

Effects of temperature, moisture and residence time in the properties of full fat soybean flour produced in a twin extruder

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SUMMARY. Soybeans were dehulled, roll-milled into grits, conditioned to 18 or 21% moisture and continuously cooked in a twin extruder at three temperature programs and two residence times. The resulting extrudates were further dried and roll-milled into flour and characterized for their physical, chemical and functional properties. The urease activity and nitrogen solubility index (NSI) decreased with increased extrusion temperature, residence time and soybean grits moisture content. The best pre-cooked full fat flours had a urease activity lower than 0.2 and a NSI higher than 15%.

RESUMEN: Efectos de temperatura, humedad, y tiempos de residencia en las propiedades de harinas de soya integral producidas en un extrusor gemelo. Granos de soya fueron decorticados y molidos a través de un molino de rodillos para la obtención de grits los cuales fueron posteriormente acondicionados a 18 ó 21% de humedad y cocidos continuamente en un extrusor gemelo bajo tres programas de temperatura y dos tiempos de residencia. Los extruidos resultantes fueron secados y molidos para la obtención de una harina, la cual fue caracterizada en sus propiedades físicas, químicas y funcionales. La actividad de ureasa e índice de solubilidad del nitrógeno (NSI) decreció con incrementos en temperatura de extrusión, tiempo de residencia y humedad de acondicionamiento de los grits. La mejor harina integral precocida presentó una actividad de ureasa menor a 0.2 y un NSI mayor de 15%.

INTRODUCTION

Brazil is the second largest world producer of soybeans (*Glycine max L.*) with 22.7 million metric tons of production in 1993 (1). Consequently, soybeans are a realistic option to upgrade the nutritional status of many people who cannot afford the high prices of animal foods. Factors limiting the direct use of the crop for human food may include prolonged cooking time, beany flavor and lack of familiarity with processed products. Furthermore, soybeans ought to be cooked to inactivate important antinutritional factors and to enhance their nutritional value. Full-fat soybean flour has a high caloric value and protein quantity and quality. More importantly, its amino acid composition complements the proteins of cereal products. Soybean protein quality is limited due to presence of antitryptic inhibitors and S-containing amino acids.

Soybean products are currently used in a limited basis by bakeries, meat processing plants, confectionary industries and creameries. The industrial process to manufacture pre-cooked soybean is energy inefficient and prolonged. An alternative process to produce full-fat soybean flour using a single screw extruder has been reported elsewhere (2-4). Extrusion cooking

offers the advantage of reduced labor, less energy input per Kg of finished product and production in a continuous basis. Cooking time, moisture and temperature are the major processing variables affecting the inactivation of antinutritional factors and functional properties of the finished product. Important properties such as water absorption, nitrogen solubility index and protein solubility index are highly dependent on processing conditions. Overcooking generally develops off-flavors, darkens the color, lowers nutritional value and significantly reduces nitrogen solubility.

The purpose of this research work was to study the effects of temperature, residence time and soybean meal moisture content in the physical and chemical properties of full-fat soybeans subjected to thermoplastic extrusion in a twin extruder.

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FIGURE 1

Flowchart of the process to obtain dehulled, full-fat soybean grits

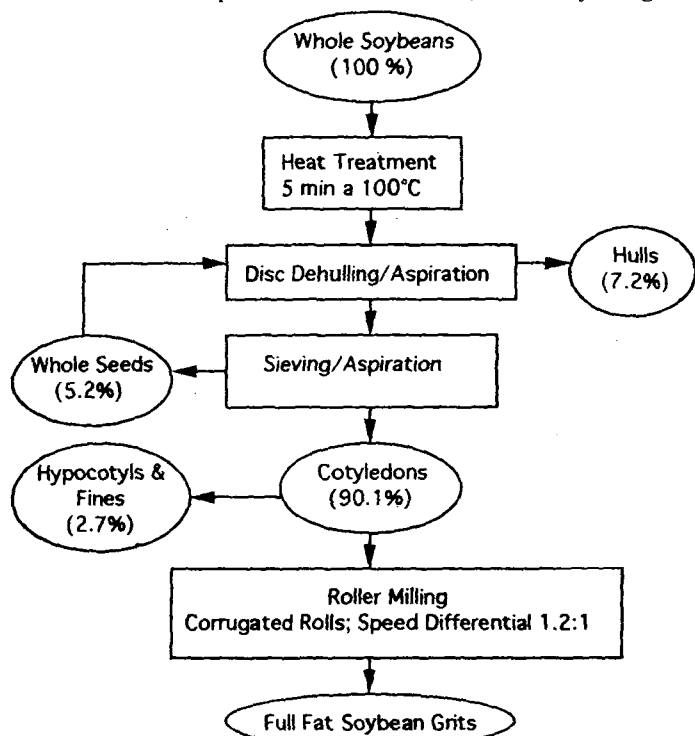
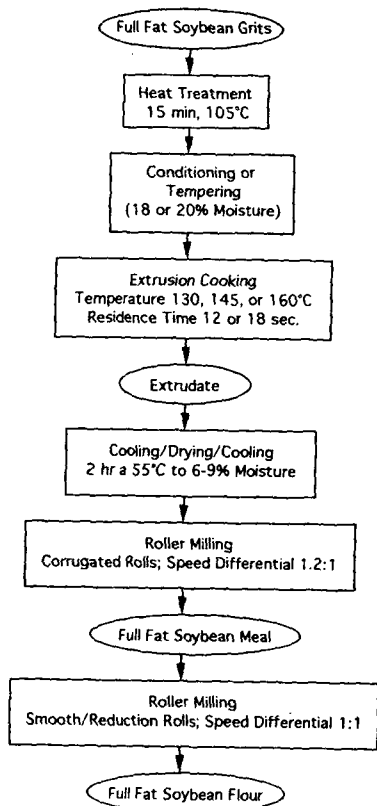


FIGURE 2

Flowchart of the experimental process to obtain pre-cooked, full-fat soybean flour via extrusion cooking



MATERIALS AND METHODS

Grain source. Soybean variety BR-16 with a beige colored hilum was procured from Serviço da Sementes Básicas da EMBRAPA, Ponta Grossa, Parana, Brasil. Seeds had an average 1,000 kernel weight of 182.2 g.

Production of dehulled grits. Whole soybeans were subjected to 5 min heating in a convection oven set at 100° C to loosen hulls. Upon cooling, the pre-heated seeds were continuously decorticated in a disk dehuller (Descascador Mecânico para Graós; Brazilian patent # 9-100-825) equipped with a fixed and rotating concave discs and an aspiration system. The dehuller had an efficiency of 94-95%. Hypocotyls, fines and whole seeds were separated from cotyledons (splits) in a clipper sieve cleaner equipped with cylindrical (2.0 X 0.5 cm) and round (0.4 cm diameter) sieves # 11 and 10, respectively and

TABLE 1

Chemical composition of whole soybeans, dehulled grits and extruded flour^a

Product	Crude protein ^b %	Crude fat %	Crude fiber %	Ash %	NFE ^c %
Whole soybeans	36.18	22.23	6.67	5.15	29.67
Dehulled grits	38.39	24.43	3.51	5.54	28.13
Extruded flours	38.09	23.55	3.06	5.25	30.04

^a Values are expressed on dry matter basis.^b Nitrogen x 6.25.^c NFE=Nitrogen free extract. Calculated by difference

TABLE 2

Effect of extrusion temperature, residence time and moisture content in nitrogen solubility index and inactivation of urease activity^a

Temperature °C	Moisture %	Residence time (sec)	Protein %	Urease activity	NSI ^b
130	18	12	38.7	2.04	46.8
130	18	18	38.6	1.75	33.4
130	21	12	38.6	1.50	28.5
130	21	18	38.6	0.45	22.2
145	18	12	38.1	1.49	30.7
145	18	18	38.1	0.18	18.9
145	21	12	38.5	0.42	21.7
145	21	18	38.4	0.11	12.6
160	18	12	38.6	1.19	24.7
160	18	18	38.3	0.14	17.5
160	21	12	38.6	0.27	20.4
160	21	18	38.5	0.15	13.7

^a Each value is the average of three extruded flours processed in three different runs.^b Nitrogen Solubility Index

an aspiration system operating at full blast. A yield of about 90 % cotyledons was obtained (Figure 1).

The resulting cleaned cotyledons were ground into coarse grits with a commercial wheat flour mill (Tecomlin São Paulo, Brasil) furnished with corrugated rolls, Grits were then exposed to 15 min heating in a convection oven set at 100°C with the objective of inactivating lipoxygenase activity.

Extrusion cooking. Soybean grits were conditioned to 18 or 21% moisture in lots of 18 kg in a mixer (Werner & Pfleiderer do Brasil DK 65 N) for 12 min. The resulting conditioned material was continuously processed in a twin extruder (Brabender DSE 45, Duisburg, Germany). The extruder was equipped with 65 cm long counter-rotating screws with a length to diameter ratio of 13:1, two feeding systems capable of delivering up to 1.5 kg/min and a barrel subdivided into 4 zones with individual temperature controls. Materials were

extruded through a die plate containing two round 1 cm diameter holes.

Experimental protocol. Extruded flour were produced using the procedure described in Figure 2. Full-fat soybean grits were first conditioned to 18 or 21% moisture and then subjected to extrusion cooking at 130, 145 and 160°C and two residence times (12 or 18 sec). Therefore, the trifactorial experiment consisted of 12 treatments. The zone # 1 of the extruder operated at 130°C, whereas the other three zones at the predetermined cooking temperature. The material feed rate when extruding for 12 and 18 sec was 1160 and 710 g/min, respectively. Extrudates with about 13-15% moisture were allowed to equilibrate to room temperature for 30 min and then dried for 2 hr in a commercial air-forced oven set at 50-55°C. Then, extrudates were ground into flours by first passing the material through a pair of corrugated rolls to obtain coarse particles and then through a pair of smooth rolls adjusted to produce a fine flour. The materials were immediately packaged in plastic bags and kept in the refrigerator (5°C).

TABLE 3
Particle size distribution of dehulled full fat
soybean grits and extruded flour

Product	US mesh N°	Fraction %
Dehulled full-fat soybean grits	+14	30.9
	+20	30.8
	+28	14.1
	+35	10.9
	-35	12.6
Extruded full-fat soybean flour	+60	66.1
	+80	26.9
	+100	3.0
	+115	1.5
	-115	0.4

TABLE 4
Effect of extrusion temperature, residence time and
moisture content in color scores of full fat soybean flour.

Temperature °C	Moisture content	Residende time	L	--- Color ---		E ^a
				a	b	
130	18	12	79.1	0.62	22.1	82.1
130	18	18	79.4	0.29	21.6	82.3
130	21	12	79.4	0.68	24.3	83.0
130	21	18	79.4	0.29	21.2	82.2
145	18	12	77.5	0.40	21.2	80.3
145	18	18	79.1	0.36	22.1	82.1
145	21	12	78.4	0.68	22.3	81.5
145	21	18	78.3	0.49	21.4	81.2
160	18	12	77.2	0.52	22.4	80.4
160	18	18	79.6	0.17	21.8	82.5
160	21	12	76.4	0.54	21.9	79.5
160	21	18	77.8	0.17	20.6	80.5

^a Color index E= (L2 + a2 + b2)^{1/2}

Physical properties. Color of, the extruded-ground products were analyzed with a Suga Colorimeter (Suga Test Instruments Co, Ltd; Model SM-4-CH; Japon). Values obtained included L, a, b and E.

Particle size distribution of dehulled soybean meal and extruded flours were determined by sieving for 10 min in a rotap. The yield of each fraction was expressed as percentage of the original sample weight.

Chemical analysis. Raw whole soybeans and dehulled-extruded products were analyzed for protein (5); urease activity (6, method Ba 9-58) and nitrogen solubility index (NSI) (6, method Ba 11-65). In addition, whole seeds, dehulled cotyledons and the optimized extruded product were characterized for proximate composition (5).

Statistical analysis. Data was statistically analyzed with ANOVA procedures using a trifactorial experimental design (7). Individual effects and interactions between extrusion temperature (3 levels), residence time (2 levels) and soybean grits moisture content (2 levels) were analyzed.

RESULTS AND DISCUSSION

As expected, whole soybeans seeds had a higher fiber and ash contents than dehulled grits and dehulled-extruded flours (Table 1). Cabral et al (8) also found decreased levels of these components after dehulling. Extrusion of dehulled grits did not affect proximate composition except for a slightly higher fat content in the extruded product. This was likely due to the release of the heat liable lipids during extrusion. Soybean will analyze approximately 1% higher oil content if the AOAC method Ac 3-44 is followed (pre-dry in 130° oven for one hour). This heat release is accomplished in the extruder.

The three extrusion factors studied (temperature,

residence time and soybean grits moisture content) significantly affected inactivation of urease activity and the index of nitrogen solubility. Results showed that urea activity decreased with higher grits moisture content, increased extrusion temperature and prolonged residence time. Interestingly, the inactivation of urease inhibitors was heat dependent indicating that it was heat labile as it has been previously reported by Mustakas et al (2,4). A 3% increase in grit moisture content significantly affected the degree of inhibition indicating that water acts synergistically with heat and exposure time (Table 2). Nitrogen solubility indexes followed the same trend as urease inhibitor activity. Increased temperature and moisture content and prolonged residence time favored protein denaturation and lowered NSI. Soybean products with a high NSI are more functional than counterparts with lower values. Important functional factors such as solubility, water absorption dispersibility and foaming are closely related to NSI (9-12).

Within the constraints of this experiment, results showed that extrusion at 130°C did not inactivate enough urease inhibitors. The maximum inactivation level (approximately 75%) was achieved at 21% moisture and 18 sec residence time. Extrusion at 145° C and 18 sec residence time yielded flours with at least 85% of urease inhibitor inactivated. Extrusion at 160°C yielded only one flour with a high urease activity resulting from the low moisture content and residence time. Roller milling of dried extrudates produced flours with a fine particle size distribution (Table 3) A fine particulate was obtained by first passing the dried extrudates through corrugated rolls to obtain a coarse meal. The meal was further reduced by two passes through a pair of smooth rolls. The milling technique proved to be suitable for producing fine flours required in many processes such as for production of bakery and meat products.

Extrusion conditions did not significantly affect the color of the flours (Table 4). This could be attributed to the small extrusion residence time that never exceeded 18 sec.

CONCLUSIONS

It was possible to produce full-fat soybean flours with trace quantities of urease activity in a twin extruder operating at temperatures above 140°C. The higher the temperature, residence or processing time and raw meal moisture content the lower the activity of urease inhibitors and nitrogen solubility index. Extrusion offers the advantage of producing an array of flours with different functionalities and residual inhibitors in a continuous basis and with small heat-processing times.

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