product in cents per pound, enter the current prices of corn (C), soybean meal 44 (S), and dicalcium phosphate (P) in cents per pound. For example, if the current price of corn is 4.5¢/lb. ($2.52/bu.), soybean meal is 9¢/lb. ($180/ton), and dicalcium phosphate is 14¢/lb. ($280/ton), then the value of dried whole milk is 1.05 (50x4.5¢ + 148x9¢ + 2x14¢)÷200=8.3¢/lb. At these prices if you can obtain the dried whole milk for less than 8.3¢/lb. ($166/ton) you might consider purchasing this by-product but only after you have satisfactorily considered the important questions at the beginning of this fact sheet. [b] This coefficient is obtained by dividing the ME value of this diet (1,530 kcal/lb) by the ME value of the corn-soy standard diet (1,458 kcal./lb). Thus, 1,530÷1,458=1.05. *Numbers within the parentheses are the pounds of corn, soybean meal, and dicalcium phosphate replaced by the by-product. For example, 200 lbs of dried whole milk replaces 50 lbs of corn, 148 lbs of soybean meal, and 2 lbs of dicalcium phosphate.**