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Joe D. Hancock

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Abstract

It has been recognized for many years that some sort of processing of soybeans will yield a product of superior nutritional value. As our understanding of the effects of different processing techniques increases, we will continue to see advances in technology that will yield soybean products of superior nutritional value. The challenge for livestock producers is to recognize the products that offer improved nutritional benefits and to have the wherewithal to use those products when they are economically advantageous.; Swine Day, Manhattan, KS, November 17, 1988

Keywords

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EFFECT OF PROCESSING ON THE NUTRITIONAL VALUE OF SOYBEAN PROTEINS

J.D. Hancock

Summary

It has been recognized for many years that some sort of processing of soybeans will yield a product of superior nutritional value. As our understanding of the effects of different processing techniques increases, we will continue to see advances in technology that will yield soybean products of superior nutritional value. The challenge for livestock producers is to recognize the products that offer improved nutritional benefits and to have the wherewithal to use those products when they are economically advantageous.

Introduction

While preparing this paper, it occurred to me that a better title might have been "Soybean Processing: New Perspectives on Very Old Concepts." Indeed, the Chinese have recognized for thousands of years that soybeans are an excellent human foodstuff when cooked, fermented, or otherwise processed. As early as 1917, data were being published (Osborne and Mendel, J. Biol. Chem.) demonstrating that heat treatment of soybeans could greatly improve their nutritional value for rats. So, the notion that some sort of processing is necessary to optimize the utilization of soybeans as food/feed is not a new concept. What is new is the intense interest currently demonstrated by swine producers wishing to use full-fat soybean products, when economically justified, as an easy means of adding fat to swine diets. This paper is a discussion of current thought on the more traditional means of processing soybeans for use in animal diets (e.g., preparation of soybean meal, roasting and extruding processes) and also new technologies that could change our thinking about the necessity for heat processing and use of soybeans in diets for baby pigs.

Production of Soybean Meal

A logical place to begin a discussion of soybean processing is with the production of commercially available soybean meal. The first successful commercial processing operation for U.S. soybeans began in 1922, with a mechanical press used to harvest soybean oil from soybean seeds. Mechanical presses were soon replaced by more efficient screw presses, and then finally, in the 1940's and 1950's, solvent extraction processing began to dominate U.S. soybean processing. Modern soybean processing, as envisioned by Dr. Stanley Balloun (Soybean Meal in Poultry Nutrition, 1980), is presented in Figure 1. As indicated, the soybeans are cleaned, cracked, dehulled, and rolled into thin flakes (.01 to .02 in thick) to improve the efficiency of oil removal during the hexane extraction process. Hexane extraction is extremely efficient at removing oil from soybean flakes, reducing the oil content from 18% to less than 1%. The defatted soyflakes are then passed through a desolventizer/toaster that functions to evaporate the residual hexane, which is recaptured and reused. A second important function of the desolventizer/toaster is to inactivate the

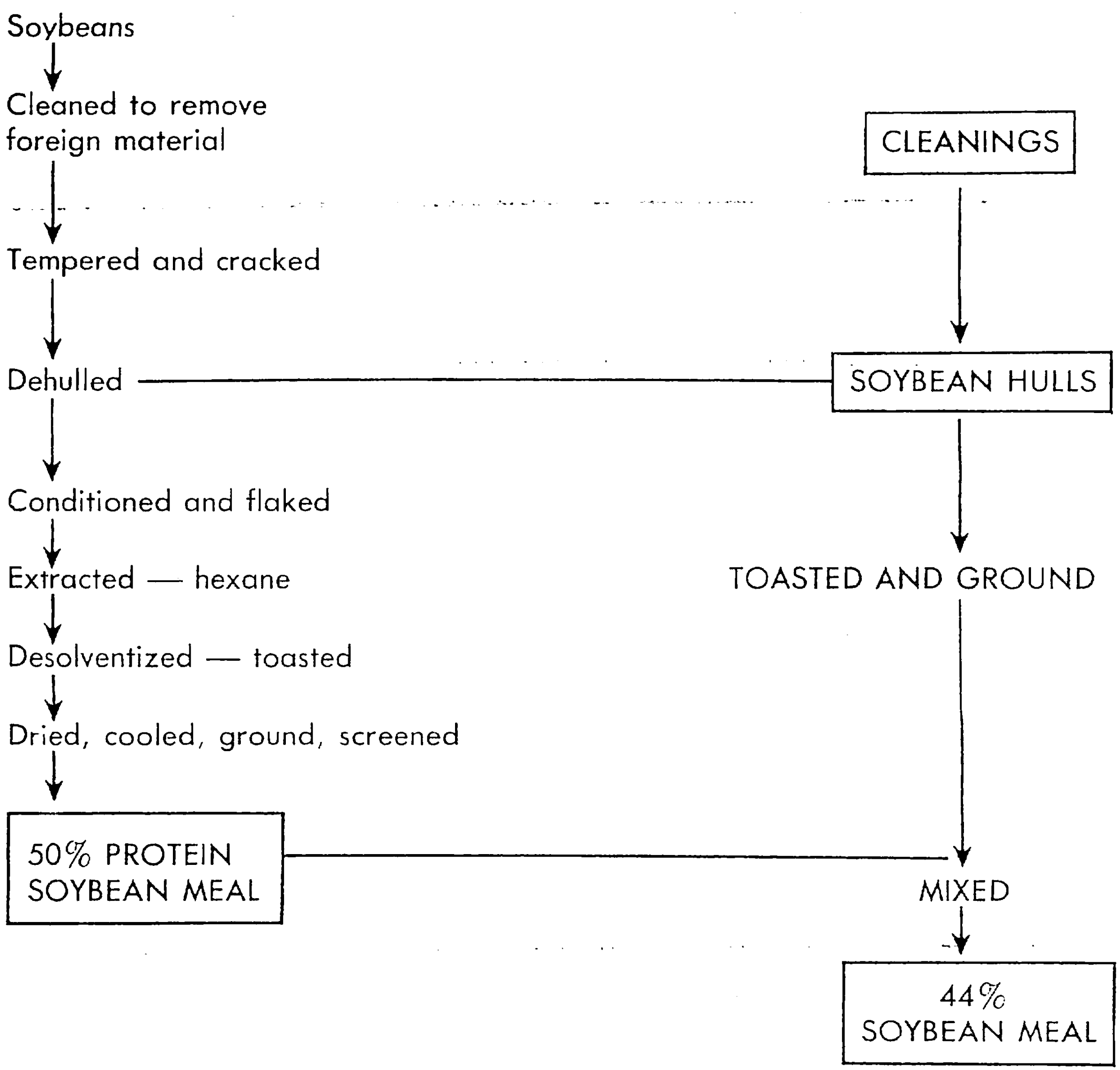

Figure 1. Preparation of Soybean Meal (Balloun, 1980).

antinutritional factors (primarily trypsin inhibitors) found in raw soybeans. The toasted soybean meal, containing approximately 50% crude protein, is then diluted with soybean hulls to yield 44% soybean meal.

It would be senseless to argue the merits of using soybean meal in swine diets with a group of swine producers. Because of price, availability, and nutritional value, soybean meal is easily "tops" as the protein source most used in U.S. swine diets. The rest of the world seems to agree with U.S. producers, since soybean meal accounts for roughly three-fourths of the total world trade in high protein meals (Soybean Research Advisory Institute, 1984). Thus, <u>any substitution of alternative soybean products must be cost effective when compared to commercially available soybean meal.</u> The remainder of this paper will be devoted to soybean processing methods that provide products alternative to commercially prepared soybean meal, but it cannot be overemphasized that use of alternative soybean products must be based on economic comparisons to soybean meal.

Feeding Full-Fat Soybeans

Soybean seeds contain approximately 38% crude protein and 18% fat as soybean oil. The term "full-fat" simply implies that no attempt has been made to remove the fat from the soybean seeds during processing. Using this definition, roasted, extruded, and raw soybeans will qualify as full-fat products. Occasionally, producers will decide that feeding fat is economically justified. If a full-fat soybean product is added to a grower/finisher diet, the full-fat diet usually will contain 3% to 4% added fat. Feed efficiency is improved by about 2% for each 1% increment of added fat, thus a 6% improvement in feed efficiency can be expected when feeding a full-fat product. Also, the use of a full-fat soybean product substantially reduces the level of airborne dust in confinement facilities, is a convenient means of adding fat to sow and baby pig diets, and allows farmer/feeders to market their soybean crop through animals. Obviously, these possible advantages must offset the cost of adding the fat to swine diets.

If the decision is made to feed fat, the next step is to decide whether it is more economical to feed a full-fat soybean product or to feed commercially prepared soybean meal plus a cheap source of feed-grade fat. Things to consider before feeding a full-fat product, both positive and negative, are:

<u>positive</u>	<u>negative</u>
I no longer have to buy soybean meal.	I either lose the selling price of my soybeans or must buty soybeans from someone else.
I will not have to buy, store, and handle the feed-grade fat.	Even if I use my own soybeans, I will still have to pay processing costs.
	Where and how will I store the full-fat product?

Nutritionists from around the U.S. often use the following formula to determine the economic feasibility of feeding "full-fat" soybean products:

$$A = .86Y + .17Z - (S + C)$$, where:

A	=	cost advantage of a full-fat product
.86	=	adjustment for lower protein content of full-fat soybeans than soybean meal (i.e., .38/.44 = .86)
Y	=	cost of 1 ton of 44% soybean meal
.17	=	allowance for 18% fat in full-fat products less the 1% fat of soybean meal
Z	=	value of 1 ton of feed grade fat
S	=	value of 1 ton of raw soybeans
C	=	cost of processing 1 ton of soybeans

Assuming that the economic evaluation warrants the use of a full-fat product (i.e., A is greater than zero), the next step is to choose between roasted, extruded, or raw soybeans.

Roasted soybeans. Roasting is processing soybeans by passing them through a flame-heated chamber. The soybeans usually spend 2 to 4 min in the roaster and exit at temperatures of 230 to 260°F. The roasting process does not rupture the soybean seeds, thus, the fat is not exposed to atmospheric oxygen and is not prone to rancidity. The protein quality of roasted soybeans can vary, depending on the care taken during the roasting process. Underprocessed soybeans have an unacceptably high trypsin inhibitor content that reduces their digestibility, and overprocessed soybeans can have reduced lysine availability. Marked fluctuations in exit temperature of the soybeans can result, depending on the temperature of the air and soybeans as they enter the roaster, fluctuations in gas pressure to the burner, moisture content of the soybeans, and flow rate of the soybeans through the roaster. A commercial firm in Manhattan (LSB Labs) offers a product known as "Soy-Check" that can be used as a quick test for underprocessing. However, it would be a good idea to occasionally have a sample of your soybeans checked for trypsin inhibitor content to ensure that you are feeding adequately processed soybeans.

Many experiments have been conducted to evaluate the nutritional value of roasted soybeans. Roasted soybeans are equal to commercially prepared soybean meal plus feed-grade fat in terms of pig performance, when properly processed and added to diets on a protein basis.

Extruded soybeans. The extrusion process is accomplished by using a screw auger to force soybeans through a small orifice. Adding steam to temper the soybeans and lubricate the orifice can help the extrusion process, but other technology (dry extrusion) uses only friction to heat the soybeans without the use of steam or water, other than that in the seeds themselves. The soybeans go from whole beans at room temperature to a boiling, oily mash shooting from the extruder at 300°F, all in less than 30 sec. The mash quickly cools and the fat is reabsorbed into the soybean meal. Claims are being made by extruder manufacturers that the extrusion process ruptures the fat cells in the soybean seeds, thus, improving lipid digestibility. Also, the heat created during the extrusion process is supposedly more uniform and less extreme than roasting, and the potential for heat damage to the soybean proteins is reduced. Though examples of improved nutritional value of extruded soybeans are not consistent, the extruded products are at least as good nutritionally as roasted soybeans and soybean meal plus feed-grade fat. When compared to roasted soybeans, extruded soybeans are more susceptible to lipid rancidity because the fat cells are ruptured. Grease-proof containers and an antioxidant will be needed if the extruded soybeans are to be stored for more than a few days in a warm environment.

Raw soybeans. Historically, swine producers have not fed raw soybeans to their pigs. Marked reductions in performance are nearly guaranteed when raw soybeans are fed to young growing swine. However, there is a concept currently being explored relative to feeding raw soybeans in certain stages of production. The ability of pigs to tolerate the antinutritional factors in raw soybeans is age dependent, thus, there is a threshold of antinutritional factor activity that can be tolerated at any age.

As pigs increase in age from nursery to growing, finishing, breeding-gestation, and lactation, their ability to tolerate raw soybeans increases dramatically. In fact, current thought is that feeding raw soybeans to gestating sows will not adversely affect reproductive performance or well-being of the animals (Crenshaw and Danielson, J. Anim. Sci., 1985). However, raw soybeans are not recommended for lactating sows or growing/finishing pigs and certainly not for feeding nursery-age pigs.

The concept of a tolerated threshold level for antinutritional factors is especially interesting in light of current attempts by plant breeders to develop soybean varieties low in trypsin inhibitor content. Vandergrift (Pig News and Info., 1985) stated that growing pigs can tolerate diets containing soybean meal with 5 to 7 mg trypsin inhibitor per gram of soybean without reducing nutrient digestibility. Raw soybeans contain 20 to 25 mg trypsin inhibitor per gram of soybean. Swine nutritionists at Kansas State University and other institutions (Illinois, Kentucky, Minnesota, and Nebraska), are conducting experiments to determine the nutritional value of soybeans with only one half of the trypsin inhibitor activity of conventional soybeans. Results thus far (Table 1) indicate that low inhibitor soybeans still depress nursery and growing pig performance if fed raw, but finishing pigs are able to consume diets containing raw low inhibitor soybeans with only a slight reduction in performance. Also, it seems likely that the heat treatment needed to optimize nutrient utilization from the low inhibitor soybeans can be reduced.

Other Processing Technology

Most swine producers are well aware of the difficulty newly weaned pigs experience when fed a simple corn-soybean meal diet. Digestive disturbances resulting in diarrhea and weight loss are the rule rather than the exception. Recently, researchers in England proposed that the problems with soy proteins cause in very young pigs might result from a mild allergic reaction to some component of the soybean meal, probably the large storage proteins that account for the majority of the protein in the soybean seeds.

Various soybean products, prepared by elaborate processing techniques, are being tested for their effects on digestive function in young pigs. One group of these products, soy protein concentrates, are produced by alcohol extraction. Recent research at the University of Nebraska (Table 2) indicates that the performance of nursery pigs is improved when soybean meal is alcohol extracted, especially when the soybean meal is over- or underprocessed during heat treatment. However, the improved nutritional value seemed to result from decreased trypsin inhibitor activity in the underprocessed soybean meal and protection of the lysine availability in overprocessed soybean meal, and not from changes in the shape of intestinal villi (i.e., shortening, blunting, and general atrophy) that would indicate a mild allergic reaction.

Table 1. Comparison of Raw Conventional and Raw Low Trypsin Inhibitor Soybeans to Soybean Meal

	Nursery Pigs (Illinois 1988)		Growing Pigs (Minnesota 1988)		Finishing Pigs (Illinois 1988)	
Item	Conventional	Low Inhibitor	Conventional	Low Inhibitor	Conventional	Low Inhibitor
Daily gain	↓ 52%	↓ 34%	---	---	↓ 13%	↓ 8%
Feed/gain	↓ 53%	↓ 24%	---	---	↓ 7%	↑ 1%
Protein digestibility	↓ 14%	↓ 8%	↓ 32%	↓ 19%	---	---

Table 2. Effects of Alcohol Extraction and Heat Treatment on Nutritional Value of Soybean Flakes[a]

	Underprocessed		Adequately processed		Overprocessed	
Item	Non-extracted	Extracted	Non-extracted	Extracted	Non-extracted	Extracted
Daily gain, lb	.14	.50	.70	.83	.39	.75
Feed/gain	6.0	2.10	2.0	1.9	2.6	2.1
Protein digestibility, %	72.6	80.7	80.9	84.7	80.0	82.3
Villus area/height, $\mu m^2/\mu m$	13.4	15.9	15.6	15.4	14.8	15.3

[a]Adapted from Hancock et al. (J. Anim. Sci., 1987 and 1988).
[b]Processing was autoclaving at 250°F and 15 lb/in^2 steam pressure.
[c]Extraction was repeated washings with a 55% ethanol-water mixture before heat treatment.