EFFECTS OF CONE OPENING, INITIAL MOISTURE CONTENT AND MULTIPLE EXTRUSION ON THE PROTEIN QUALITY OF EXTRUDED SOYBEAN USING THE BRADY CROP COOKER[1]

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SUMMARY

In the present study, three cone openings (0.133; 0.106, and 0.080 cm) and three initial moisture content values (9o/o, 15o/o and 21o/o) were used as treatments to evaluate their effects on the protein quality of full-fat soybean flour, extruded in the Brady Crop Cooker.

The specific volume, protein and oil contents as well as available lysine content characteristic of the final product, were not affected by the treatments used. Processing temperatures, however, decreased when the initial moisture content of the material was increased.

The nitrogen solubility index was affected by the cone opening but not by the moisture content of the material. With respect to the trypsin inhibitors content, the increase in the initial moisture content in soybeans gave conflicting results. At the 21o/o moisture treatment, the amounts of trypsin inhibitors were higher than those present in the raw material; a similar efffect was also observed with urease activity. At the other two moisture contents (9 and 15o/o) the amounts of trypsin inhibitors and urease activity were decreased by heat treatment, mainly at the 9o/o moisture level, which were related to the cone opening of the extruder.

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PER values in rats were influenced by the moisture content and were not affected by the cone opening. Results obtained in the biological assays with chicks, both for weight gain and conversion efficiency, were favored by a decrease in cone opening. Nevertheless, the increase in the moisture content induced a decrease in weight gain at the 5- and 8-week periods, without affecting the conversion efficiency.

The effect of consecutive passes of the material through the extruder was also studied. The product obtained with two extrusions presented a good biological value, probably as a consequence of the low values in the trypsin inhibitors and urease activities. When the material was extruded three times, results proved to be poor, due to a reduction to significant low levels of available lysine content —wich becomes limiting—, and nitrogen solubility index of the full-fat soybean flour.

INTRODUCTION

Availability to consumers of high-quality protein foods at low prices, using conventional and non-conventional local food sources and prepared through low-cost technology, still constitutes a problem of concern and interest at national level.

The extrusion process has been greatly recommended, but the equipment used requires a high investment that usually goes beyond the desirable limits for the intended objective.

The Brady extruder, a low-cost equipment (Brady, Division of Koering Co., Des Moines, Iowa) appears to be a good alternative. To a certain degree, it allows the production of processed products, which are similar in certain physical characteristics to products obtained through the use of more costly and sophisticated equipment.

The Brady equipment can facilitate application of the extrusion process, both at farm and community level, where local products can be used either for animal feeding or human consumption.

Research work carried out at the Institute of Nutrition of Central America and Panama (INCAP) (1-5), using this extruder, has shown that mixtures between cereals and legumes (soybeans + corn; soybeans + rice; soybeans + oats) yield products of better nutritional quality, than when these food materials are fed by themselves.

The thermic treatment applied to the raw material in the Brady extruder is basically obtained by the number of rotations of the feeding screw and by the opening of the exit cone; these two factos have direct influence on the residence time of the product inside the cylinder.

It has been verified that a short residence time, obtained as a consequence of a high feeding rate and of a large opening of the exit cone, gives rise to a low temperature during processing, resulting in a high output of the product, probably not completely processed.

The final product presented low specific volume, with a low rate of water absorption and retention but with a high viscosity, which could be due to its low expansion. From the biological value point of view, this short residence time did not decrease the amount of trypsin inhibitors in mixtures containing food legumes; as a consequence, PER values were low (3). Nevertheless, in 1977 Molina *et al.* (4) observed that the nitrogen dispersibility of the product was significantly favored by increasing the retention of the material inside the cylinder, through control of the cone opening.

These authors, working with cereal + legume mixtures, concluded that the nature of the raw material used, influenced the processing conditions and its effects.

Under constant conditions of feeding rate, cone opening and processing temperature, Molina *et al.* (3) observed that the initial moisture content of the material had an inverse relationship with the extrusion speed and the trypsin inhibition activity of the final product. Furthermore, there was a direct relationship with the specific volume, water absorption and PER values. These observations may lead to the conclusion that an increase in the moisture content of the initial product has the same effect as a decrease in feeding rate, a fact that was observed by Bressani *et al.* (1). This effect is similar to that found by Muelenaere and Buzzard (6), and by Bressani *et al.* (1), when varying the oil content of the raw material.

Bressani (5), observed that extruding whole soybeans three consecutive times in the Brady Crop Cooker, gave a final product of better nutritional quality than samples extruded only once or twice.

There is need for obtaining more information about the best processing conditions for optimizing the quality of soybean protein extruded in the Brady Crop Cooker. The present study, therefore, had the following objectives: to determine the effects that cone opening, moisture content in the raw materials and number of passes of whole soybeans through the extruder, had on protein quality of the resulting full-fat soybean flour.

MATERIAL AND METHODS

Extrusion was performed with a Brady Crop Cooker, Model 160, already being used at the Division of Agricultural and Food Sciences of INCAP. The opening of the exit cone was controlled by the number of turns of the regulation handle; later, the correct opening of the exit cone was measured, as shown in Figure 1.

Seeds from the "Pelikan" soybean cultivar obtained from a local farmer were used. Soybeans were processed by cracking the seeds twice in a hammer mill, and then passed three times through an air flow to remove the seed coats. The initial moisture content of the material was 9%.

The ground soybeans were then divided into three lots, keeping one at the original moisture content, and adjusting the other two to 15% and 21% of moisture, respectively. These lots were extruded according to the scheme presented in Table 1 (A).

To study the effect of extruding two and three times on the protein quality, the scheme presented in Table 1 (B) was followed.

During extrusion, a constant feeding rate of 32 rpm was used, and the temperature of processing was registered. The material was then ground with a hammer mill to 20 mesh.

The extruded material was then evaluated for the following characteristics: specific volume (1), moisture, protein and oil contents by the AOAC method (7); urease activity, according to the AOCS technique (8); the trypsin inhibitors content was determined as per Kakade, Simons and

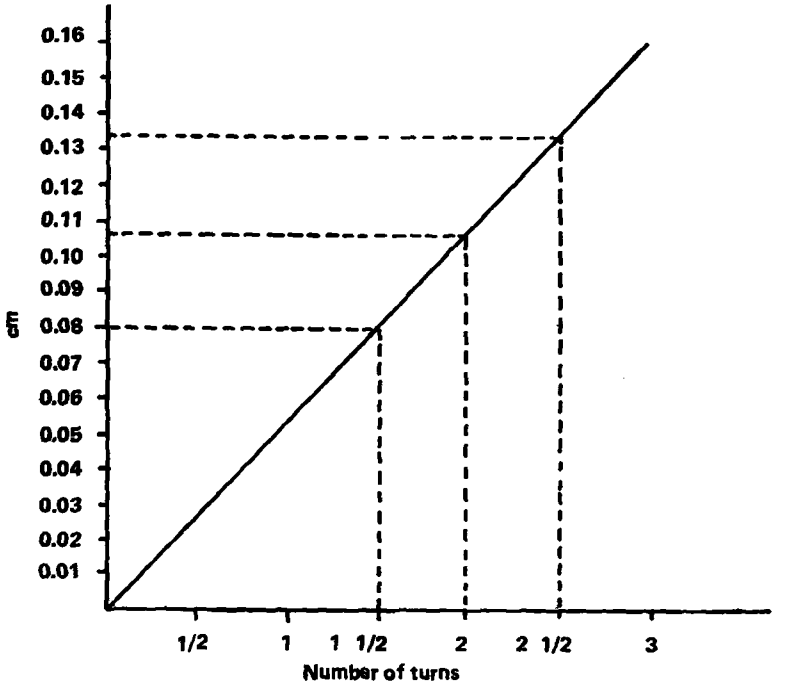

FIGURE 1

Cone opening in the Brady Crop Cooker, relation between the number of turns of the regulating handler, and extent of opening (cm)

Liener (9), and available lysine content as recommended by the AOCS (8) and by Conkerton and Frampton (10), respectively.

Two biological assays were performed:

One by the determination of PER, according to the methodology propossed by AOAC (7), using rats of the Wistar strain from the rat colony of INCAP. Diets were prepared with the extruded material adjusting to 10o/o protein, 6o/o oil, and supplementing with 4o/o minerals and vitamins. Two control diets with casein at 10o/o protein were used, one containing 6o/o oil, and the other, 10o/o oil, in order to compensate the oil excess present in the extruded material.

The other biological assay was performed with chicks, where 10 male, one-day old chicks were used in each of two repetitions per treatment. Two rations were prepared, one with 21o/o protein for the first five weeks, and the other one with 18o/o to administer during the last three weeks of the study. Rations were prepared according to the following composition: 95.00o/o extruded full-fat soybean flour + corn (30/70); 2.10o/o of bone meal; 1.50o/o $CaCO_3$; 0.45 iodized salt; 0.10o/o DL-Methionine; 0.55o/o of a vitamin and mineral mixture[5] and 0.30o/o sand.

5 Premix Pfizer.

TABLE 1

EXPERIMENTAL SCHEME USED IN THE EXTRUSION OF FULL-FAT SOYBEAN FLOUR EXTRUDED IN THE BRADY CROP COOKER

	Treatment	Moisture content of the flour %	Cone opening		Number of extrusions
			No. of turns in handle	cm	
	11	9	2.5	0.133	1
	12	9	2.0	0.106	1
	13	9	1.5	0.080	1
	21	15	2.5	0.133	1
(A)	22	15	2.0	0.106	1
	23	15	1.5	0.080	1
	31	21	2.5	0.133	1
	32	21	2.0	0.106	1
	33	21	1.5	0.080	1
	11	9	2.5	0.133	1
(B)	11-2T	9	2.5	0.133	2
	11-3T	9	2.5	0.133	3

For comparison purposes, a control, commercially-prepared ration was used.

During the first five weeks the chicks were kept in wire cages in a controlled temperature room; later, they were removed to the avian instalations of the Experimental Farm of INCAP.

RESULTS AND DISCUSSION

Table 2 shows the effects caused by the different treatments on the physical and chemical characteristics of the extruded material. As the data reveal, when the cone opening was reduced there occurred an increase in the processing temperature, as previously observed by Molina *et al.* (3, 4). The processing temperature decreased with the increase in the initial moisture content of the material.

Specific volume, protein and oil contents, available lysine content and urease activity were not affected by the moisture content of the raw material. However, the nitrogen solubility and specific volume data obtained in the present work, did not agree with the results reported by Molina *et al.* (4).

The trypsin inhibition activity and urease activity were not affected by the conditions under which the samples were processed. When the initial moisture content was increased, a sufficiently high temperature did

TABLE 2

RESULTS OBTAINED FROM THE CHEMICAL ANALYSIS PERFORMED IN THE EXTRUDED MATERIAL

Treatment	Extrusion temperature °F	Specific volume cc/100 g	Moisture content o/o	Protein DWB* o/o	Oil o/o	Trypsin inhibitor TIU/ml	Urease pH units	NSI WWB**	Available lysine g/16 gN
Raw	—	—	9.0	41.65	23.4	46.79	1.1	—	—
11	245	198	6.2	40.41	22.7	37.87	1.7	51.15	5.96
12	272	198	6.2	42.14	22.5	24.93	0.8	46.64	5.60
13	270	184	6.2	44.14	20.5	21.33	0.7	41.50	3.99
21	220	188	8.2	40.96	22.9	38.55	1.3	49.87	5.76
22	230	205	8.0	40.98	23.0	40.35	1.4	47.70	6.67
23	230	207	9.0	41.87	22.4	34.25	1.2	46.75	6.03
31	205	204	13.1	40.16	20.0	44.30	1.4	51.34	6.03
32	205	214	17.3	43.41	18.8	54.81	1.5	43.20	6.52
33	215	186	14.2	38.58	20.6	56.91	1.5	40.03	6.96
11-2T	280 - 330	192	3.8	45.32*	19.5	8.77	0.3	27.81	4.83
11-3T	330	198	3.5	43.52	23.2	0.77	0.2	18.45	1.20

* DWB = Dry-weight basis.

** WWB = Wet-weight basis (Using 100 g of sample).

not developed so as to destroy these antinutritional factors. More specifically, for the 9o/o moisture treatments there was a reduction in the quantity of inhibitors in relation to the raw material, and this effect was higher when the cone opening was smaller. With the 15o/o moisture content treatments, the activity of the inhibitors in relation to the raw material values was smaller in all treatments, but not related to the cone opening. Finally, when the material had 21o/o moisture, no effect of extrusion on reducing the inhibitor content was verified; on the contrary, an increase in the anti-trypsin activity was observed when the cone opening was reduced. These data do not agree with the results obtained before by Muelenaere and Buzzard (6), and by Bressani *et al.* (1).

If a decrease in the cone opening increases the residence time of the material inside the extruder as well as the temperature that acts on it, this effect is reduced or even annulled by an increase in the initial moisture content, when the effects of extrusion on the trypsin inhibition activity and urease activity are evaluated. This negative effect was not observed for the nitrogen solubility index.

The reason for the results obtained in the study herein reported could be the nature of the material used, as mentioned by Molina *et al.* (3, 4), when working with cereal + legume mixtures.

The effect of the different initial moisture contents and cone openings on the protein quality of the extruded full-fat soybean flour, evaluated with rats and chicks, are presented in Table 3.

PER values were not affected by the cone opening, but they were lower in samples with a higher moisture content.

With respect to the chick assay, weight gain and conversion efficiency at the fifth and eighth week were favored by an increase in the residence time of the material, as a consequence of a decrease in cone opening.

Moisture content in the sample showed a negative relationship with the weight gain of chicks at 5 and 8 weeks, respectively; however, no effect was observed on the conversion efficiency.

When results presented in Table 3 are compared with those shown in Table 2, it can be appreciated that the increase in the amount of trypsin and urease inhibitors in the 21o/o moisture content treatments, with the longer residence time (smaller cone opening), did not have any effect on chick weight gain nor on the conversion efficiency at 5 and 8 weeks. Why these contradictory effects occur is still unknown, thus suggesting the need for more at-depth studies in this area. Those effects were also observed by Harper (11) when extruding different soybean cultivars of different origins.

Data on Tables 2 and 3 also reveal the effects of extruding the same sample two and three times. It may be observed, in Table 2, that when the material was passed again through the extruder, processing temperature increased, with no effects observed on the specific volume, nor on protein and oil contents. Nevertheless, the final product presented a lower moisture content, and lower nitrogen solubility, available lysine, trypsin inhibitors, and urease activity. These were significantly lower when the material was extruded three consecutive times.

PER values obtained with the material extruded once and twice can be considered good for full-fat soybean flour. A third extrusion of the material, however, yielded negative PER values (Table 3). The weight

TABLE 3

RESULTS OBTAINED IN THE PER AND CHICKS ASSAYS

Treatment	Moisture o/o	No. of turns	No. of extrusions	In rat PER	In chick 5 weeks Δweight	In chick 5 weeks Conversion efficiency	In chick 8 weeks Δweight	In chick 8 weeks Conversion efficiency
11	9	2.5	1	2.1 ±0.28*	851.65	1.85	1720.00	2.24
12	9	2.0	1	2.2 ±0.20	932.95	1.78	1801.95	2.10
13	9	1.5	1	2.2 ±0.28	901.85	1.82	1818.70	2.09
21	15	2.5	1	1.8 ±0.27	750.90	2.04	1617.05	2.29
22	15	2.0	1	1.7 ±0.42	752.90	2.01	1596.55	2.27
23	15	1.5	1	1.8 ±0.33	805.30	1.95	1617.55	2.28
31	21	2.5	1	1.6 ±0.36	697.50	2.03	1431.75	2.52
32	21	2.0	1	1.4 ±0.30	748.22	2.10	1540.95	2.47
33	21	1.5	1	1.9 ±0.21	826.25	1.74	1689.25	2.06
11-2T	9	2.5	2	2.2 ±0.28	890.25	1.71	1807.45	2.02
11-3T	9	2.5	3	Negative values	56.60	5.05	Eliminated**	
Casein, 6o/o oil				3.1 ±0.17				
Casein, 11o/o oil				3.3 ±0.47				
Commercial ration					940.70	1.78	1967.75	2.08

* Standard deviation.

** Eliminated because animals did not show any increase in weight and body development and would not survive until the end of the experiment.

gain and conversion efficiency of chicks improved with the second extrusion of the material, but the third extrusion brought along such drastic effects, that this treatment was eliminated from the study, because animals could not suffer the conditions under which the experiment was carried out until the eight-week period (Table 3). The conversion efficiency values obtained with the material extruded twice, were slightly higher than those obtained with the commercial ration.

The effects observed with the biological assays must be interpreted on the basis of the information shown in Table 2. The processing temperature obtained with the sample extruded for the second time, decreased the trypsin inhibitors and urease activity to very low values, without affecting significantly the available lysine content and nitrogen solubility index. As a consequence, a good biological quality of the product was obtained, as results of the experiments with rats and chicks, respectively, suggested. When the material was extruded three times —which reduced the antinutritional factos drastically (trypsin inhibitors content to 0.77 TIU/ml)— this treatment also decreased nitrogen solubility, and available lysine content. The latter was reduced 80o/o in comparison to the lysine content present in the material extruded only once. This finding could be the reason which may well explain the results obtained, since lysine became the limiting amino acid in the diets used.

The results obtained can lead to the conclusion that double extrusion improved the protein quality of the full-fat soybean flour; but if material is extruded again, highly negative effects can be induced on the protein quality of the product. These findings do not agree with results obtained by Bressani in 1976 (12). Finally, it may be concluded that to destroy the antiphysiological factors in whole soybeans with the extruder used in the present study, it is necessary to process them at a higher temperature (longer residence time), which can not be obtained when the material contains above 10o/o moisture.

RESUMEN

EFECTOS DE LA ABERTURA DEL CONO, CONTENIDO INICIAL DE HUMEDAD Y EXTRUSION MULTIPLE, EN SOYA PROCESADA CON EL EXTRUSOR BRADY

En el estudio aquí descrito se evaluaron los efectos de tres aberturas de cono (0.133, 0.106 y 0.080 cm) y tres contenidos iniciales de humedad (9, 15 y 21o/o) en grano de soya procesado con el extrusor Brady, en la calidad proteínica del producto.

El volumen específico, contenido de proteína, aceite y lisina disponible del producto final no fueron afectados por los tratamientos utilizados. Las temperaturas de procesamiento, sin embargo, disminuyeron al aumentarse el contenido inicial de humedad.

El índice de solubilidad de nitrógeno se vio afectado por la abertura del cono, pero no por el contenido de humedad de la materia prima. No obstante, las temperaturas de procesamiento descendieron al aumentar el contenido inicial de humedad. Los resultados en cuanto al contenido de inhibidores de tripsina y ureasa, sin embargo, fueron conflictivos en relación al contenido inicial de humedad del grano. Así, cuando la humedad inicial era de 21o/o, la actividad de los inhibidores de tripsina fue superior

a la de la materia prima, a 9o/o de humedad. Se detectó un efecto similar en lo referente a la actividad de la ureasa. Los niveles de estos factores antifisiológicos fueron menores en las muestras que contenían 9 y 15o/o de humedad inicial, respectivamente, debido al proceso térmico, principalmente al nivel de 1o/o de humedad, que estaban relacionados con la abertura de cono.

Los valores de PER, en ratas, fueron influenciados por el contenido de humedad inicial, y no lo fueron por la abertura de cono. La reducción de esta última favoreció el aumento ponderal y la conversión alimenticia de los pollos, utilizados en las pruebas biológicas para evaluar la calidad nutricional del producto. El aumento en el contenido inicial de humedad, sin embargo, redujo el incremento en peso a las 5 y 8 semanas de estudio, sin afectar por ello la eficiencia de conversión del alimento.

Se evaluó también el efecto de la extrusión del grano de soya, tres veces consecutivas, en la calidad nutricional. El producto extruido dos veces acusó un buen valor biológico, probablemente como consecuencia de los bajos valores de actividad de los inhibidores de tripsina y de ureasa. El producto extruido tres veces rindió resultados pobres, debido a la reducción a valores significativamente bajos del contenido de la lisina disponible —que se convierte en limitante— y nivel de índice de solubilidad del nitrógeno de la harina de soya integral.

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BIBLIOGRAPHY

1. Bressani, R., J. E. Braham, L. G. Elías & M. R. Molina. Protein quality of a corn whole soybean mixture processed by a simple extrusion cooker. In: **36th Annual Meeting of the Institute of Food Technologists, Annaheim, California,** 1976, 17 p.
2. Bressani, R., M. R. Molina, L. G. Elías, H. Gudiel & R. Cuevas. Exploration of the potential for low-cost extrusion cookers in Latin America. In: **Workshop on Low-Cost Extrusion Cookers, Colorado University, Fort Collins, Colorado,** 1976, 17 p.
3. Molina, M. R., R. Bressani, R. Cuevas, H. Gudiel & V. Chauvin. Effects of processing variables on some physico-chemical characteristics and nutritive quality of high-protein foods. In: **9th Symposium on Extrusion and Related Technology in Food Industries-AICHE,** 1976, 16 p.
4. Molina, M. R., V. Chauvin, H. Gudiel, R. Cuevas & R. Bressani. Effects of cone opening on different products characteristics using different cereal/soybean mixtures. Evaluation of simple cooker extruders (Brady Crop Cooker). **Progress Report No. 3.** Guatemala, Institute of Nutrition of Central America and Panama (INCAP), 1977, p. 1-12.
5. Bressani, R. Evaluation of simple cooker extruders (Brady Crop Cooker). **Progress Report No. 3.** Guatemala, Institute of Nutrition of Central America and Panama (INCAP), 1977, 30 p.
6. Muelenaere, H. J. H.de & J. L. Buzzard. Cooker extruders in service of world feeding. **Food Technol., 23:**345, 1969.

7. Association of Official Analytical Chemists. **Official Methods of Analysis of the AOAC.** 11th ed. Washington, D. C., The Association, 1970.
8. American Oil Chemists Society. **Official and Tentative Methods of the AOCS.** 3rd. ed. Washington, D. C., The Society, 1970.
9. Kakade, M. L., N. Simons & J. F. Liener. An evaluation of natural vs synthetic substrates for measuring the antitryptic activity of soybean samples. **Cereal Chem., 46**:518-526, 1969.
10. Conkerton, E. J. & V. L. Frampton. Reaction of gossypol with free E-amino groups of lysine in proteins. **Arch. Biochem. Biophys., 81**:130-134, 1959.
11. Harpers, J. M. Comparison of lab analysis of Guatemalan extruded soy to AERC extruded soy. Fort Collins, Colorado State University, 1977, 4 p. (Memorandum).
12. Bressani, R. Exploration of the potential for low-cost extrusion cookers in Latin America. In: **Workshop on Low-Cost Extrusion Cookers, Colorado State University, Fort Collins, Colorado, 1976, p. 75-80.**