Pak. J. Sci. Ind. Res. 2006 **49**(1) 48-52

Production and Quality Evaluation of Extruded Full-Fat Soy Flour

Hamida Abid*, Surruya Wadud and Hussan Ara

PCSIR Laboratories Complex, Jamrud Road, Peshawar, Pakistan

(received April 7, 2004; revised December 8, 2005; accepted January 16, 2006)

Abstract. Full-fat soy flour was prepared for human consumption by using extrusion technology. Various process parameters such as feed rate, grain size, moisture content of the ingredients, cooking time, temperature, and speed of the extruder cooker were standardized. The samples of raw soy flour and extruded full-fat soy flour were evaluated by chemical analysis, biological assays, organoleptic evaluation, microbiological analysis and storage stability. Soy flour prepared by extrusion cooking with 22 % moisture content at 138 °C temperature was in the form of creamy white flakes, which had a good taste, flavour, and nutritive value. These flakes remained stable daring the storage period of 10 months.

Keywords: soy flour, extrusion technology, full-fat flour, soybean

Introduction

Malnutrition is a wide spread problem, which commonly ocurrs at various stages of growth from infancy to adulthood. Soybean has been shown to have the potential of overcoming protein calorie-malnutrition (PCM) on account of its high protein and fat contents (38- 42 % protein and 18-20 % fat). Soy flour is the common form in which soybean can be incorporated in various food preparations (Pokorny *et al.,* 2002; Chauhan and Bains, 1985; Dubois and Hoover, 1981; Sushma *et al.,* 1979; Hoover, 1974; Rathod and William, 1973). Soy flour is comparatively inexpensive and easy to process. It is one of the most promising forms in which it can be used to minimize the problems concerning flavour, antinutritional factors and stability of the products (Patel *et al.,* 1990; Schemer *et al*., 1973).

Extrusion cooking process is used to convert raw soybean into food products with improved nutritional and storage qualities. The process is useful to minimize damage to nutritional properties, to inactivate antinutritional factors, and yields a product which possesses proteins of high biological value as well as fat energy. The process is low cost. The extruder achieves high productivity in a single processing step, which both cooks and shapes the products having high cost effectiveness of the process. The high temperature processing capability of extruders, with a short residence time, has been termed as high temperature short time (HTST) processing. The HTST process has been used to beneficially heat treat foods in order to denature enzymes which cause rancidity or other kinds of food deteriorations (Mustakas *et al*., 1970; 1964). It also inactivates antinutritional factors, such as the trypsin inhibitors present in soybean, kills microorganisms present in the food materials, and renders the product sterile. The precooking of food products by using the HTST process improves digestibility of the food constituents by gelatinizing starches and modifying proteins so that their functional properties are usefully changed (Mouquet *et al*., 2003; Beaufrand *et al.*, 1978; Paul, 1976).

The full-fat soy flour offers two-fold advantage by supplying calories due to its high oil content, and is also a good protein source rich in amino acid lysine, which is usually too low in cereals (Dimler, 1968). The soy flour protein is of good quality. The full-fat soy flour contains excess levels of lysine, and is well balanced in respect of other amino acids, except for the sulphur amino acids. Full-fat soy flour can be used to improve both the quantity and quality of proteins in foods low in proteins or deficient in one or more of the essential amino acids (Inglett *et al*.,1969).

The object of the present work was to develop a process for the preparation of full-fat soy flour with high nutritional value, by inactivating antinutritional factors, and to produce a palatable product free from unpleasant taste, beany odour, and having high storage stability.

Materials and Methods

Soybean, Lee variety 1999, used in the present studies was procured from Tarnab Agricultural Farm, Peshawar, Pakistan. Prior to analysis, whole and sound soybeans were cleaned manually to remove stones, damaged seeds and other impurties. Cleaned soybeans were ground and moisture was determined before extrusion. The ground soybeans were moistened batch-wise at various moisture levels, viz., 16%, 22% and 24%. Each batch was extrusion cooked at various tem-

*Author for correspondence

peratures, 108 °C, 122 °C , 138 °C and 149 °C. The extruder cooking was done in the Brady extruder cooker. The product was dried in a cabinet shelf dryer up to the moisture level of 3.4%. The dried material was ground to a fine powder of 60° mesh.

Analytical procedures. Samples of raw soy flour and extruded soy flour were analyzed for moisture content, protein, fat, ash, and crude fibre by standard methods (AOAC, 2002). Nitrogen solubility index and urease activity were also determined (AOCS, 2001-2002; AACC, 1995).

Biological evaluation. Biological studies were conducted on raw full-fat soy flour, extruded full-fat soy flour, and casein according to Miller and Bender (1955) by using Albino rats of same age and weight. Digestibility and biological values were also determined.

Organoleptic evaluation. The samples of raw soy flour and extruded soy flour were taken randomly, three at a time, and were organoleptically evaluated according to Land (1988). The products were presented to a panel of judges comprising of six members who rated the product for odour, flavour, colour and taste using the 9-point score sheet.

Storage life studies. Samples of raw full-fat soy flour A and samples of extruded full-fat soyflour B and C were investigated for their storage life. To sample B was added a food grade antioxidant, butylated hydroxy anisole (0.02% of oil content), whidh was compared with sample C, as the control, to evaluate the effect of the added antioxidant on the extruded full-fat soy flour. Samples were packed in polyethylene bags (200 g each), sealed and kept at the storage temperature of 25 °C and 35 °C. Two samples from each lot were examined at monthly intervals for peroxide value and moisture content for the storage period of 10 months in accordance with AOAC (2002).

Trypsin inhibitor. Trypsin inhibitor activity in the raw soy flour and extruded soy flour was determined by the method of Kakade *et al.* (1974).

Microbiological evaluation of the product. Samples of raw soy flour and extruded full-fat soy flour were analysed microbiologically for total viable bacterial count, total coliform bacteria, yeast and mould, *Salmonella* and *Shigella* (Speck, 1984; Busta, 1971).

Results and Discussion

Proximate analysis of raw full-fat soyflour and extruded full-fat soy flour are presented in Table 1. Raw soy flour contained 6.9% moisture, 22.9% fat, 6.3% nitrogen, 39.6% proteins, 4.2% ash, and 2.2 % fibre. The results are similar to the findings of William (1974), but a little different from the results of Circle and Smith (1972). Extruded full-fat soy flour contained 3.4% moisture, 22.1 % fat, 6.6 % nitrogen, 41.2 % proteins, 4.6% ash, and 2.5% fibre. The results of extruded full-fat soy flour composition confirmed the findings of Frank (1974).

Samples of raw and extruded full-fat soy flour prepared at different extrusion temperatures and moisture contents were analyzed for nitrogen solubility index, trypsin inhibitor and urease activity (Table 2). These studies showed that extrusion temperature of 138 °C and 22 % moisture content resulted in maximum destruction of trypsin inhibitor activity (96.2 %), which remained at this level at temperatures above 138 °C. It was also observed that increase in the initial moisture content of the raw materials significantly reduced the trypsin inhibitor and urease activity. Nitrogen solubility was decreased with the increase of temperature. The results are comparable

Table 1. Proximate composition (%) of extruded and raw full-fat soy flour

Sample	Moisture	Fat	Nitrogen	Protein	Ash	Fibre
Raw	6.9	22.9	6.3	39.6	4.2	2.2
Extruded	3.4	22.1	6.6	41.2	4.6	2.5

Table 2. Moisture content, trypsim inhibitor destruction, urease activity change, and nitrogen solubility of full-fat soy flour extruded at different temperatures as compared with raw full-fat soy flour

Sample	Temp (°C)	Moisture (%)	Trypsin inhibitor destroyed (%)	Urease activity (pH change)	Nitrogen solubility (%)
Raw	0	5.6		2.00	79
Extruded	105	16	4	1.00	63
	105	22	20	0.23	59
	105	24	26	0.20	56
	122	16	30	0.17	52
	122	22	69	0.05	27
	122	24	73	0.02	23
	138	16	86	0.01	20
	138	22	96	0.01	14
	138	24	96	0.01	12
	149	16	96	0.01	12
	149	22	96	0.01	12
	149	24	96	0.01	12

with the findings of Book-Walter *et al*. (1971). The effect of extrusion temperature on the nutritional value of full-fat soy flour was also studied (Table 3). The protein efficiency ratio (PER) of the raw and full-fat soy flour prepared at the extruder temperatures of 105 °C, 122 °C, 138 °C and 149 °C were calculated to be 1.2%, 2.15%, 2.39%, 2.46% and 2.46%, respectively, whereas the PER value of casein was noted to be 2.50%. These results indicate that nutritional value of the flour prepared at the temperature of 138 °C was almost equal to casein used as the reference protein source, which meant that the PER value was maximum at 138 °C and was not further increased at higher extrusion temperatures.

All the samples of raw and extruded full-fat soy flour prepared at different extrusion temperatures were organoleptically evaluated by 6 judges on three different days and mean scores of these judges for odour, flavour, taste and colour were recorded. The data regarding the organoleptic evaluation (Table 3) showed that the overall acceptability of the flour prepared at 138 °C extrusion temperature was higher than the raw soy flour and the soy flour samples extruded at other temperatures. It had nutty flavour and was free from beany flavour.

Samples of raw and extruded full-fat soy flour were also studied for their storage life (Table 4). It was observed that samples B and C had good stability, whereas the sample A had a high peroxide value at the end of 10-month stroage period at the temperature of 25 °C. Moisture content of samples B and C increased from 0.55% to 0.7%, while the moisture content of sample A increased from 6.9 % to 10.0 %, respectively, at the storage temperature of 25 °C at the end of 10-month storage period. At the higher storage temperature of 35 °C, sample C began to show rancidity as evidenced from its elevated peroxide value of 6.14 meq/1000 g at the end of 9-month storage and reached the value of 7.1 meq/1000 g at the end of 10-month storage. Peroxide value of sample A was 1.3 meq/1000 g at the start, while after 10-months at 35 °C storage temperature it reached 12.1 meq/1000 g. Peroxide value of sample B with the added antioxidant was 2.2 meq/1000 g after 10-month storage.

The effect of extrusion temperature on the bacteriological load status of various food products prepared at different

Table 3. Organoleptic evaluation on 9-point scoring system and biological values as protein efficiency ratio (PER) of raw and extruded full-fat soy flour

Description of sample	Odour	Flavour	Taste	Colour	Overall acceptability (%)	PER (%)
Raw soy flour	4.9	5.4	5.4	5.0	57.5	1.20
Soy flour extruded at 105 °C	6.1	5.5	5.9	5.1	62.7	2.15
Soy flour extruded at 122 °C	7.9	6.4	7.8	8.1	83.8	2.39
Soy flour extruded at 138 °C	8.4	8.8	8.2	8.3	93.6	2.46
Soy flour extruded at 149 °C	8.3	8.5	8.0	8.0	91.1	2.46
Casein*						2.50

* casein was used as the reference protein source

Table 4. Storage life of soy flour extrusion cooked at 25 °C and 35 °C, during 10 months of storage period

Storage temperature (°C)	Storage period (months)	Peroxide value (meq/1000 g oil)			Moisture (%)		
		A	B	C	A	B	C
25	0	1.40	1.37	1.37	6.90	3.4	3.50
	1	1.82	1.48	1.56	7.30	3.46	3.57
	2	2.28	1.50	1.57	7.48	3.51	3.60
	3	2.91	1.56	1.63	7.82	3.60	3.63
	4	3.60	1.58	1.69	8.00	3.63	3.70
	5	4.19	1.60	1.73	8.40	3.68	3.78
	6	4.98	1.64	1.99	8.80	3.70	3.82
	7	5.94	1.69	2.41	9.00	3.72	3.85
	8	6.38	1.74	2.68	9.40	3.75	4.90
	9	7.54	1.79	2.91	9.81	3.80	4.00
	10	8.20	1.88	3.00	10.00	3.95	4.20
35	0	1.3	1.40	1.37	6.3	3.40	3.50
	1	1.88	1.49	1.52	6.91	3.50	3.59
	2	2.46	1.51	1.53	7.34	3.54	3.63
	3	3.00	1.52	1.69	7.88	3.61	3.65
	4	4.54	1.60	1.78	8.32	3.65	3.69
	5	5.45	1.68	1.89	8.71	3.69	3.74
	6	6.68	1.73	2.21	8.91	3.71	3.79
	7	7.71	1.79	2.45	9.20	3.74	3.85
	8	8.99	1.84	2.81	9.74	3.79	3.92
	9	10.87	1.91	6.14	10.13	3.83	4.92
	10	12.1	2.20	7.10	10.50	4.47	5.40

A: raw soy flour; B: extruded soy flour with added antioxidant (butylated hydroxy anisole @ 0.02% of oil content); C: extruded soy flour to which no antioxidant had been added (contorol)

Table 5. Bacteriological, yeast and mould count of the raw and extruded full-fat soy flour

Description of sample	Total bacteria (count/g)	Coliform bacteria	Yeast and moulds (count/g)	*Salmonella* and *Shigella*
Raw soy flour	105,000	nil	35	nil
Soy flour extruded at 105 °C	17,000	nil	30	nil
Soy flour extruded at 122 °C	4,600	nil	nil	nil
Soy flour extruded at 138 °C	500	nil	nil	nil
Soy flour extruded at 149 °C	450	nil	nil	nil

temperatures, viz., 105 °C, 122 °C, 138 °C and 149 °C, was also studied (Table 5). It was observed that when the extrusion temperature was raised to 138 °C and 149 °C, the total bacterial count was 500 and 450 bacteria/g, while the yeast and moulds were absent. The results indicate that high extrusion temperature decreased the bacterial count and the product prepared had a good taste, texture, flavour and storage stability. These results are in accordance with the findings of Nielsen (1976).

References

AACC. 1995. Approved Methods of Analysis, 9th edition, American Association of Cereal Chemists Inc., St. Paul, Minnesota, USA.

AOAC. 2002. Official Methods of Analysis, 17th edition, Association of Official Analytical Chemists, Virginia 22201, Arlington, USA.

AOCS. 2001-2002. Official Methods of Analysis, 5th edition, American Oil Chemists Society, Chicago, USA .

Beaufrand, M.J., Gueriviere, D.L., Monniers, J.F., Pollain, C. B. 1978. Effect of the cooking extrusion process on protein availability. *Ann. Nutr. Aliment*. **32**: 353-364.

Book-Walter, G.N., Mustakas, G.C., Kwolek, W.F., McGhee, J.E., Albrecht, W.J. 1971. Full-fat soy flour extrusion cooked: properties and food uses. *J. Food Sci*. **36:** 5-9.

Busta, F.F., Schroder, D.J. 1971. *Advances in Applied Microbiology,* pp. 205-210, 13th edition, New York, USA.

Chauhan, G. S., Bains, G. S.1985. Effect of defatted soy flour on the physicochemical characteristics of extruded rice products. *J. Food Sci. Technol*. **22:** 115-118.

Circle, S.J., Smith, A.K. 1972. Processing soy flours, protein concentrates and protein isolates. In: *Soybean*: *Chem.Technol.* pp. 294-338, 1st edition, Avi Publishing, Westport, England.

Dimler, R.J. 1968 . Soybean and corn join forces in food. *Soybean Digest* **27:** 50-55.

Dubois, D.K., Hoover, W.J. 1981. Soy protein products in cereal grain foods. *J. Am. Oil Chem. Soc*. **58:** 343-346.

Frank, E.H. 1974. Soy protein products and their production. *J. Am.Oil Chem. Soc.* **51:** 67A-74A.

Hoover, W.J. 1974. Use of soy products in cereal products. *J. Am. Oil. Chem. Soc.* **51:** 186A-187-A.

Inglett, G.E., Cavins, J. F., Kwolek, W.F., Wall, J.S.1969. Using a computer to optimize cereal based food composition. *Cereal Sci. Today* **14:** 69-72.

Kakade, M.L., Reckis, J.J., McGhee, J.E., Pushi, G. 1974. Determination of trypsin inhibitor activity of soy products: a collaborative analysis of an improved procedure. *Cereal Chem.* **51:** 376-382.

Land, D.G., Shephered, R. 1988. Scaling and ranking methods in sensory analysis of foods. In: *Elsevier Applied Science,* J.R. Piggot (ed.), pp. 155-185, 4th edition, New York, USA.

Nielsen, E., 1976. Whole seed processing by extrusion cooking. *J. Am.Oil Chem. Soc.* **53:** 305-309.

Miller, D.S., Bender, A.E.1955. The determination of net utilization of protein by shortened method. *Brit. J. Nutr.* **11:** 382-389.

Mouquet, C., Saluignol, B., van Hoan, N., Monvois, J., Treche, S. 2003. Ability of a “ very low-cost extruder” to produce instant infant flour at a small scale in Vietnam. *J. Food Chem.* **82:** 249-255.

Mustakas, G.C., Albrech, W. J., Book-Walter, G.N., McGhee, J.E., Kwolek, W.F., Griffin, E. L.1970. Extruder processing to improve nutrition, flavour, and keeping quality of full-fat soy flour. *Food Technol.* **24:** 1290-1296.

Mustakas, G.C., Griffin, E.L., Allen , L.E., Smith, O.B.1964. Production and nutritional evaluation of extrusion cooked full-fat soybean flour. *J. Amir. Oil Chem. Soc*. **41:** 607-614.

Paul, R.C. 1976. Extrusion cooking as a utilizable technology to produce nutritious foods. In: *Low Cost Extrusion Cooker,* pp. 9-11,Colorado State University, Fort Collins, Colorado, USA.

Patel, R.T., Singh, D.S., Tribelhorn, R.E. 1990. Effect of processing conditions on the extrusion cooking of soy-rice blend with a dry extrusion cooker. *J. Food Sci.Technol.* **27:** 376-378.

Pokorny, J., Mansour, F., Pudil, F., Janda, V. 2002. Effect of defatted soybean on the flavour of extruded mixture with wheat flour. *J. Food Sci.* **20:** 229-236.

Rathod, K.L., Williams, S.W. 1973. Acceptance of soybean enriched wheat flour for use in chapaties. *Indian J.Nutr. Dietet*. **10:**18-20.

Schemer, M., Wei, L.S., Perkins, E.G. 1973. Nutritional and chemical studies of three processed soy foods. *J. Food Sci*. **38:** 112-115.

Speck, M.L. 1984. *Compendium of Methods for the Microbiological Examination of Foods,* American Public Health Association, Washington D.C., USA.

Sushma, K., Satinder, B., Bhat, C.M. 1979. Nutritional composition and acceptability of soybean supplemented dishes. *J. Res. Punjab Agric. Univ.* **16:**111-113.

William, P. 1974 . Full-fat soy flour. *J. Am. Oil Chem. Soc*. **51:** 74A-76 A.