2002

Characterization and Utilization of Soy Flour Produced from Extrusion-Expelling Processing

Tong Wang
Iowa State University, tongwang@iastate.edu

Deland J. Myers
Iowa State University

Adrianna A. Heywood
Iowa State University

Characterization and Utilization of Soy Flour Produced from Extrusion-Expelling Processing

Abstract

The number of extrusion-expelling (E-E) plants, often referred to as "mini-mills", built to process soybeans produced in local areas has been increasing. E-E processing is a mechanical processing, and it has several advantages over conventional processing methods. E-E mills, such as the Express System (Insta-Pro Div., Triple "F", Inc., Des Moines, Iowa), are relatively small, with capacities ranging from 6 to 120 tons/day. They require low initial capital investment ($150,000-200,000) and have relatively low operating costs ($25/ton) as described by Nabil Said (inform 9:139-144,1998). E-E mills can be used for processing identity-preserved (IP) soybeans. Large-scale solvent extraction (SE) facilities are usually not designed for IP seeds because of their low production tonnage while these seeds are being developed, and because of the large number of value-added traits being developed.

Disciplines

Food Science | Human and Clinical Nutrition

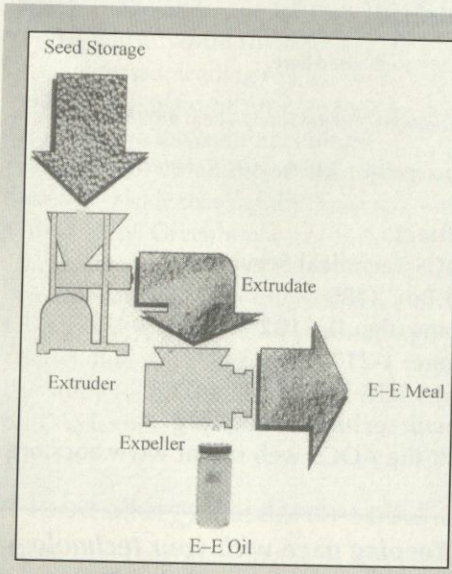
Comments

This article is published as Wang, T., D. J. Myers, and A. A. Heywood. 2002. Functionality and utilization of soy flour produced from extrusion-expelling processing. *Inform* 13:708-713. Posted with permission.

Characterization and utilization of soy flour produced from extrusion-expelling processing

This article is by Tong Wang, Deland J. Myers, and Adrianna A. Heywood, all of Iowa State University.

The number of extrusion-expelling (E-E) plants, often referred to as "mini-mills," built to process soybeans produced in local areas has been increasing. E-E processing is a mechanical processing, and it has several advantages over conventional processing methods. E-E mills, such as the Express System® (Insta-Pro Div., Triple "F", Inc., Des Moines, Iowa), are relatively small, with capacities ranging from 6 to 120 tons/day. They require low initial capital investment ($150,000–200,000) and have relatively low operating costs ($25/ton) as described by Nabil Said (*inform* 9:139–144, 1998). E-E mills can be used for processing identity-preserved (IP) soybeans. Large-scale solvent extraction (SE) facilities are usually not designed for IP seeds because of their low production tonnage while these seeds are being developed, and because of the large number of value-added traits being developed. Recently enacted stringent environmental laws also restrict construction of new SE plants, and E-E mills can be an alternative. In addition, because E-E products are not treated with organic solvent, their crude oil and meal may be considered as organic or natural provided appropriate methods are used during soybean production. Currently, the partially defatted soybean flour (about 6% residual oil) produced from these operations is not used extensively in foods due to limited information on protein functionality and food applications. Some of the potential applications include baking and meat extending.



Scheme 1
Extrusion-expelling (E-E) system used for soybean processing (adapted from Insta-Pro International product brochure).

E-E Processing

In E-E processing, dry extrusion is used as a heat pretreatment to denature the protein and interrupt the cellular organization of the seed. A screw press is then used to press out the oil and to separate oil and meal. The extruder, as used for over 70 years in the food industry, consists of a flighted screw that rotates in a tightly fitting barrel and conveys and compresses the feed. The feed material entering the screw is compacted and worked into a molten material. As the material progresses toward the die, both temperature and pressure increase as a result of the relatively shallow screw flights. The sudden pressure drop as the product is forced through the die causes expansion of the extrudate. Entrapped water vaporizes or "flashes off" because the extrudate temperature is often higher than the boiling point of water. The extrusion action is affected by the configurations of the screws and their rotational speeds, the back-pressure requirements of the dies, and the characteristics of the feed material. Temperature control systems are often added to extruders to control and monitor the temperature of specific barrel sections.

Dry extrusion processing of soybeans was developed in the 1960s to enable soybean growers in the U.S. Midwest to cook their seeds for livestock feed. The process uses friction as the sole source of heat to deactivate antinutritional factors present in oilseeds. The main product is the dry extrudate, with an average of 38% crude protein and 18% oil; it has been successfully used in high-energy diets for all livestock. On the other hand, continuous screw pressing (expelling) was the major soybean processing technique before World War II. This mechanical method has relatively low oil removal efficiency and has been largely replaced by solvent extraction.

Coupling dry extrusion and expelling was first used at the University of Illinois to process soybeans to obtain good-quality oil and protein meal. A schematic diagram of E-E processing is shown in Scheme 1. The coarsely ground whole soybeans with 10–14% moisture content were extrusion-cooked. The residence time in the extruder was less than 30 s, and the internal temperature was about 135°C. The extrudate that emerged from the die in a hot semifluid state was immediately pressed in a continuous screw press. Extrusion prior to expelling greatly increased the throughput of the screw press, and an oil recovery of 70% was obtained in single-pass expelling. For the experimental conditions used, press cake with 50% protein, 6% residual oil, and 90% inactivation of trypsin inhibitor (TI) was obtained. The high temperature and short elapsed time needed for heat treatment during extrusion eliminated the prolonged heating and holding of raw materials as in conventional screw-pressing operations.

Quality comparison of E-E and SE protein meals

Soybean oil and meal produced by E-E have unique characteristics compared with products produced by SE. Tong Wang and Lawrence Johnson at the Center for Crops Utilization Research at Iowa State University conducted a survey to compare quality characteristics of the oils and meals produced from different types of soybean processing methods. Soybean oil and meal samples were collected from thirteen E-E mills, eight SE plants, and one continuous screw-press (SP) plant. The quality characteristics of the soybean meals are presented in Table 1. SP was slightly more efficient in oil recovery than E-E, leaving 6.3% oil, compared with a mean of 7.2% for E-E meals. These values are considerably higher than those of the SE meals (1.2%).

The degree of protein denaturation in soybean meal is typically measured by determining protein solubility under alkaline/potassium hydroxide (KOH) conditions, urease activity, and protein dispersibility index (PDI). Solubilities in KOH of E-E and SE meals were not significantly different, nor were urease activities, indicating the amounts of heat exposure were equivalent. SP meal had 61.6% KOH solubility and 0.03 pH unit urease activity, suggesting much greater protein denaturation. PDI values of E-E meals (18.1) were much lower than those of the SE meals (44.5), indicating higher degrees of protein denaturation of the E-E meals.

Rumen bypass or rumen undegradable protein (RUP) is an important measure of potential protein utilization by ruminant animals. The higher the bypass protein value, the more protein that will escape from rumen bacterial fermentation and be utilized by the animals. It was surprising that RUP values were similar for E-E and SE meals (37.6 vs. 36.0%, respectively), which had different degrees of protein denaturation as measured by PDI. TI activity is an important quality parameter of soybean meal, especially if the meal is fed to monogastric animals or used as a food ingredient. Urease activity and TI assay are usually used as indicators for TI activity. The few differences between the E-E and SE meals, and the low values suggest that the antinutritional factors should be sufficiently inactivated.

TABLE 1
Quality characteristics of soybean meals produced from extrusion–expelling (E-E), solvent extraction (SE), and screw-press (SP)[a]

	E-E	SE	SP
Moisture (%)	6.9 b	11.7 a	11.0 a
Oil (%)[b]	7.2 a	1.2 b	6.3 a
Protein (%)[b]	42.5 b	48.8 a	43.2 b
Fiber (%)[b]	5.4 a	3.7 b	5.9 a
Urease (ΔpH)	0.07 a	0.04 a	0.03 a
KOH solubility (%)	88.1 a	89.1 a	61.6 b
PDI	18.1 b	44.5 a	10.6 c
Rumen bypass (%)	37.6 b	36.0 b	48.1 a
Trypsin inhibitor (mg/g)	5.5	5.5	0.3

[a]The values with different letters are significantly different at 5%.
[b]Percentages are based on 12% moisture content. From Wang and Johnson (4). PDI, protein dispersibility index.

Characterization of E-E meals produced under various processing conditions

Currently, partially defatted soy flour (ground E-E meal) is not used extensively in food products because there is little information available about its functionality and applicability in foods. One potential use for partially defatted soy flour is the production of texturized vegetable proteins. However, it is believed that partially defatted E-E soy flour will perform much differently from the traditionally defatted soy flakes or flours because of the heat denaturation of protein and its high oil content. Research conducted at Iowa State University by Crowe *et al.* (1) and A. Heywood, D.J. Myers, T.B. Bailey, and L.A. Johnson (unpublished data) focused on (a) the range of PDI and residual oil contents that could be produced by E-E processing and (b) the functional characteristics of these low-fat flours.

Whole or dehulled soybeans were processed using an Insta-Pro 2500 extruder and an Insta-Pro 1500 screw press. The extruder temperature was adjusted by manipulating the screw design and shear lock configuration, as well as the die (nose cone) restriction. Screw press conditions were modified by changing choke settings. Production of partially

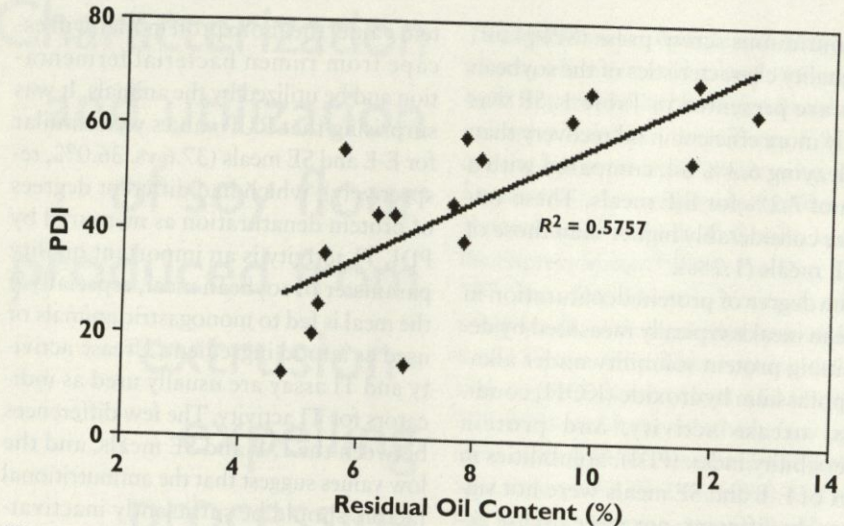


Figure 1. Relationship of protein denaturation and residual oil content of E-E meals (1). PDI, protein dispersibility index.

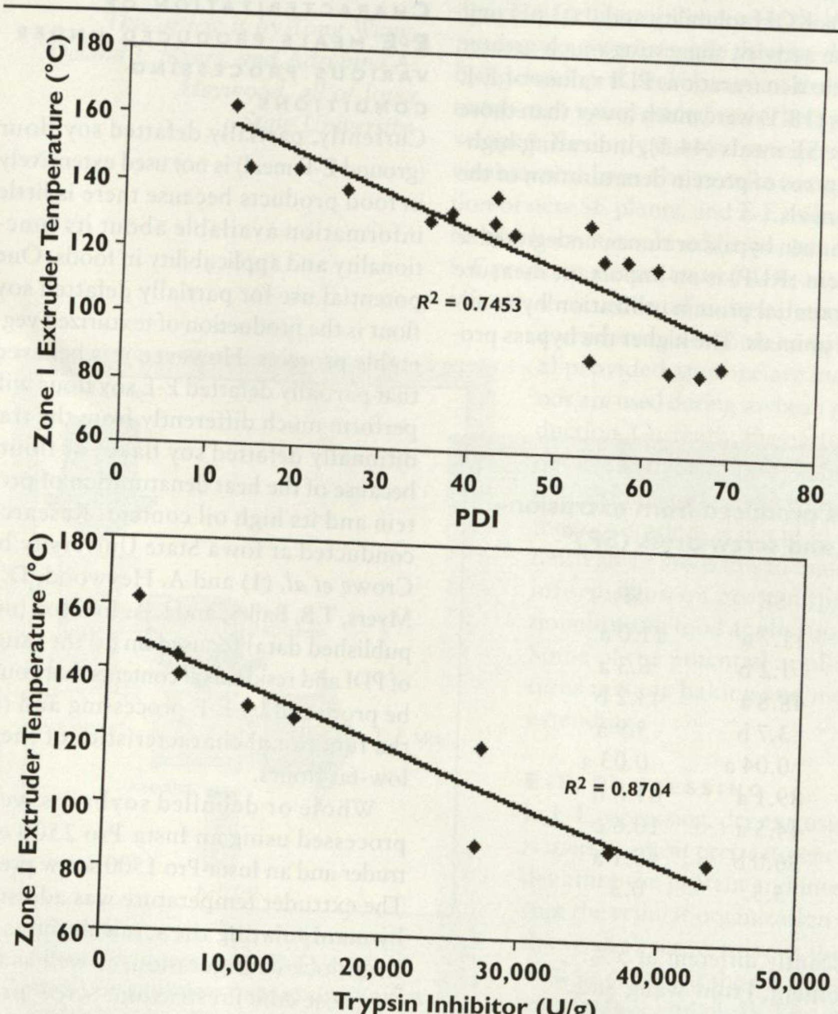


Figure 2. Relationship of extruder temperature and denaturation of storage protein and antinutritional factor (1).

defatted soy flour with a wide range of PDI values and residual oil contents was achieved by changing these extruder and screw press operating conditions. The relationships between residual oil content and PDI are shown in Figure 1. Protein denaturation and inactivation of TI are correlated with extruder temperature (zone 1, the highest temperature region), and the relationships are shown in Figure 2. PDI correlated with residual oil content and extruder temperature. Dehulled soybeans tended to have higher PDI values and higher residual oil contents than whole soybeans under identical E-E conditions. Whole soybeans produced significantly higher extrusion barrel temperatures than dehulled soybeans. These data indicate that it is possible to design a product with desirable PDI and residual oil content.

Application of E-E flour in doughnuts

Soybean flour is often used in commercial bakery doughnut mixes. The primary purpose is to decrease the amount of oil uptake by the doughnut during frying. Soybean flour also aids in improving gas retention and controlling crust color and volume. Typical usage levels of soybean flour in commercial doughnut mixes range from 1–3% of the total flour in the formulation. However, additional research has investigated using larger volumes of soybean flour to reduce costs further. Most research has focused on including defatted soy flour in a standard cake doughnut formulation. A. Heywood, D.J. Myers, and L.A. Johnson (unpublished data) studied the effects of low-fat soy flour, i.e., E-E flour, on selected chemical, physical, and sensory attributes of the standard cake doughnut. Certain differences were observed between the two types of soy flours. Low-fat soy flour was not as effective in reducing fat absorption as the defatted soy flour. The physical and chemical properties of the low-fat-flour fortified donuts were somewhat unpredictable.

Texturized soybean protein (TSP) production from E-E flour

Extrusion can be used to produce meat analogs or extenders from soy protein. TSP is produced primarily by extruding defatted soybean flour, soybean protein concentrate, and soybean protein isolate. Mian Riaz and Edward Lusas at Texas A&M University used partially defatted E-E products to produce TSP. E-E meal was adjusted to 21% moisture content, and extruded shreds or chunks were produced by a secondary extruder. These products hydrated readily, resembled ground or chunk meat, and retained a chewy texture when cooked. An E-E protein product with a PDI as low as 25 could be satisfactorily texturized.

Troy Crowe and Lawrence Johnson in our group have studied the effects of PDI and residual oil content of E-E soy flour on the texturization of soy protein and functionality of the TSP products. Ten partially defatted soy flours with residual oil contents and PDI values ranging from 5.5–12.7% and 35.3–69.1, respectively, were texturized using a twin-screw extruder. The TSP products, including a commercial sample from Archer Daniels Midland, Decatur, Illinois, were tested for water-holding capacity, and the hydrated TSP textures were analyzed. TSP-extended ground beef was evaluated for its sensory quality. Water-holding capacities, bulk densities, and sensory evaluation of TSP produced from partially defatted soy flour are shown in Figure 3. Residual oil content negatively correlated with water-holding capacity, and water-holding capacity negatively correlated with bulk density. TSP hardness was significantly reduced in high residual oil samples. The negative correlation between residual oil and all instrumental texture measurements indicates that the higher lipid contents of these samples may have inhibited protein interactions responsible for desirable extrudate textural attributes. However, neither PDI value nor residual

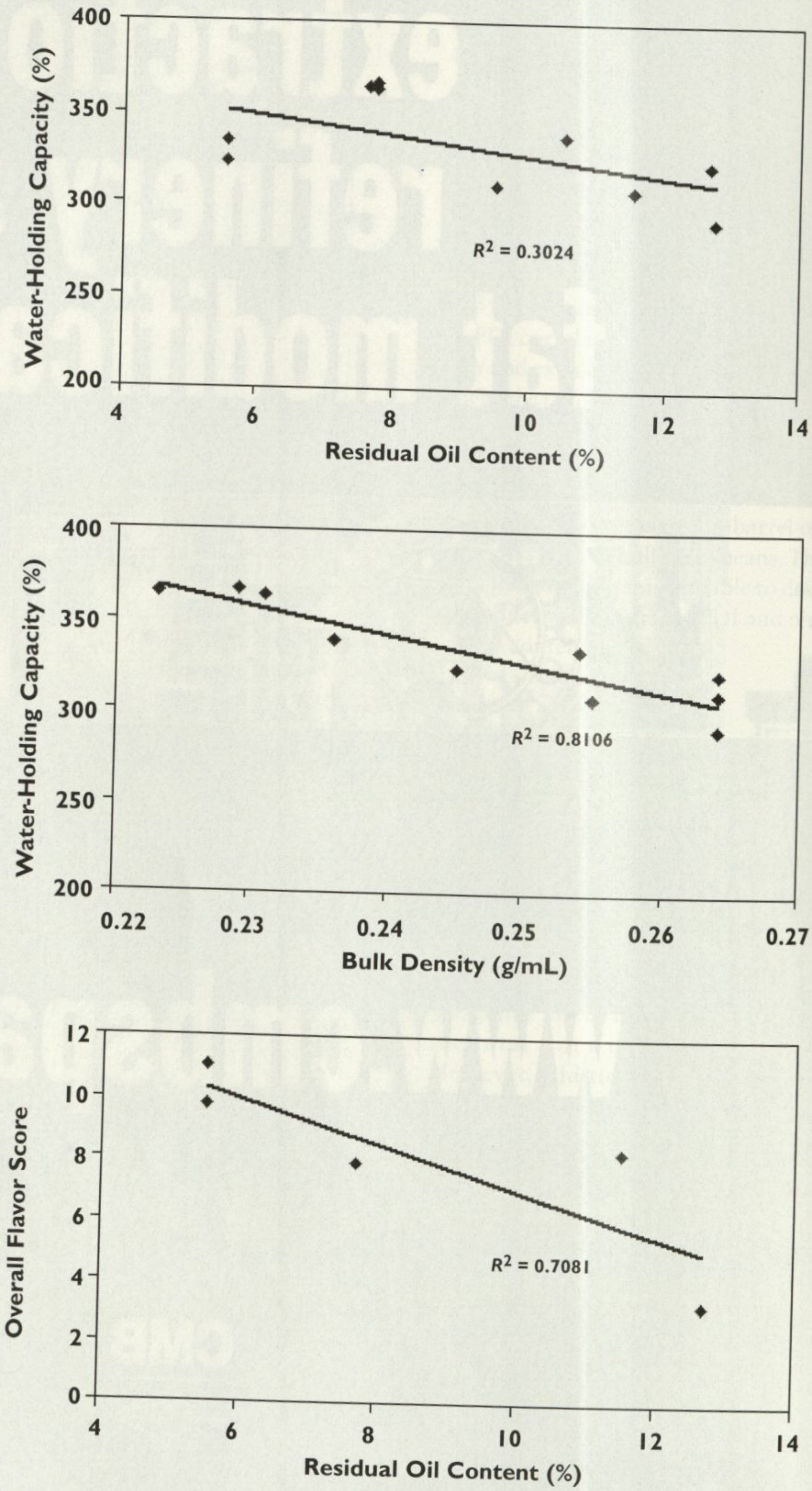


Figure 3. Correlation among residual oil content, water-holding capacity, density, and overall flavor quality of TSP from E-E flour (2).

oil content affected textural attributes measured in the TSP-extended ground beef system.

Results from sensory evaluation of TSP-extended ground beef patties indicated that there were no significant differences in hardness or chewiness in the TSP-extended ground beef compared with the 19% fat control. Nevertheless, residual oil content of partially defatted soy flour correlated with overall flavor (Fig. 3). In general, TSP from low-fat, partially defatted soy flour had less soy flavor and better overall flavor than TSP from high-fat partially defatted soy flour.

In summary, E-E may be used as a convenient method of soybean processing. The protein meal or flour can be used in certain food applications, despite the heat denaturation and some functionality change. More products, food applications, and further processing techniques are currently being developed at our Center for Crops Utilization Research at Iowa State University.

Bibliography

1. Crowe, T.W., L.A. Johnson, and T. Wang, Characterization of Extruded-Expelled Soybean Meals and Edible Flours, *J. Am. Oil Chem. Soc. 78*:775–779 (2001).

2. Crowe, T.W., and L.A. Johnson, Twin-Screw Texturization of Extruded-Expelled Soybean Flours, *J. Am. Oil Chem. Soc. 78*:781–786 (2001).

3, Riaz, M.N., Extrusion-Expelling of Soybeans for Texturized Soy Protein, in *Proceedings of the World Conference on Oilseed Processing and Utilization*, edited by R.F. Wilson, AOCS Press, Champaign, IL 2001, pp. 171–175.

4. Wang, T., and L.A. Johnson, Survey of Soybean Oil and Meal Qualities Produced by Different Processes, *J. Am. Oil Chem. Soc. 78*:311–318 (2001).

Readers may contact the authors at Iowa State University, 2312 Food Sciences Building, Ames, IA 50011.