Creating Niche Market Opportunities in Animal Feeding for Small Farmers with Soybeans

Executive Summary

The goal of this project was to identify and refine soybean (SB) processing methods that add value to SB products as feed for swine and poultry. The knowledge gained as a result of conducting this research is meant to be applied in small-scale processing facilities owned and operated by small- to medium-sized SB farmers with the intention of increasing profitability of SB production.

The plan of work involved a sequence in which (a) soybean meals (SBMs) produced using specific process modifications were screened using laboratory procedures for comparative nutritive value, (b) promising treatments were tested further in animal feeding experiments, (c) economic analyses of results were conducted, and (d) research outcomes were disseminated using an array of traditional and electronic outlets to SB growers and animal producers. The research results were used to identify opportunities that SB farmers could use to exploit alternative markets for their products, thus recommending the development of smaller local SB processing facilities that generate specialized feeds for animal production.

Key results of this research project include: (a) Processing of SBs introduced compositional variability that impacted the nutritive value of the resultant SBMs. (b) Optimal processing conditions were dependent on the composition and characteristics of the variety of SB used. (c) Composition of SBs and SBMs varied depending on the country of origin and where they were processed. (d) Amino acids in SBMs produced in Argentina and Brazil were less digestible than those in SBMs from the U.S., India, and China. (e) When gums, soapstock, and weeds/trash were added back to the meal at the time of processing, an 11 percentage unit decrease in amino acid digestibility by swine and a 10 percentage unit decrease by poultry occurred. (f) SBMs produced at bed depths in the desolventizer/toaster higher than the current industry standard result in improvements in amino acid digestibility without over-processing the meal. (g) Increasing the length of time that SBs spend in the extractor from 45 min (traditional extraction time) to 90 min led to an increase in bioavailable phosphorus, but a decrease in bioavailable lysine, potentially negating the positive effect on phosphorus. (h) Using extruder/expeller processing technology, optimal processing temperature should be >135 C, and temperatures as high as 160 C do not result in overprocessing of the meal. (i) The negative nutritional effects of SB oligosaccharides noted for poultry cannot be demonstrated with swine. Indeed, SB oligosaccharides have prebiotic activity (i.e., stimulation of the gut microbiota associated with good health) in the colon of pigs. The implication is that these agents may serve as a partial proxy to traditional antibiotics in swine diets. (j) Using farm-level economic production models, it was determined that value-added SBM increased swine profitability by 5-10% and allowed low density poultry production systems to be profitable, even when production ceased during the winter months. (k) The development of a website showcasing the study results was completed. The **Soy in Animal Nutrition Database (SAND)** site presents a venue for practicing animal nutritionists to access tables of data with nutritional information that

can be used to formulate higher quality SBM-containing diets for livestock. The site also provides links to the research publications, as well as to SBM, soy processing, and animal feeding web pages. (l) Farmer/producer groups interested in possible niche market opportunities for SBM resulting from biodiesel production were identified and contacted with information about the project, its goals, and how the research could be adapted for their benefit.

Primary Objectives and Goals

Presently, the United States SB processing industry offers only one type of SBM for all species of livestock. **This is the major PROBLEM addressed by the research conducted.** Quality specifications of this SBM are designed so they can be achieved by processing a wide range of commodity SB varieties. Additionally, the specifications allow for SBM production at any of approximately 70 SB processing plants that vary greatly in size, age, plant layout, geographical location, and type of processing technology utilized. Although SBM quality standards (the National Oilseed Processors Trading Standards) meet the needs of the SB production/processing industry, they do not allow for the variation in quality traits for different species of livestock. With the introduction of transgenic SB varieties that have special output traits, along with new processing technologies, it is now possible to produce SBMs designed to meet the specific feeding requirements for each animal species. "Species-specific" SBMs will have some of the following quality advantages over commodity SBM: (a) higher concentrations and less variability of important nutritional and physical factors (metabolizable energy content, purity [fewer weed seeds and less soapstock, bleaching earth, and gums], protein concentration and digestibility, amino acid profile, particle size distribution, pelletability); (b) reduced volume of animal waste; and (c) reduced concentrations of phosphorus (P), nitrogen (N), and heavy metals in the waste stream.

Soybean meal nutritive value is influenced greatly by processing conditions and, therefore, the effects of processing conditions on the concentration and availability of SBM nutrients is an area where research must be expanded. Little research has been conducted that monitors the effects of processing on compositional characteristics, indicators of nutritional value, and digestion and performance of animals fed SBM. **Our OPPORTUNITY was to integrate all of these factors using several processing approaches in a single comprehensive effort, keeping in mind that approximately 34 million tons of SBM are produced in the U.S. annually with 80% of that volume consumed domestically, mainly by swine and poultry.** We aimed to produce SBMs of consistently high nutrient concentrations with readily available nutrients that could be optimally utilized by the animal.

It is difficult for new entrants to the SB processing industry to gain market access because the primary commodity purchasing decision is based on product price. This allows existing processors to selectively lower the price of SB products below the cost of processing to the new entrant's local markets. This selective pricing strategy forces the new entrant to sacrifice profitability to maintain product market access. Lowering these barriers to entry can be done by developing differentiated non-commodity products to be produced and processed by small farmers, developing a smaller processing plant model compared with the industry average, developing a business model that reduces the

transaction and transportation costs inherent in the commodity SB product delivery model (higher processing costs associated with smaller processing plants are offset by lower transaction and transportation costs), or utilizing the closed cooperative business model for SB production and processing.

Principal Investigators and Co-Investigators

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Outcomes and Impacts

The knowledge gained as a result of the research conducted in this C-FAR Sentinel project contributes to development of strategies to optimize nutrient utilization of SBM-based swine and poultry diets, and thereby consolidates and expands the position of SBM as a key ingredient in swine and poultry feeds. This is important as there are a host of concerns regarding SBM to include ash content, P content, amino acid concentration and consistency, amino acid digestibility, fiber content and consistency, particle size, additions of bleaching earth, soapstock, and gums back to the meal, foreign material additives, pelletability, oil content, carbohydrate profile and digestibility, metabolizable energy content, trypsin inhibitor content, and residual hexane content. We identified a number of steps in the preparation of SBM from whole SBs that could result in a product of higher nutritive value with greater uniformity. The following paragraphs will summarize the major outcomes and impacts of the Sentinel Project.

The first project conducted involved determination of the variation in U.S. SBMs. A major portion of this project was funded by the Illinois Soybean Association through the Soy/Swine Nutrition Program administered by the National Soybean Research Laboratory in Urbana, IL, but a small part was funded by Sentinel. Meals from 55 U.S. processors were evaluated. Results demonstrated that the processing of SBs introduced compositional variability that impacted the nutritive value of SBM. We also found that optimal processing conditions were dependent on the composition and characteristics of the variety of SB used. Therefore, optimal processing procedures for one batch of SBs were not necessarily optimal for another batch. The key outcome of this project is that to maintain and enhance a stable market share for SBM in the U.S. and internationally, quality characteristics of SBs entering and SBM leaving the processing plant must be

accurately and consistently monitored throughout the year *(Journal of Agricultural and Food Chemistry 51:7684-7691, 2003).*

Chemical composition and protein quality comparisons of SBs and SBMs from five leading SB-producing countries were assessed in the second project conducted. The composition of SBs and SBMs varied depending on the country of origin and where they were processed. When SBMs subjectively deemed to be of low, intermediate, or high qualities were evaluated, amino acid concentrations and protein solubility in potassium hydroxide tended to improve as subjective quality increased. Differences in SBM composition and quality will impact swine and poultry diet formulation practices, and the more accurate the compositional analyses, the more precise the dietary formulation and the better growth and feed efficiency responses that would be expected *(Journal of Agricultural and Food Chemistry 52:6193-6199, 2004).*

Chemical and biological assays of ingredient quality are useful in predicting the nutritive value of that ingredient for the animal itself, but in vivo ileal digestibility assays are the gold standard to more accurately determine the bioavailability of amino acids in SBMs for pigs. Five experiments were conducted to determine the true amino acid digestibilities of SBs and SBMs produced in the U.S., Brazil, China, Argentina, and India. Soybeans obtained from these countries were processed in the U.S. The high, intermediate, and low quality SBMs from each country differed in chemical composition, but few differences existed in the true amino acid digestibilities as determined in swine. When comparing countries, the SBMs produced in Argentina and Brazil were less digestible, whereas the SBMs produced in China, India, and the U.S. were similar in digestibility. These differences in true amino acid digestibilities among countries might offer a competitive advantage to feed formulators/swine producers with knowledge of the highest quality SBMs available on the market *(Journal of Animal Science 82:3198-3209, 2004).*

Processing of SBs was a major thrust of this C-FAR Sentinel project, and a considerable body of information was collected. Addition of common by-products such as gums, soapstock, and weeds/trash back to the SBM affected apparent ileal digestibility of amino acids by pigs. All additives together resulted in consistently lower digestibilities of dry matter, organic matter, crude protein, and amino acids compared with a no by-product control, or the by-products fed separately. Roasted SBs resulted in even lower values. This experiment proved conclusively that if by-products are being disposed of by returning them to the meal, the nutritive value of that meal will be compromised as demonstrated by an 11 percentage unit decrease in amino acid digestibility. This is in line with poultry results where a 10 percentage unit decrease in amino acid digestibility was demonstrated. These reductions in amino acid digestibility values could result in potential amino acid deficiencies and lead to reductions in feed intake, increased feed wastage, impaired growth, reduced feed efficiency, and reduced animal growth performance *(Journal of Animal Science 84:1403-1414, 2006).* A companion study was conducted with swine evaluating animal growth performance, carcass characteristics, and pork quality using the same experimental treatments as above. Discount factors associated with feeding the by-product contaminants were identified and quantified *(Journal of Animal Science, In Preparation).*

To determine optimal processing conditions for preparation of a SBM that will result in optimal amino acid digestibilities, six lots of high protein SBM were produced under different toasting conditions (bed depth in the desolventizer-toaster was altered). Linear increases in digestibility were noted with increased bed depths for several amino acids. Data fail to suggest a single bed depth used in SBM processing as being superior to all others in terms of improving nutritional value of the resultant SBM. Data suggest that SBMs produced at somewhat higher bed depths than the current industry standard may result in some improvement in digestibility without overprocessing the SBM *(Animal Feed Science and Technology, In Press).*

Another study determined if lengthening the time that SBs spend in the extractor during preparation of SBM results in increased relative bioavailability of P without negatively impacting true amino acid digestibility, and to compare modified SBMs with that produced from a low-phytate SB. Phosphorus bioavailability from SBM prepared from a low phytate SB was 1.5 times higher than for SBM extracted for 45 min (traditional extraction time). Increasing the length of time that SBs spend in the extractor from 45 to 90 min led to an increase in bioavailable P but a decrease in bioavailable lysine, potentially negating the positive effect on P *(Poultry Science 84:1555-1561, 2005).*

With recent increases in the production of biodiesel fuel, the number of SB processing plants that use extruder/expeller processing, compared with traditional solvent extraction, has increased. Small changes in extruder/expeller processing conditions may result in a SBM that is more digestible when fed to pigs or poultry. An experiment was conducted to quantify the variation in chemical composition and protein quality of SBs and the resultant SBMs obtained from extruder/expeller processing plants in the U.S. and to determine the effects of altering temperatures (121 - 160 C) during extruder/expeller processing on in vivo amino acid digestibilities by poultry. Substantial differences were noted in amino acid composition and protein quality of the SBMs produced in this manner. The SBMs extruded at 121 and 135 C were underprocessed as noted by high urease activities and lower amino acid digestibilities. Meals extruded at 150 and 160 C resulted in higher amino acid digestibilities and lower urease activities, indicating adequate processing. Large variation exists in the nutritional quality of extruder/expeller SBMs currently in the marketplace. Optimal processing temperatures should be >135 C, and temperatures as high as 160 C do not result in overprocessing *(Journal of Agricultural and Food Chemistry 54:8108-8114, 2006).*

Carbohydrates make up approximately 35% of the SB and 40% of SBM, yet information on their nutritional effects is scant. We reviewed this area thoroughly and found that the ability of nonruminants to digest and utilize SBM carbohydrates depends on several factors including the composition of SB carbohydrates as influenced by cultivar, environmental and growing conditions, processing of SBs, and perhaps by age of animal fed SBM. Use of exogenous enzymes appears to be fertile ground for research to improve dietary SBM carbohydrate utilization. Improved utilization of SBM carbohydrates will lead to overall improvements in feed efficiency, greater animal growth performance, and reduced feed costs *(Livestock Production Science 97:1-12, 2005).*

Soybean oligosaccharides are not eliminated by processing and make up 4-6% of SBM dry matter. Their anti-nutritional effects have been demonstrated in poultry, but limited research has been conducted in swine. Removing the oligosaccharides from SBM

in poultry diets increased the true metabolizable energy value of the diet by 20%. Our studies showed that, unlike the case with poultry, SB oligosaccharides only minimally affected apparent or true ileal dry matter, nitrogen, or amino acid digestibilities, and did not increase the incidence of diarrhea in the pig. They were partially digested prior to the cecum, indicating ileal fermentative activity. Prebiotic activity was demonstrated as indicated by increasing concentrations of gut bifidobacteria and lactobacilli, two major genera associated with gut health, as well as by increasing concentrations of short-chain fatty acids. Oligosaccharides present in a soy matrix (i.e., soy solubles) behaved differently than chemically pure raffinose, stachyose, and verbascose in a simulated colonic environment, with greater gas and short-chain fatty acid production demonstrated by the latter, as well as higher rates of gas production *(Journal of Animal Science 80:2433-2441, 2002; Journal of Animal Science 81:2505-2514, 2003; Journal of Animal Science 81:2535-2545, 2003).*

Two farm-level economic production simulation models were constructed to examine effects of feeding diets with value-added SBMs that optimized growth performance. One simulation was built for 300 sow operations that have three-site operations and phased feeding. The second was for a small broiler operation that used genetic stock from France selected for slow growth, lower-than-normal subcutaneous fat deposits, and for free-range production. These simulation models were constructed in STELLA, a graphical simulation environment that permits users to rapidly assess the effects of different production criteria. The swine model allows producers to choose either a target market weight (e.g., 260 pounds) or a fixed finishing period (e.g., 130 days). Results showed that for the small- and medium-sized operations, value-added SBM-based diets permitted decreased time on feed (by 10-12 days) to reach target weight, lower variance in finished weight across animals, and increased turns to the production unit over a 5 year period. That is, the significant fixed costs of finishing floors and maintaining a sow herd are spread over more finished hogs, lowering total production costs per head. For the fixed feeding period option, there was a lower feed intake per pound of gain (depending on the chemical composition of the SBM) and heavier average weights. At 2003 and 2004 market prices, profitability per head was increased by 5-10%. The poultry model showed that a diet containing value-added SBM could be successfully used to replicate the Label Rouge poultry production system that exists in France. If SBs are chosen and processed specifically to optimize poultry growth, the low density production system can be profitable in Illinois, even if production ceases during the winter months.

Beneficiaries

Soybean processors now have the information necessary to prepare value-added, species-specific SBMs.

Soybean producers now know how their product compares with that of their counterparts in other major SB-producing countries and the importance of proper preparation of SB products.

Swine and poultry producers now have information related to the discount factors in SBM that will negatively impact growth performance, feed conversion efficiency, and meat quality.

Producers interested in small-scale swine and poultry production, particularly in niche markets, now can budget effectively for profits despite lacking the economies of scale of large integrated systems.

Large feed companies, many of whom manufacture commercial diets as well as feed livestock and poultry, now know those areas in the "feed to fork" continuum that may be impacted so as to add value to the final product. These companies often contract out the production and (or) management of the animals to many individual small- and medium-size farmers. This contract production method enables small farmers to maintain a stable, secure source of farm income or to use animal production as a stable part of a total farming enterprise.

Small feed companies now have the necessary information to produce diets targeted to niche market segments.

Nutrition consultants now have the information to service their clients in a more efficient and effective manner using niche SBM as the protein source in animal diets.

University researchers and teachers now have a reliable database to use in teaching the next generation of agricultural professionals about the many significant issues related to use of SBM in animal agriculture.

Consumers benefit by having access to a safe and nutritious supply of pork and poultry that is available at an affordable price.

Outreach

The swine and poultry simulation models have been presented to 9 extension audiences in 2005 and 2006. In addition to agricultural bankers from Illinois and the midwestern region, the small-scale swine and poultry models have been presented to commodity associations in Alberta, Ontario, New Brunswick, and Quebec, Canada. In addition, the modeling results are presented on a regular basis to executive development programs in the agri-food sector. The models are being prepared to be ported to a web-based version of STELLA so they may be accessed by producers and other interested parties directly.

A desired outcome of this Sentinel project was to contact and work with producer groups interested in using information from this project's animal nutrition and feedstuff evaluation research to help develop niche markets in SBM processing and feeding. By the end of 2004, Frazier, Barnes & Associates identified 9 producer groups in 7 midwestern states and 2 in the eastern U.S. that were in various stages of planning to develop small scale SB processing plants to produce biodiesel from SB oil, with SBM as a co-product of oil production. Contacts with these organizations were made to spark the planners' interests in the research results from the animal nutrition research. The goal was to make these groups aware that SBM quality could be enhanced substantially, and the resulting SBMs would have a higher feeding value if processing characteristics were selected and designed into the plants. The National Trail Biodiesel Group, LLC is presently making plans to begin construction of a biodiesel plant in Newton, IL that will be operational in 2008.

With biodiesel production being a major opportunity for midwestern farmers, access to the research results from this study comes at a very timely point in the industry's development. Biodiesel plants coming on line are smaller in scale than

existing plants and are more adaptable to processing modifications such that the SBM co-product can be of enhanced nutritional value. Soybean meal as a co-product of biodiesel production only reaffirms that its widespread availability will continue.

Traditional animal nutrition studies provide incremental improvements in the knowledge base as regards the contributions of feed ingredients to the nutrition of the animal. Rarely do the research results become part of a comprehensive database. As part of this project, the extensive body of soy in animal nutrition data collected over 4 years of C-FAR Sentinel funding and 3 years of Soy/Swine Nutrition funding was compiled and made available to animal feeding decision makers and SB processors interested in value-added SBM. The primary venue for information dissemination of research results is through the SAND website **(www.traill.uiuc.edu//sand/)**. This website makes easily accessible the research results and the large body of SBM nutritional information. From the homepage of SAND, 14 research articles are linked to concise summaries presented in bulleted format with the impact statement prominently displayed. For more in-depth consideration of the research methods and results, each article is linked to full articles and abstracts from the on-line publication sources. Articles also can be viewed as separate lists by topic. Considerable effort was involved in developing a format for presenting the data from this project and the soy/swine nutrition studies in ways that an animal nutritionist desires when developing feed formulations. These databases represent the nutritional information for SBM from maturity zones 1 through 7, or aggregated across regions. Similar data also are presented from the study of international SBM sources. Tables are user-friendly, with tabs representing "general composition and processing measures", "total amino acids with standardized and apparent digestibility values", "carbohydrates", and "mico- and macro-mineral values". The SAND homepage also links to a conveniently illustrated reference on how SBM is prepared by solvent extraction. The diagram shows the path that SBs take in a typical solvent extraction plant. This includes steps through direct extraction, meal handling, pre-press preparation, and solvent extraction. Images and descriptions of equipment appear for each processing step. Finally, the SAND Resource page provides external links to information about animal nutrition, feed formulation, general swine and poultry information, organizations, associations, and programs.

Leveraged Funding

West Central Soy	$ 5,100
Schillinger Seed	$ 9,500
Land O' Lakes/Purina	$ 4,000
Wenger Manufacturing and Northwood Mills	$ 4,250
University of Minnesota/North Carolina State University/ Louisiana State University	$ 6,000
Ajinomoto and Novus International	$ 12,000
U. S. Poultry and Egg Association/Novus International/ Heartland Lysine/ADM/Degussa/Fats and Proteins Research Foundation	$170,000
Midwest Poultry Consortium	$ 24,400

Quality Technologies, Inc.	$ 25,000
Novus International	$ 25,000
Illinois Soybean Association	$193,346
United Soybean Board	$ 50,000
American Protein Corporation	$ 79,000
Pyxis	$233,250
The Iams Company	$ 80,000
Massey University, New Zealand	$ 25,000
Illinois Soybean Association	$ 50,000
Hatch	$ 20,000

Websites

SAND **(www.traill.uiuc.edu//sand/)**
StratSoy **(www.stratsoy.uiuc.edu)**
Varietal Information Program for Soybeans **(web.aces.uiuc.edu/VIPS/)**
TRAILL **(www.traill.uiuc.edu//sand/)**