By-Products in Swine Diets – Pork Industry Handbook

Michigan State University Cooperative Extension Service
Elwyn R. Miller, Michigan State University; Palmer J. Holden, Iowa State University; Vernon D. Leibbrandt, University of Wisconsin

Issued October 1987
10 pages

NUTRITION

Extension Bulletin E-2103
October 1987 (New)

pork industry handbook

Cooperative Extension Service • Michigan State University

By-products in Swine Diets

Authors:
Elwyn R. Miller, Michigan State University
Palmer J. Holden, Iowa State University
Vernon D. Leibbrandt, University of Wisconsin

Reviewers:
Vivian Baathe, Indianola, Iowa
Ted and Ann Diehl, Indianola, Iowa
James D. Green, Columbia, Missouri
Lynn A. Jones, Memphis, Tennessee
Ronnie L. Moser, University of Minnesota
Howard and Marilyn Tucker, Eden, Maryland

Feed costs comprise the major portion of the cost of pork production. While most of the feed for pork produced in developed countries consists of grains and oilseed meals, many by-products are supplied for swine diets by the industries in 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 on the basis of their appearance in least cost formula specifications. Other by-products may be major ingredients in unique swine diets because of their abundant supply from nearby sources.

The purpose of this fact sheet is to identify by-products that are useful in swine diets, to describe how these by-products result from processing, to present their nutrient value, and to 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? Toxic substances, disease organisms, 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 eliminated or neutralized inexpensively.

2. Is the nutrient composition suited to swine feeding? Check 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. By-products with low nutrient density and quality should generally be avoided, except, perhaps for gestating or open sows.

3. Is the value of the by-product greater than the cost of incorporating the by-product into the diet? The major costs in the swine diet are for ingredients that provide energy, lysine, or phosphorus. If the by-product does not provide one or more of these nutrients at a competitive cost, it should be dropped from consideration. The major ingredients of conventional swine diets (grains and soybean meal) provide most of the requirements for energy and lysine (plus the other indispensable amino acids) and about one-half of the total phosphorus requirement. The by-product must replace a portion of these major ingredients without increasing cost to receive much consideration.

4. 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, waste disposal complications, increased risk of animal health problems, and reduced performance caused by by-product variability. Experience of others and accurate cost of production records for the existing feeding program are valuable tools when projecting costs.

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 the past price patterns for conventional ingredients is necessary for making wise decisions.

6. Is by-product availability and quality sufficiently consistent to support longtime use? A steady supply of by-product, a reliable price, and uniform quality are essential to consistent cost savings.

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

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 in its usage.

Milk By-products

Milk by-products have a concentration and balance of nutrients that make them desirable as swine feeds (Table 6). 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 6). Milk may be fed to all classes of swine but is best suited for pigs from weaning through market weight. About 9.5 lb. of liquid skim milk is equivalent to 1 lb. of soybean meal (44%) on an energy and lysine basis.

Daily nutrient requirements of growing-finishing pigs may be met by feeding the rations shown in Table 1. One gallon of milk (8 lb.) will provide the daily supplemental protein needs of a pig that receives adequate energy from corn (fortified with minerals and vitamins) at any weight from 50 lb. to market. From an applied feeding standpoint, pigs from 40 lb. to market weight may be fed 1 gal. of milk daily plus continual access to a self-feeder containing the feed mixture shown in Table 2.

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 (semisolid) 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 lb. of liquid buttermilk or 3 lb. 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, produced from roller-drying or spray-drying of low fat milk, contains about 50% lactose and 33% of a very high quality protein (table 6). This by-product is very palatable and highly digestible. On an available lysine basis it is equal to soybean meal (44%). Because dried skim milk is expensive compared to other feed ingredients, its use should be limited to prestarter diets. This is a diet 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 prestarter diets.

Liquid sweet whey is the by-product from making hard cheeses (Cheddar, Munster, and Monterey Jack). When

Table 1. Rations for pigs consuming 1 gallon (8 lb.) of whole milk daily.

	Pig weight, pounds					
Daily diet	**50**		**100**		**150**	
	Pounds daily					
Milk	8		8		8	
Ground shelled corn	2		3.5		6	
Dicalcium phosphate	.02		.02		.03	
Calcium carbonate	.02		.03		.04	
Salt	.01		.01		.02	
Vitamin-trace mineral mix[a]	.01		.01		.02	
Daily energy and nutrient intake[b]						
	Consumed	**Required**	**Consumed**	**Required**	**Consumed**	**Required**
	kcal					
Metabolizable energy	4,968	4,740	7,178	6,320	10,968	9,480
	grams					
Lysine	13.2	10.5	14.9	12.2	17.7	17.1
Calcium	10.2	9.0	12.0	11.0	15.0	15.0
Phosphorus	7.6	7.5	9.4	9.0	13.2	12.0

[a] PIH-23, *Swine Rations*, Table 17. March 1983.

[b] *Nutrient Requirements of Swine* (1979). National Research Council, National Academy of Sciences.

Table 2. Feed mixture to be self-fed to pigs from 40 pounds to market weight and consuming one gallon of whole milk daily.

Ingredient	Pounds per ton
Ground shelled corn	1,950
Dicalcium phosphate	20
Calcium carbonate	20
Salt	7
Vitamin-trace mineral mix[a]	3
	2,000

Daily energy and nutrient intake[b]

	50-pound pig		100-pound pig		150-pound pig	
	Consumed	Required[c]	Consumed	Required[c]	Consumed	Required[c]
			kcal			
Metabolizable energy	4,918	4,740	7,078	6,320	10,968	9,480
			grams			
Lysine	13.1	10.5	14.7	12.2	17.4	17.1
Calcium	10.2	9.0	14.6	11.0	21.8	15.0
Phosphorus	7.6	7.5	10.6	9.0	15.6	12.0

[a] PIH-23, *Swine Rations*, Table 17. March 1983.

[b] Assuming that the 50-lb., 100-lb., and 150-lb. pigs consume 2, 3.5, and 6 lb. of the feed mixture daily, respectively.

[c] *Nutrient Requirements of Swine* (1979). National Research Council, National Academy of Sciences.

the cheese curds are separated, the liquid whey has a temperature of about 100°F, is slightly acid (pH 6.0 to 6.5), and contains about 5% lactose, 1% high quality protein, and .05% phosphorus of high availability.

Liquid sweet whey is best suited for pigs from 50 lb. to market weight. While it may be fed to sows in gestation, 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 lb. when it will average 3.5 gal. per head per day (Table 3). When fed in this manner, liquid sweet whey can replace 100 lb. of soybean meal (44% crude protein) per pig from 40 lb. to market weight.

Nipple drinkers with strainers removed or troughs have been used in free choice feeding of liquid sweet whey. 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.

Table 3. Consumption of liquid sweet whey provided continuously free choice with ground corn fortified with vitamins and minerals.[a]

Pig weight	Daily whey intake
lb.	gal.
50	2.0
75	2.5
100	3.0
125	3.5
150	3.5
200	3.5

[a]Reported by N.J. Benevenga et al., University of Wisconsin.

Fresh liquid sweet whey *must be delivered daily*. Up to 40% of the nutrients can be lost during a 48-hr. 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. Cheese press drippings that may contain up to 10% salt *should not* be added to liquid whey. Wash water *should not* be added to whey because liquid intake must increase to compensate for the dilution caused by adding the extra volume.

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 whey 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 waste 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 6). The principal 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. Therefore, a 13% crude protein complete finishing feed should be fed free choice with liquid acid whey to growing-finishing pigs from 50 lb. to market weight. Pigs will decrease their intake of dry feed by 30% if acid whey is the only liquid available compared to what they would consume if water were available.

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 milk 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 lb. at weaning, while pigs weighing under 13 lb. may benefit from dried whey in the diet for 2 to 3 weeks postweaning. 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% 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 slaughtering 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.*

Animal fat is obtained from the tissues of slaughtered animals by commercial processes of rendering or extracting. Animal fat consists primarily of true fats (triglycerides) and can be classified into four types: lard, 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 soapmaking. 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.

Growing-finishing pigs that are full-fed 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.

Addition of about 10% of animal fat to the sow's diet in late gestation and early lactation may improve livability of nursing pigs through the first few days of life by tending to increase birth weight and energy reserve of newborn pigs. This trend is only in herds where livability is less than 80% and the benefit is not dramatic (about 3% improvement in livability).

Animal fat may be added to the diet by melting and then dripping 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.

Meat meal and meat and bone meal are made from the trimmings at slaughter. 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 when incorporated into the diet.

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 6). 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 meals is a safe, conservative value to use in least cost formulation of swine rations. In a growing pig diet, 50 lb. of flash dried blood meal (FDBM) plus 80 lb. of ground shelled corn (C) can replace 130 lb. of soybean meal (SBM) containing 44% protein. Thus, with corn at $2.40/bu. (4.3¢/lb.) and soybean meal (44%) at $172/ton (8.6¢/lb.) the value of flash dried blood meal is:

$$50\ FDBM + 80C = 130\ SBM$$

$$FDBM = \frac{130\ SBM - 80C}{50} = \frac{\$11.18 - \$3.44}{50}$$

$$= 15.5¢/lb. = \$310/ton$$

Hydolyzed hog hair is prepared from cleaned hair of slaughtered animals by heat and pressure to produce a by-product suitable for animal feeding. It contains 94% crude protein (which is about 75% digestible) and 3.5% lysine (Table 6) 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 slaughter. 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 6). 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 6). Studies with finishing pigs in which one-third of the energy of the diet was from eggs showed satisfactory performance. This would indicate that growing-finishing pigs could safely consume a dozen eggs in the shell daily. This would eliminate the need for supplemental calcium and reduce the supplemental protein need. A feed available in a self-feeder along with the dozen eggs per pig daily may consist of the following formula:

Ingredient	lb./ton
Ground shelled corn	1,858
Soybean meal (44% protein)	100
Dicalcium phosphate	30
Salt	7
Vitamin-trace mineral mix[a]	5
	2,000

[a]PIH-23, *Swine Rations*, Table 17.

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 being 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 6) 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.

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 contain 5 to 10% crude fiber, and consequently, is lower in energy (ME=1,200 kcal/lb.) than the whole corn grain. It is similar to whole corn grain in protein, lysine, calcium, and phosphorus. 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 (ME=1,400 kcal/lb.), protein (10%), lysine (0.3%), and tryptophan (0.1%) concentrations. It could 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 of no. 2 corn (56 lb.) yields 31.5 lb. of starch, 3.5 lb. of germ, 9.2 lb. of gluten feed, and 2.7 lb. 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 (ME=1,100 kcal/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 rations for egg yolk color and in broiler rations 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 (ME=890 kcal/lb.) is low. Wheat bran is a good laxative agent to incorporate into the sow diet 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 (ME=1,300 to 1,400 kcal/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 30% of corn-soybean meal growing-finishing pig diets, replacing 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 (ME=1,350 kcal/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 (ME=1,200 kcal/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.

Grain Fermentation By-products

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

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.

Distillers dried grains is the residue remaining after the removal of alcohol and water from a yeast-fermented grain mash. The coarse material may be dried and marketed as such, or the solubles may also be dried and added to the dried grains and sold as *distillers dried grains with solubles*. Distillers by-products are primarily from corn but may also be from barley or other grains. Although quite high in protein (25%) it retains the poor amino acid balance of grains and is particularly limiting in lysine (0.6%).

Stillage is the wet mash resulting from on-farm alcohol production with corn as the grain. 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 of the wet product varies from 7 to 20% depending upon the thoroughness of separation of liquids from solids. Liquid stillage may be kept for about a week without spoilage. Stillage may be offered free choice along with a typical growing diet to growing-finishing pigs. Stillage is better utilized by ruminants than by swine because of the poor protein quality and the high fiber and water content.

Bakery By-products

Dried bakery product is a mixture of bread, cookies, cake, crackers, and doughs. 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 (ME=1,650 kcal/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. Dried bakery product could be fed to growing-finishing pigs on a free-choice basis with a 20% protein, corn-soybean meal diet that contains increased (double) levels of minerals and vitamins.

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 around farrowing time.

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 sows around farrowing time as a laxative feed. 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.

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. 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. When making a corn-soybean meal-base mix diet to feed free choice with cooked potatoes, the protein source (soybean meal) and vitamin-mineral source (base mix as in Table 14 of PIH-23 *Swine Rations*) should be increased 50%. For example, a ton of a normal 16% protein grower diet consists of 1,540 lb. of corn, 400 lb. of soybean meal, and 60 lb. of a base mix. When feeding cooked potatoes free choice, 600 pounds of soybean meal and 90 pounds of base mix should be mixed with 1,310 lb. of corn. This mixture may be self-fed to growing-finishing pigs along with unlimited access to cooked potatoes.

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 lb./sq. in. 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 (ME=2,000 kcal/lb.) but little else of nutritional value. They could be used as shown in Table 4.

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. Grower, finisher, and gestation diets (ton mixes) using 15% of cooked, dried, and ground cull navy beans are shown in Table 5.

Table 4. Daily rations using potato chips or fries.

Ingredient	Growing-finishing pigs, wt. lb. 50	100	200	Sow in gestation
	Daily pounds per animal			
Shelled corn	1.5	2.0	3	1.5
Potato chips or fries	.5	1.5	3	1.5
40% commercial supplement	1.0	1.0	1	1.0
Total	3.0	4.5	7	4.0

Table 5. Ton mixes of grower, finisher and gestation diets using cooked and dried navy beans.

Ingredient	Grower	Finisher	Gestation
	Pounds per ton		
Corn, ground shelled	1,390	1,500	1,434
Soybean meal (44% CP)	260	150	200
Cull beans, dried cooked	300	300	300
Dicalcium phosphate	24	24	34
Calcium carbonate	16	16	20
Salt	7	7	7
Vitamin-trace mineral mix[a]	3	3	5
Total	2,000	2,000	2,000

[a]PIH-23, *Swine Rations*, table 17.

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 6. 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. Check with a livestock specialist in your state cooperative Extension service.

Calculating the Value of By-products

Formulas have been developed and are presented in Table 7 to enable you to determine the value of air-dried by-products which 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 lb. of this by-product will replace 100 lb. of corn, 96 lb. of soybean meal, and 4 lb. 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:

$$0.98\ (100 \times 4.5 + 96 \times 9 + 4 \times 14) \div 200 = 6.7¢/\text{lb.}$$

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. 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.

Table 6. By-product nutrient composition (as fed).

By-product	Metabolizable energy	Dry matter	Crude fiber	Protein	Amino acids Lys	Amino acids Trp	Ca	P
Milk by-products	kcal/lb.				Percent			
Liquid whole milk	290	12.8	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	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	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	0.9	0.07	0.01	0.05	0.05
Liquid acid whey	95	6.6	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	0.0	0	0.0
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	10.0	0.50	0.10	6.00	0.20
Hatchery by-product meal-broiler chick type	800	90.0	0	22.2	1.16	0.22	24.60	0.33
Hatchery by-product meal-egg chick type	1,000	90.0	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 with solubles	1,540	91.0	10.0	27.0	0.70	0.20	0.15	0.70
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	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	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	0.4	0	0.0	0.04	0.04
Salvage candy	1,600	93.5	0	3.0	0	0	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 7. Formulas for calculating the value of dry by-products in a corn-soybean meal (44) grower diet.

By-products	Max. use	Lys	ME	Ingredients per ton (2,000 lb.) Corn	Soy	Max.	Dical	Diet ME	Formula calculating value of by-product (cents/lb.)[a]
	(%)	(%)	(kcal/lb.)	(C)	(S)	(lb.)	(P)	(kcal/lb.)	
Corn-soy standard grower diet				1,550	400	0	24	1,458	
Dry milk by-products									
Dried whole milk	10	2.09	2,200	1,500	252	200	22	1,530	1.05[b](50C+148S+2P)*÷200
Dried skim milk	10	2.50	1,520	1,530	222	200	22	1,463	1.01(20C+178S+2P)÷200
Dried buttermilk	10	2.20	1,380	1,510	242	200	22	1,450	0.99(40C+158S+2P)÷200
Dried whey	10	0.80	1,445	1,404	348	200	22	1,454	1.00(146C+52S+2P)÷200
Dried whey product	10	1.40	1,240	1,450	304	200	20	1,436	0.98(100C+96S+4P)÷200
Dry meat by-products									
Animal fat	6	0	3,550	1,418	410	120	26	1,580	1.08(132C-10S-2P)÷120
Meat meal	5	3.00	1,200	1,582	285	100	7	1,460	1.00(-32C+115S+17P)÷100
Meat and bonemeal	5	2.50	1,100	1,571	303	100	0	1,460	1.00(-21C+97S+24P)÷100
Flash dried blood meal	5	7.00	1,300	1,711	135	100	28	1,450	0.99(-161C+265S-4P)÷100
Hydrolyzed hog hair	3	3.50	1,000	1,573	317	60	24	1,444	0.99(-23C+83S)÷60
Hydrolyzed feather meal	3	1.94	1,000	1,538	352	60	24	1,443	0.99(12C+48S)÷60
Poultry by-product meal	3	3.70	1,300	1,582	312	60	20	1,456	1.00(-32C+88S+4P)÷60
Dry hatchery by-products									
Hatchery by-product meal, broiler type chick	3	1.16	800	1,520	370	60	24	1,450	0.99(30C+30S)÷60
Hatchery by-product meal, egg chick type	3	1.83	1,000	1,535	355	60	24	1,443	0.99(15C+45S)÷60
Grain by-products									
Corn bran	10	0.20	1,200	1,356	394	200	24	1,428	0.98(194C+6S)÷200
Hominy feed	60	0.30	1,400	386	364	1,200	24	1,400	0.96(1,164C+36S)÷1,200
Corn gluten feed	20	0.60	1,100	1,214	336	400	24	1,378	0.95(336C+64S)÷400
Corn gluten meal	20	0.80	1,400	1,244	306	400	24	1,438	0.98(306C+94S)÷400
Wheat bran	10	0.56	890	1,408	342	200	24	1,400	0.96(142C+58S)÷200
Wheat middlings	30	0.64	1,300	1,050	300	600	24	1,400	0.96(500C+100S)÷600
Rice bran	20	0.60	1,350	1,214	336	400	24	1,428	0.98(336C+64S)÷400
Rice bran, fat extracted	10	0.60	1,200	1,386	364	200	24	1,428	0.98(164C+36S)÷200
Rice polishings	20	0.50	1,500	1,198	352	400	24	1,458	1.05(352C+48S)÷400
Brewers dried grains	10	0.90	1,000	1,409	341	200	24	1,408	0.97(141C+59S)÷200
Distillers dried grains	10	0.60	1,300	1,386	364	200	24	1,438	0.98(164C+36S)÷200
Distillers dried grains, w solubles	10	0.70	1,540	1,394	356	200	24	1,462	1.00(156C+44S)÷200
Bakery and sugar by-products									
Dried bakery by-product	40	0.30	1,650	777	373	800	24	1,518	1.04(773C+27S)÷800
Cane molasses	10	0.20	1,000	1,356	394	200	24	1,414	0.97(194C+6S)÷200
Dried cane bagasse	5	0.10	500	1,454	396	100	24	1,408	0.97(96C+4S)÷100
Beet molasses	10	0.15	1,060	1,352	398	200	24	1,414	0.97(198C+2S)÷200
Dried beet pulp	5	0.65	1,020	1,474	376	100	24	1,436	0.98(76C+24S)÷100
Corn molasses	10	0	1,200	1,341	409	200	24	1,428	0.98(209C-9S)÷200
Salvage candy	20	0	1,600	1,123	427	400	24	1,472	1.01(427C-27S)÷400
Dry potato and bean by-products									
Potato meal	20	0.25	1,100	1,161	389	400	24	1,378	0.95(389C+11S)÷400
Potato flakes	40	0.25	1,600	762	388	800	24	1,498	1.03(788C+12S)÷800
Potato slices	40	0.25	1,500	762	388	800	24	1,458	1.00(788C+12S)÷800
Potato pulp	10	0.20	1,000	1,356	394	200	24	1,408	0.97(194C+6S)÷200
Potato chips and fries	30	0.20	2,000	950	400	600	24	1,608	1.10C
Cooked cull dry beans	15	1.50	1,400	1,390	260	300	24	1,442	0.99(160C+140S)÷300

[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 (50 x 4.5¢ + 148 x 9¢ + 2 x 14¢) ÷ 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 lb. of dried whole milk replaces 50 lb. of corn, 148 lb. of soybean meal, and 2 lb. of dicalcium phosphate.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. W.J. Moline, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824.

19.47.13 - Livestock: Swine

10:87-3M-New-SDC/RP-Price: 45¢