



Soybean Processing

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Introduction

Today, soybeans are by far the most important crop in the world and are grown for a variety of agricultural and industrial uses. The United States of America, Brazil, China and Argentina are the world's largest producers with a capacity of over 150 million tons a year.

Soybean utilization can be traced back to over 4000 years ago. The Chinese are believed to be the first in recognizing the value of this crop as a source of food for humans. Ancient literature does not refer to the oil or other soy products, so it is more likely that the history of oil extraction is relatively recent. It was reported that Japan imported soybean cake from China in the late 1800's for use as fertilizer.

In the United States, the earliest recorded processing of soybeans for oil and meal was in 1915 in a cottonseed mill in North Carolina. The oil was expelled through screw press. Its value was realized for military and industrial use while there was prejudice against plant protein sources for animal feed.

Animal protein sources almost always gave better results when fed to livestock and poultry. The knowledge for the need of animal minerals was in its infancy. Soybean and other plant protein lack the needed minerals.

Although when used in human diets, soybeans were always cooked, fermented or otherwise processed. There was a lack of appreciation of the importance of heating in processing soybean meal. At that time research in animal feeding indicated that processing ingredients, such as fish meal or meat meal at high temperatures, resulted in a decrease in their nutritional value as compared to low temperatures.

Why heat processing?

Raw soybeans can not be used successfully in animal feed or human food. Many anti-nutritional factors have been identified in raw soybeans, but the ones generally considered to be of consequences are:

- A) Trypsin and chymotrypsin inhibitors - inhibit protein digestion.
- B) Phytohaemagglutinins (Lectins) - Decrease the digestibility of nitrogen-free extract by interfering with normal absorption of pancreatic amylase to the intestinal epithelium, thereby allowing the enzyme to be quickly eliminated in the feces.
- C) Urease. This enzyme is of importance in monogastric nutrition only as a guide for measuring the adequacy of processing. Urease is of some concern in diets for ruminants as these diets quite often contain considerable urea.
- D) Allergenic Factors - Glycinin and Beta-Conglycinin (reduce nutrient absorption due to their effect on the integrity of the micro-villi in the small intestine).
- E) Lipase and Lipoxygenase - result in peroxidation and beany flavor, respectively.

Fortunately, these anti-nutritional factors can be deactivated, modified or reduced through proper heat treatment to minimize or eliminate their adverse effect. However, since these inhibitors are proteins, caution should be taken to assure that no destruction of the oil seed protein occurs. This can be done only through optimal processing and good quality control measures.

Processing Methods

More attention is being given to the quality of ingredients used in compound feed formulation as it relates to their nutritional value, availability of nutrients, the possible variation between sources of raw material and the influence of processing on the quality of ingredients in an attempt to improve the precision of feed formulation.

In this presentation, we will attempt to describe the major processing techniques of soybeans and their nutritional consequences as they relate to animal performance. There are several ways of processing soybeans, but the main processing methods are:

A) Solvent Extraction

The majority of soybeans are being processed by the Solvent Extraction Method where the beans are cleaned, tempered, dehulled, conditioned and flaked prior to extracting the oil with hexane. Because hexane is highly flammable, extreme caution is necessary in the solvent extraction plant to prevent explosions. This method is capable of removing all but 0.5-1.0% of the oil from the meal. The extracted flakes are then transferred to the desolventizer-toaster unit where the remainder of the solvent is recovered and the flakes are subjected to steam heat to inactivate the growth inhibitors. The flakes are finally dried in a rotary dryer, cooled and ground to size acceptable to the feed trade. Dust can be a problem at this stage if care is not taken to insure proper grinding. The meal can be adjusted to the desired protein content by adding soybean hulls to it. An inert ingredient is allowed to be added to reduce the flowability problem of the meal.

B) Processing Whole Soybeans.

Several methods of processing whole soybeans are available. Most of the systems that have been developed for commercial or on-the-farm use fall into two basic categories:

1. **Toasting or Roasting** - The whole beans are subjected to a gas flame or other heat source for short intervals to accomplish the cooking. This process does not disrupt the cells and the beans must be ground, rolled or flaked before mixing into the diet.
2. **Extrusion** - In simple terms, extrusion is a process of cooking under pressure, moisture and elevated temperatures. Among the functions that an extruder provides includes grinding, hydration, shearing, mixing, thermal treatment, gelatinization, protein denaturation, destruction of micro-organisms and some toxic compounds, shaping, expanding, texture alteration, and partial dehydration.

There are several different types of extruders. Some have a single screw and some have double screws. The extruder can be considered either wet or dry. Wet extrusion requires pre-conditioning of the beans, steam injection, and the resulting extrudate may require drying. Dry extrusion capitalizes on the heat generated through friction as the sole source of heat to cook, sterilize and dehydrate the product.

In the late 1960's, Triple "F", Inc. of Des Moines, Iowa introduced Insta-Pro® Dry extruder (which is a single screw extruder) to the farm communities and feed mills in the Mid-West as a means to locally process whole soybean and grains on-the-farm thus allowing the local communities the opportunity to obtain the full value and advantages of feeding their home grown soybeans and cereal grains to their animals.

Today, Insta-Pro extruders have the flexibility of being utilized with or without the need for a pre-conditioner and steam, thus depending on the need, they can be either wet or dry extruders. Their capacity ranges from a few hundred kilograms to several tons per hour depending on the size of the extruder and whether or not a pre-conditioner is being used.

2.2 Extrusion-Mechanical Pressing of Soybeans - A new concept for mechanical extraction of oil from soybeans that has been recently introduced. The soybeans are first extruded using an Insta-Pro dry extruder before entering a horizontal screw press. Extrusion prior to expelling greatly increases the throughput of the expeller over the rated capacity. An oil recovery of up to 70% can be achieved in a single pass. The high-temperature short-time extrusion cooking process eliminates the prolonged heating and holding of raw material in conventional expelling. The oil and the meal produced by this method are remarkably stable due to the fact that extrusion results in releasing the natural anti-oxidants (tocopherols) from the beans. Hill (1990) stated that when compared to solvent extracted crude soybean oil, the extruded-expelled soy oil contained lower amounts of peroxides, free fatty acids, trace minerals, sterols, phosphatides, unsaponifiable matter, moisture and volatile matter. The expelled soy oil contained the same amount of pigments, fatty acids, and triglycerides as crude solvent extracted. He also reported that the high stability of extruded expelled soy oil is due to the high levels of natural antioxidants (carotenoids and tocopherols), while also having low levels of phospholipids and peroxides.

This concept is being used in the United States, Russia and other countries to process soybeans and other oil seeds.

In this presentation, we will discuss the effect of processing techniques on the nutritional quality of whole soybeans as compared to solvent extracted soybean meal and subsequently, on animal performance.

C) Nutritional Value

Whole soybeans contain not only high quality protein (38-42%) but also a rich source of energy due to the oil they contain (18-22%). They have the potential of supplying major amounts of both energy and protein to all types of livestock and poultry feed.

Collective terms that are being used to describe processed soybeans range from "full fat soybeans", "heat processed soybean seeds", "heat treated soybeans", to simply "Whole Soybeans". More specific references are seldom used to correctly identify the processing method.

Although many reviews and papers are available regarding the nutritional value of processed whole soybeans, only few have realized the effect of the processing method on the nutritional value, particularly, the energy value. The following is a summary of selective papers and articles.

1. Poultry - Wiseman (1984), reported considerable differences among different processing methods on the Apparent Metabolizable Energy (AME) and Nitrogen Retention (NR) values for 2.5 week old chickens. His data indicates that extruded soybeans have the highest Metabolizable Energy (ME) value (17.88, 17.69 MJ/KG) for wet and dry extrusion respectively) followed by soybean meal and added oil

(17.46 MJ/KG, Micronized (15.8 MJ/KG), Toasted (15.56 MJ/KG), Jet Sploded (14.25 MJ/KG), and raw soybeans (13.53 MJ/KG). The highest NR value was achieved with Insta-Pro dry extruder (84%) followed by Toasted (67%), Micronized (66%), Jet Sploded (63%), Soybean Meal Plus Oil (60%), Wet extrusion (56 %), and Raw Soybeans (30 %).

The National Research Council (NRC) for poultry (1994) used the collective term “Heat Processed Soybean Seed”. It reported an ME value of only 3300 kilocalorie per kilogram (13.8 MJ/KG). Not much difference from that of raw soybeans listed above. No mention to the method of processing was made.

Zhang et. al., 1993 studied the effect of extrusion and expelling on the nutritional quality of conventional and kunitz trypsin inhibitor-free soybeans in chicken. Their results indicated that increasing the extrusion temperature of conventional soybeans (CSB) to 138°C and 154°C significantly increased the TME_n compared with CSB extruded at 104°C or 121°C (3815, 3936 vs. 3665, 3678 Kcal/kg DM respectively). Extruding Kunitz free soybeans (KFSB) at 104°C, 121°C and 138°C resulted into similar TME_n as that of CSB extruded at 138°C and 154°C.

The expelled the CSB meal had a TME_n value of 3265 Kcal/kg DM. They also reported that amino acid digestibility of CSB extruded at 138°C or 154°C did not differ from that of extruded KFSB. Expelling of CSB has no significant effect on amino acid digestibility values when compared with extruding alone.

Stillborn et. al (1987) compared the effect of three processing techniques on broiler performance. They reported that significantly higher body weight and better feed efficiency ($P < .05$) were obtained with whole soybeans processed by the Insta-Pro Dry Extruder as compared with the Wenger Wet Extruder or the Gem Crop Roaster.

Sell (1984) found no significant differences ($P > .05$) in either growth rate or feed efficiency in broilers when fed diets from 0-53 days of age containing up to 47% extruded whole soybeans in the starter diet and 32% in the finisher diet as compared with the control soybean meal plus animal/vegetable fat diet. He also reported no significant differences ($P > .05$) in turkey tom performance in 140 day feeding trial when fed 22.2% extruded whole soybeans as compared with the control soybean meal plus animal/vegetable fat diet.

Waldroup and Hazen (1978) compared feeding soybean meal, roasted soybeans, dry extruded soybeans, and raw soybeans to laying hens. Their results show that hens fed the extruded soybeans have the highest egg production and the best feed conversion as compared to the control soybean meal diet. Hens that were fed the raw soybeans showed inferior results compared to the other groups.

It is widely accepted that the nutritional value of dietary proteins depends on their amino acid composition and how effectively these amino acids are utilized by the animal receiving the diet. In an experiment designed to assess the effectiveness of different heat treatments on the amino acid digestibility of full fat soybeans, McNab (1989) reported that although the trypsin inhibitor activity (TIU) was variable among the different processes, it was considered to have been reduced to safe levels in all cases (2 TIU/mg). His results show that autoclaving and extrusion by the Insta-Pro method provided the highest digestible amino acids (93.1% and 92.5% for autoclaved and dry extruded, respectively) as compared to toasted (91.4%), micronized (90.4%), micronized after water addition (87.9%), continuous toasting (87.6%), or Wenger Wet Extruded (85.6%).

These results illustrate the need to evaluate products and processes effectively to establish the correct nutritional properties.

2. Swine - Marty and Chavez (1993) studied the effect of heat processing on digestible energy and other nutrient digestibilities of full fat soybeans fed to weaner, grower and finishing pigs. Their results show that extruded soybeans have superior crude protein digestibility (86.4%) than other heat treatments (79.8%, 79.8%, 80%, and 78.2% for jet sploded, micronized, roasted and solvent extracted soybean meal, respectively). Their results indicate that extrusion was most beneficial for weaner pigs as compared to growing and finishing stages.

Kim et. al 1994, conducted metabolism studies on nursery pigs to determine the effect of extruding or roasting on the nutritional value of Williams 82 Soybean with (+K) and without (-K) gene expression for the Kunitz Trypsin Inhibitor. They reported that apparent values for nitrogen digestibility, biological value, percent nitrogen retention, gross energy digestibility, and metabolizable energy were greater for pigs fed extruded soybean as compared with pigs fed roasted soybean.

All the above criteria were greater for pigs fed (-K) as compared to (+K) soybeans. The control soybean meal fed pigs showed intermediate results as compared to extruded and roasted groups. Their results indicate that the NRC M.E. value of 1664 kcal/lb. for full fat soy products should be revised to indicate the type of processing used.

In a study to determine the effect of roasting and extrusion on the ideal digestibility of nutrients in growing and finishing pigs, Kim et.al, 1994 concluded that ideal digestibilities of dry matter, gross energy, nitrogen and various amino acids tend to be greater for extruded soybeans, intermediate in soybean meal and lowest for roasted soybeans. These trends were true for both growing and finishing pigs.

Hancock et.al (1991) reported that the improved feed efficiency for pigs fed extruded sorghum and soybeans indicate that the M.E. value of sorghum grain is dependent on the processing method, and the NRC value for M.E. of heat processed soybeans is probably too low, at least for dry extruded whole soybeans. Their data showed a 6% increase in dry matter digestibility and a 14% increase in nitrogen digestibility due to extrusion of soybeans and sorghum as compared with soybean meal-sorghum-soy oil non-extruded control diet.

3. Ruminants - Aldrich and Merchen (1995), studied the effect of heat treatment of whole soybean on protein digestion by ruminants. They reported that increasing the extrusion temperature from 220° to 320° at 20° F increment resulted in linear decrease of in situ degradation of soybean protein. As expected, raw soybean protein degraded very fast. The extent of degradation were 84.1%, 45.7%, 40%, 40.9%, 48.6%, 36.7%, and 30.4% for the raw, 220°F, 240°F, 260°F, 280°F, 300°F, and 320°F treatments respectively. In another word, extruded soybean at 320°F had a by-pass protein value of 69.6% as compared to 15.9% for raw soybeans.

Precision-fed cecectomized roosters assay was used to determine the total amino acid digestibility both before and after ruminal incubation. Unincubated raw soybean had a value of 68.5% compared with 87.7% for extruded soybean at 320°F. Digestibility of residues of extruded soybeans (average of 90% for 240°F, 280°F, 320°F treatments) following in situ incubation were higher than those of raw soybeans (82%) after incubation.

This reflects the differences in trypsin inhibitor activities and underscores the fact that the postruminal digestibility of the ruminal escape protein from raw soybeans is likely to be lower than that of escape protein of extruded soybeans.

Socha and Satter (1991) conducted a study to determine the production response of early lactation cows fed either solvent extracted soybean meal, raw soybeans, extruded whole soybeans or roasted soybeans with alfalfa silage as the sole forage source. They reported that dry matter intakes were lower for cows on the raw and roasted soybeans treatments. Cows on the extruded soybean diet produced more milk, milk protein, and more 3.5% fat corrected milk than cows fed the other diets. Body weight changes and body condition scores did not differ among the different treatments.

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References

- Aldrich, C. G. and N. R. Merchen, 1995.** Heat Treatment of Whole Soybeans: Influence on Protein Digestion by Ruminants. Triple "F", Inc. Nutrition Conference, Des Moines, Iowa.
- Balloun, S. L., 1980.** Soybean Meal in Poultry Nutrition. Pages 3-9. American Soybean Association, St. Louis, Missouri.
- Hill, S. E., 1990.** Characterization and Oxidation Stability of Mechanically Expelled Soybean Oil. M. Sc. Thesis. University of Illinois, Urbana, Illinois.
- Kim, I. H., J. D. Hancock, R. H. Hines and M. S. Kang, 1994.** Roasting and Extruding Affect Ileal Digestibility of Nutrients from Soybeans in Growing and Finishing Pigs. Kansas State University Swine Day 1994. Pages 176-181.
- Kim, J. H., J. D. Hancock, R. H. Hines, and T. L. Gugle, 1994.** Roasting and Extruding Affect Nutrient Utilization from Soybeans in 10-20 lb. Pigs. Kansas State University Swine Day 1994. Pages 58-62.
- Marty, B. J. and E. R. Chavez, 1993.** Effect of Heat Processing on Digestible Energy and Other Nutrient Digestibilities of Full Fat Soybeans Fed to Weaner, Grower and Finisher Pigs. Canadian Journal of Animal Science. 73: 411-419.
- McNab, J. M., 1989.** Recent Advances in Amino Acid Digestibility Research: An Applied Perspective. 26th Annual Georgia Nutrition Conference for the Feed Industry. November 9, 1989.
- National Research Council, 1994.** Nutrient Requirement of Poultry. 9th Rev. Ed. Natl. Acad. Sci., Washington, D.C.
- National Research Council, 1988.** Nutrient Requirement of Swine. 9th Rev. Ed. Natl. Acad. Sci., Washington, D.C.
- Sell, J. L., 1984.** Use of Extruded Whole Soybeans in Turkey Diets. Iowa State University Poultry Newsletter, January. Pages 3-7.
- Socha, M. I. and L. D. Satter, 1991.** Effect of Feeding Early Lactation Multiparous Cows Heat Treated Full Fat Soybeans. M.Sc. Thesis. University of Wisconsin, Madison, Wisconsin.
- Stillborn, H., L. I. Ndife, B. L. Bowyer, H. M. Hellwig and P. W. Waldroup, 1987.** The Use of Full Fat Soybeans in Chicken Diets. Poultry Misset International. February 1987. Pages 20-23.
- Waldroup, P.W. and K. R. Hazen, 1988.** An Evaluation of Roasted, Extruded and Raw Unextracted Soybeans in the Diet of Laying Hens. Nutrition Report Int., 18: 99-103.
- Wiseman, J., 1984.** Full Fat Soybeans in Diets. Watt Publishing, Feed International, February 1984.
- Zhang, Y. E., C. M. Parsons, K. E. Weingartner and W. B. Wijerante, 1993.** Effect of Extrusion and Expelling on the Nutritional Quality of Conventional and Kunitz Trypsin Inhibitor-Free Soybeans. Poultry Science 72: 2299-2308.