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Research Article
Production of some Snack Foods by Extrusion Processing of some Cereals and their By-products

Ahmed Ramy M. Abd-Ellatif, Amir A. Ibrahim and Gamal H. Ragab

Department of Food Science and Technology, National Research Centre, Dokki, Giza, Egypt

Abstract

Background: Extrusion industry is a process in which raw materials are forced to flow under various conditions of moisture content, temperature and extruder screw speed. Several types of raw materials were used in this industry. In the present study broken rice which considered as a by-product of rice whitening industry and semolina were studied as raw materials for extrusion industry. **Materials and Methods:** Various conditions of moisture content, temperature and screw speed were studied. **Results:** Obtained results of physical characteristics of the products showed a relation between expansion ratio and specific weight of extruded materials i.e., the greater the expansion volume, the lower the specific weight. The optimum conditions obtained for the lowest specific weight of broken rice and semolina flours were 15% moisture content, 130°C and 150 rpm for extruder screw speed. The same conditions were found to obtain the best shear force for broken rice and semolina. The Water Solubility Index (WSI) and Water Absorption Index (WAI) for extruded broken rice and semolina showed that the maximum values of WAI and WSI were obtained at 15% moisture, 170°C and 150 rpm for extruder screw speed. Broken rice flour had the lowest value of cooked-paste viscosity at 50°C after coding while semolina extrudate had the highest value of the cooked-paste viscosity. **Conclusion:** Thus broken rice and semolina could be considered as suitable materials for extrusion technology.

Key words: Extruder, food extradites, broken rice, semolina

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Corresponding Author: Amir A. Ibrahim, Department of Food Science and Technology, National Research Centre, P.O. Box 12622, Dokki, Giza, Egypt Tel: 01002331852 Fax: +20233370931

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Food extrusion is a process in which a food material is forced to flow, under one or more of various conditions i.e., different moisture content of the raw material. Shearing and heating through a die which is designed to form and/or puff-dry the extrudate[1].

Several types of raw materials have been used. To produce a wide variety of starchy foods including snack, ready to eat cereals, confectioneries and extruded crisp bread[2]. Temperature used for a definite time affects the characteristics of the extruded product. Using high temperature for short time causes gelatinization of starch, denaturation of protein, modify lipid pattern and inactivate many anti nutritional factors[3].

Extruded foods have been proven to provide nutritious products contains precise level of each required nutrient[4]. The aim of this investigation was to replace the imported yellow corn which considered the main raw material used by all food extrusion factories in Egypt, with local raw materials and by-products[1]. Broken rice in comparable with semolina were used to produce extruded products[5]. Effect of extrusion conditions on physical and functional characteristics of the extruded products were studied.

MATERIALS AND METHODS

Materials:

- Broken rice is a by-product of rice whitening industry was obtained by using a screener from the polished rice obtained from rice technology training, Alexandria, Egypt
- Semolina flour was obtained from flour Milling company of South Cairo, Egypt

Methods

Milling of raw materials: Broken rice was milled by using brabender mill wiley.

Particle size analysis was necessary after milling in which milled flour should have almost the same average of particle size before extrusion. Particle size was measured as described by Hendersan and Perry[6].

Chemical analysis: Broken rice and semolina were chemically analyzed for moisture, protein, fat, crud fiber and ash contents according to the methods described by AACC[7]. Total carbohydrates were calculated by difference.

Samples were ignited at 550°C in a muffle, until constant weight was obtained. Ash from 1 g of each sample was dissolved in 100 mL concentrated HCL. Zinc, iron, calcium, potassium and sodium were determined using atomic absorption spectroscopy technique as described by AOAC[8].

Adjusting the moisture content of the raw material: The amount of water necessary to bring 1000 g of samples to the desired moisture level for extrusion was calculated according the equation:

$$\text{Water added (g)} = \frac{\text{Moisture desired (\%)-Sample moisture (\%)}}{\text{100-Moisture desired (\%)}} \times 10^3$$

Water was added gradually to the samples and mixed for 5 min by using mechanical mixer. The samples were placed in plastic bags and stored for 60 min at room temperature in order to equilibrate moisture content[5].

Extruder operation: A Bartender single-screw equipped (model 823) with a grooved barrel of internal diameter 1.90 cm and length/diameter ratio of 20:1 was used. The extruder was powered by a modified Bartender Do-corder having a DC motor with speeds continuously variable electrically from 0-350 rpm. A 3:1 compression ratio screw was used and feed rate were 60 g min^{-1}. The temperature of extruder was controlled by electric heating and compressed air cooling. The barrel first section was always kept at 85°C, while the second section and die head were varied together from 110-170°C. The die nozzle diameter was 4 mm.

The extruder operating conditions were selected from factorial combinations of the following parameters:

- Barrel temperature: 110, 130, 150 and 170°C
- Moisture content: 15, 17, 20 and 25%
- Screw speed: 150 rpm

The extruder was set for the temperature profile and screw speed of the experiment in question. When all zones of the extruder indicated the desired temperature, a sample of 200-300 g with a high moister content of 25-26% was placed in the feed hopper. The feeding rate was started with a screw speed ranging from 25-30 rpm. When the extruder reached steady state or stable conditions samples of the extruded product were then collected[1].

Methods of analysis: Expansion ratio, bulk density, water absorption index, water solubility index, shear force, cold-viscosity, hot-paste viscosity and cooked-paste viscosity were measured by methods recommended by Mercier and Feillet[9] and Breen *et al.*[10].

Expansion ratio: Expansion ratio of extruded products were determined[11] by measuring the diameter of the product (average of 10 measurements) and comparing with the die diameter of extruder.

Bulk density: Bulk density of samples (raw materials and its extradites) were determined by weighing the quantity required to fill a known volume, as described by Aas *et al.*[12]. A quantity of the sample that filled approximately 30 mL was placed in graduated cylinder. Volume and weight were recorded to calculate bulk density.

Water absorption index (WAI) and water solubility index (WSI): The methods described by Anderson[13] were used to determine:

- Water absorption index defined as the grams of gel obtained per gram of solid (the total solids in the original sample were corrected for the loss of soluble matters in the supernatant)
- Water solubility index, defined as the water-soluble fraction expressed as a percent of dry sample

Sample of ground product (2.5 g) was sieved at <60 mesh save was suspended in 30 mL of water at 30°C in a 50 mL tarred centrifuge tube, then stirred intermittently over a 30 min and centrifuged at 3000 rpm for 10 min. The supernatant liquid was poured carefully into a tarred evaporating dish. The remaining gel was weighed and the water absorption index was calculated from its weight. As an index of water solubility, the amount of dried solids recovered by evaporating the supernatant from the water absorption test expressed as percentage of dry solids.

Water solubility index and water absorption index were calculated according to the following equations:

$$\text{Water Solubility Index (WSI)} = \frac{\text{Solid weight}}{\text{Sample weight}}\times 100$$

$$\text{Water Absorption Index (WAI)} = \frac{\text{Weight of gel}}{\text{Sample weight (100-WSI)}}\times 100$$

Shear force determination: Shear force was measured by using Warner-Bratzler machine. Each extruded material was sheared for five times and the sample was cut across by the car of the machine. Low shear force values indicates more weakening extruded material, while high shear force value indicate less weakening extruded material[5].

Viscosity determination: Viscosity of each sample was measured according to Anderson *et al.*[14] by using a Bartender viscoamylo graph, which was calibrated by water to give a viscosity of zero (BU).

About 50 g sample, 450 mL distilled water was added and transferred quantitatively to viscoamylo graph container. The temperature was adjusted to 29°C then raised to 95°C at a rate of 1.5°C min^{-1}. The temperature was held at 95°C for 16 min. Then reduced to 50°C at rate of 1.5°C min^{-1}. The initial viscosity at 29°C represents cold-paste viscosity. While, viscosity at 95°C represents hot-paste viscosity. The viscosity at 50°C represents the cooked-paste viscosity.

RESULTS

Chemical composition: The chemical composition of the broken rice and semolina are given in Table 1. They were characterized by its high carbohydrate content (90.74 and 84.38), respectively. While semolina flour had highest protein content 12.02% in comparison with broken rice 7.60%. However ether extract, fiber and ash contents showed a reversible trend when compared with total carbohydrate in tested samples.

Water solubility index and water absorption index: Water Solubility Index (WSI) and Water Absorption Index (WAI) of the extruded products prepared from broken rice flour and semolina are shown in Table 2.

The WSI of broken rice-flour steadily increase with extrusion temperature. The highest value of WSI was obtained at 170°C.

With extrusion-cooking, the water solubility index was higher at low moisture levels (Table 2). The maximum WSI was obtained at 15% moisture content.

Viscosity: Cold-paste viscosity at 29°C, hot-paste at 95°C and cooked paste viscosity at 50°C (cooled after cooking at 95°C) of the material and their extrudate were determined and the obtained results are presented in Table 3.

The cold-paste viscosity (29°C) increased with increasing extrusion temperature and moisture content. These results

Table 1: Chemical composition of the raw materials (calculated on dry weight basis)

Percentage	Broken rice flour	Semolina
Moisture	10.69	13.15
Ether extract	0.54	0.92
Protein	7.60	12.20
Ash	0.50	0.80
Fiber	0.62	1.40
Carbohydrates	90.74	84.68

are in agreement with those obtained by Mason and Hoseney[15] shows the relationship between cold-paste viscosity and the two variables, feed moisture and barrel temperature.

The effect of extrusion process conditions i.e., moisture content (15 and 25%) and temperature (130 and 170°C) at 150 rpm on viscosity at 95°C of extruded broken rice flour was studied and the results were presented in Table 4. The obtained results indicated that the maximum viscosity was found at 130°C and 25% moisture content using 150 rpm while. The minimum viscosity was observed at 170°C and 25% moisture content. Viscosity at 95°C was also found to decrease by increasing the applied temperature especially at 25% moisture content.

Results for particle distribution of broken rice flour are shown in Table 5. Results showed that the broken rice had more than 70% of particle size between 500 and 1000 µ. The chemical analysis of the products processed from the materials used in this study are shown in Table 6.

Table 2: Effect of various extrusion-cooking conditions on the water solubility index (WSI) and water absorption index (WAI)

		Water solubility index		Water absorption index	
Moisture (%)	Temperature (°C)	Broken rice flour	Semolina	Broken rice flour	Semolina
15	110	10.10	4.75	4.90	3.50
	130	13.15	5.19	5.35	3.70
	150	15.70	6.50	6.10	3.85
	170	17.05	7.30	7.70	4.01
17	110	9.92	4.55	4.12	3.40
	130	11.50	5.00	4.50	3.65
	150	13.81	6.30	5.99	3.80
	170	15.50	7.10	7.50	3.98
20	110	6.39	4.10	4.10	3.30
	130	7.89	4.50	4.30	3.50
	150	10.01	5.80	5.40	3.70
	170	13.10	6.70	6.70	3.80
25	110	4.91	3.50	3.20	3.25
	130	5.90	3.95	3.80	3.35
	150	8.79	5.00	4.50	3.55
	170	10.20	6.00	6.40	3.60

DISCUSSION

Results shown for particle size distribution of broken rice (Table 5) indicates that it is suitable for extrusion process than the semolina flour.

On the other hand, particle size of broken rice flour was found to be the suitable size for good feeding to the extruder for adequate heat treatment during extrusion compared to the semolina flour[15].

Table 3: Effect of extrusion variables on viscosity of broken rice flour and semolina at screw speed 150 rpm

		Viscosity (B.U.)					
		Cold-paste at 29°C		Hot-paste at 95°C		Cooked-paste at 50°C	
Moisture (%)	Temperature (°C)	Broken rice flour	Semolina	Broken rice flour	Semolina	Broken rice flour	Semolina
Control	Control	40	0	610	360	1920	890
15	130	365	57	250	520	200	1020
	170	510	120	2702	550	210	1050
25	130	500	100	480	700	410	1100
	170	690	155	180	400	260	820

Table 4: Effect of various extrusion-cooking conditions on the expansion ratio, specific weight and sheer force of the extruded products

		Expansion ratio		Specific weight		Shear force	
Moisture (%)	Temperature (°C)	Broken rice flour	Semolina	Broken rice flour	Semolina	Broken rice flour	Semolina
15	110	2.95	1.35	28.70	72.50	8.70	19.00
	130	3.20	1.50	26.10	69.00	7.90	16.40
	150	3.00	1.45	26.80	69.90	8.50	18.00
	170	2.75	1.30	30.10	73.00	9.20	18.75
17	110	2.75	1.30	30.60	73.00	13.20	26.50
	130	2.95	1.43	27.90	70.50	12.30	24.00
	150	2.80	1.39	28.50	71.40	12.90	25.30
	170	2.60	1.25	31.00	74.00	13.90	26.10
20	110	2.55	1.24	32.40	74.40	20.70	38.70
	130	2.70	1.37	30.33	72.50	19.50	34.70
	150	2.60	1.31	31.05	73.30	20.30	37.00
	170	2.40	1.20	32.22	75.90	21.00	38.00
25	110	2.10	1.20	34.10	76.90	26.20	49.00
	130	2.45	1.30	32.49	74.10	24.90	46.70
	10	2.20	1.25	33.80	75.40	25.91	50.20
	170	1.95	1.19	36.45	77.90	29.30	50.70

Table 5: Particles size distribution of raw materials after milling

Fraction	Broken rice flour	Semolina
Fraction>1000 µ	10.00	0.00
800 µ<fraction<1000 µ	51.00	10.00
600 µ<fraction<800 µ	15.00	10.50
500 µ<fraction<600 µ	11.00	38.00
400 µ<fraction<500 µ	7.00	37.00
315 µ<fraction<400 µ	5.00	3.00
Fraction<315 µ	1.00	1.50

Table 6: Chemical composition of extruded products (calculated on dry weight basis)

Percentage	Broken rice flour	Semolina
Moisture	6.52	4.10
Ether extract	0.53	0.90
Protein	7.57	12.20
Ash	0.50	0.78
Fiber	0.60	1.50
Carbohydrates	90.80	84.62

The effect of extrusion-cooking conditions on the physical characteristics are shown in Table 3.

Results showed that extrusion process caused an expansion of the product. The degree of expansion was varied according to the raw material used and its effect on density, friability and tenderness of the product[1,11]. Expansion ratio of the final extruded product were found to increase with every decrease in moisture content of the material faded. The optimum conditions obtained for the highest expansion ratio of broken rice and semolina flours were 15% moisture content at 130°C and 150 rpm.

From these results it could be concluded that the best conditions to obtain the highest expansion ratio were 15% moisture, temperature 130°C and speed 150 rpm. Also, the moisture content of feed material and the temperature of extrusion process were the important factors affecting the expansion ratio of the extruded product.

A relation between expansion ratio and specific weight of extruded materials i.e., the greater the expansion volume, the lower the specific weight. The optimum conditions obtained for the lowest specific weight of broken rice and semolina flours were 15% moisture content at 130°C and 150 rpm.

The optimum conditions obtained for the best shear force of broken rice and semolina flours were 15% moisture content, at 130°C and 150 rpm.

From these results it could be concluded that the best conditions to obtain the maximum WSI for investigated broken rice flour were 15% moisture content, at 150 rpm and 170°C.

The WAI was higher for the product extruded at 15% moisture content than 25% moisture content. These findings were in agreement with the results of Mercier and Feillet[9].

Generally, the best quality of WAI was achieved at 15% moisture content, 170°C barrel temperature and 150 rpm screw speed.

From these results it could be generally concluded that the best conditions to obtain maximum WSI were at 170°C, 15% moisture content and 150 rpm. These results were in agreement with those obtained by Mercier and Feillet[9], who found that the amount of soluble starch increased with increasing of extrusion temperature (170-200°C) and with decreasing of moisture content of raw materials. These results were in agreement with Anderson[13].

In general, the highest maximum of water absorption index was achieved at 170°C, 15% moisture content and 150 rpm. Also, WAI of semolina was slightly improved by extrusion process as compared to broken rice[13].

It could be also observed that viscosity at 50°C after cooling was found to decrease by increasing the temperature and decreasing the moisture content of extruded broken rice compared to the control.

Table 3 shows the effect of two levels of barrel temperature (130-170°C) and two levels of moisture content (15 and 25%) on cold-paste viscosity, hot-paste viscosity and cooked-paste viscosity of extruded products. From this Table 3 it could be revealed that the highest maximum value of cold-paste viscosity (155 B.U.) was obtained at 170°C and 25% moisture level. While the lowest minimum values (57 B.U.) was obtained at 130°C and 15% moisture level.

However, the hot-paste viscosity of the extruded showed a reversible trend with respect to the cold-paste viscosity. The obtained results indicated that the minimum hot-paste viscosity was found at 130°C and 15% moisture content, while the maximum viscosity was observed at 130°C and 25% moisture content. These results were in agreement with Mason and Hoseney[15].

On following up the effect of extrusion conditions on viscosity of extruded semolina. The obtained data proved that the maximum value of final cooked-paste viscosity was found at 25% moisture content and 130°C, while minimum value was found at 25% moisture level and 170°C.

The chemical analysis of the extruded products showed that there is no noticeable changes in the ether extract, protein, ash, fiber and total carbohydrates contents of the extruded materials than that of the flours used (Table 1, 6). However, it was found that the processed samples had less moisture content than the flour. This might be due to the evaporation of moisture by heat treatment during extrusion[1].

CONCLUSION

The main findings of this study showed that broken rice which considered as a by-product of rice whitening industry was used successfully in the production of snack foods by extrusion process. Results showed that snacks produced using broken rice have nearly the same physical characteristics of extruded yellow corn.

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