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USING LOCAL WHITE CORN AS A SUBSTITUTE TO IMPORTED YELLOW CORN IN FOOD EXTRUSION INDUSTRY

Ahmed Ramy M. Abd-Ellatif, Amir A. Ibrahim* and Gamal H. Ragab
Food Science and Technology Department, National Research Centre, Dokki, Giza, Egypt

*Corresponding Author: dr_amiramin@yahoo.com

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ABSTRACT

Food extrusion is considered as one of the most recent industries in the field of snack food industries. The objective of the present study is to find local alternative for imported yellow corn used in the production of food extruded products. The most suitable methods and conditions for such industry are studied. According to the obtained results of physical and chemical evaluation of extruded products by yellow corn grits or white corn grits, the obtained data indicated nearly the same results such as [Expansion ratio, texture, bulk density, water absorption index, water solubility index and viscosity]; when the white corn grits were used. Thus, the yellow corn grits could be considered as white corn grits which are available in extreme quantities in Egypt.

Keywords: Yellow corn, White corn, Extrusion, Water Absorption Index

INTRODUCTION

Food extrusion is a process in which a raw material is forced to flow under various conditions of moisture and temperature. To produce a palatable product, such as snack cereals, pasta foods, confectionery products, etc. The extruder achieves high productivity in a single processing step results in cooking and forms, which decreases processing cost. Extrusion technology applied high temperature for short time (H.T.S.T) which improves the product quality, prevent rancidity through inactivation of enzymes causing rancidity, inactivate antinutritional factors such as trypsin inhibitors in addition to sterilization effects. The obtained product through this technology generally has a light and crispy texture, porous structure and a pleasant taste. Almost sterile and have excellent shelf life. In Egypt, the first application of extrusion process was in 1978. The main raw material used was imported yellow corn.

In (2014) the cultivated area of white corn in Egypt reached 1636816 feddan. (According to Field Crops Research Institute. Ministry of Agriculture, Egypt). White corn is one of the major corps in Egypt and the country is self sufficient with its white corn production. Many studies on the effect of extrusion temperature, screw speed and moisture content on the gelatinization properties of extruded corn starch was carried out by (Sayed.El. Dash 1985) he found that degree of gelatinization can be effectively controlled by controlling the moisture content of raw material and extrusion temperature. The aim of this investigation was to reduce the amount of imported yellow corn by using local white corn (maize) in food extrusion technology.

MATERIALS AND METHODS

MATERIALS

1- American yellow corn grains were obtained from Chipsy Company for foods industries, Giza, Egypt.
2- White corn grains were purchased from local market, Giza, Egypt.

METHODS

Yellow corn grain and white corn grain were milled by using Maize Milling Plant "ORR/HELIOS 240 2M 1000 SH" available at the chipsy for foods industries, Giza, Egypt.

Particle size analysis was necessary after milling in which milled flour should have almost the same average particle size before extrusion. Particle size was measured as described by Henderson and Perry (1955).

CHEMICAL ANALYSIS

Yellow corn grits and white corn grits were chemically analyzed for moisture, protein, fat, crud fiber and ash contents according to the methods described in the A.A.C.C (2010). Total carbohydrates were calculated by difference.

Samples were ignited at 550 °C in a muffle, until constant weight was obtained. Ash from one gram of each sample was dissolved in 100 ml HCL. Zinc, Iron, Calcium, Potassium and Sodium were determined using atomic absorption spectroscopy technique as described by A.O.A.C (2012).

ADJUSTING THE MOISTURE CONTENT OF THE RAW MATERIAL

The amount of water necessary to bring 1000 grams of samples to the desired moisture level for extrusion was calculated according the equation:

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

Water was added gradually to the samples and mixed for 5 minutes by using mechanical mixer. The samples were placed in plastic bags and stored for 60 minutes at room temperature in order to equilibrate moisture content (Sayed El-Dash, 1985).

EXTRUSION – COOKING

EXTRUDER OPERATION

A Bartender single – screw equipped (model 823) with a grooved barrel of internal diameter 1.90 cm and length/diameter ration 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 to 350 rpm. A 3:1 compression ratio screw was used and feed rate were 60 gram 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:

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

EXTRUSION PROCEDURE

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 gram 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 to 30 rpm. When the extruder reached steady state or stable conditions samples of the extruded product were then collected (El- Dash 1983).

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 (1975) and Breen et al., (1977)

EXPANSION RATIO

Expansion ratios of extruded products were determined according to Gomez an Aguilera, (1984) by measuring the diameter of the product (average of 10 measurements) and comparing with the die diameter of extruder.

BULK DENSITY

Bulk densities of samples were determined by weighing the quantity required to fill a known volume. Bulk density of ground samples (raw material and its extrudate) was measured by Aas *et al.* (2011), a quantity of the sample that filled approximately 30 ml was placed in cylinder. Volume and weight were recorded to calculate bulk density.

WATER ABSORPTION INDEX (WAI) AND WATER SOLUBILITY INDEX (WSI)

The Methods were described by Anderson (1982) were used to determine:

a – 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).

B – Water solubility index, defined as the water-soluble fraction expressed as a percent of dry sample.

Sample of ground product (2.5 gram) 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 minutes and centrifuged at 3.000 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:

$$\text{Water solubility index (WAI)} = \frac{\text{Solids weight}}{\text{Weight of sample}} \times 100$$

$$\text{Water absorption index (WAI)} = \frac{\text{Weight of gel}}{\text{Weight of samples (100-WSI0}} \times 100$$

SHEAR FORCE DETERMINATION

Shear force was measured by using Warner-Bratzler machine. Each extrudate 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 extrudate, while high shear force value indicate less weakening Sayed El-Dash (1985).

VISCOSITY DETERMINATION

Viscosity of each sample was measured according to Anderson *et.al.*. (1969a) by using a Bartender viscoamylograph. The viscoamylograph was calibrated by water to give a viscosity of zero Brabender amylograph unit (B.U). A 50 gram sample was added 450 ml distilled water and transferred quantitatively to viscoamylograph container. The temperature was adjusted at 29°C then raised to 95°C at a rate of 1.5°C per minute. The temperature was held at 95°C for 16 minutes. Then cooled to 50°C at rate of 1.5°C per minute. 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 AND DISCUSSION

CHEMICAL COMPOSITION OF THE RAW MATERIALS

The chemical compositions of the materials used are given in Table (1). Yellow corn grits and white corn grits were characterized by its high carbohydrate contents where ranged from 86.70 to 87.34. However, ether extract, fiber and ash contents, showed a reversible trend when compared with total carbohydrates in all tested samples. Protein % in the yellow corn grits and white corn grits showed little variation.

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

%	Yellow corn grits flour	White corn grits flour
Moisture	11.90	12.00
Ether extract	0.80	1.00
Protein	9.20	9.80
Ahs	0.56	0.60
Fiber	2.10	1.90
Carbohydrates	87.34	86.70

MINERAL CONTENT OF THE RAW MATERIALS

Mineral contents of the raw materials are shown in Table (2). Yellow corn grits and white corn grits had almost the same iron content ranging from 3.47 to 3.60 and zinc from 1.00 to 1.27.

Table (2) chemical composition of the raw materials (calculated on dry weight basis)

mg/100g	Yellow corn grits flour	White corn grits flour
Iron	3.60	3.47
Sodioum	31.89	29.99
Zinc	1.00	1.27
Potassium	197.92	201.50
Calcium	8.43	7.09

PARTICLE SIZE ANALYSIS OF THE RAW MATERIALS

The materials feed into an extruder vary in particle size from grits to flour. Grits provide the best flow characteristics to produce homogeneous products. Therefore, all raw materials used are to screening analysis as shown in Table (3). From this table, all produced floures have more than 70% of particle s size between 500 and 1000µ. Yellow corn grits and white corn grits had the highest value of particle size greater than 500µ (90.70% and 93.10%) respectively. These results indicated that all the flour of raw materials used was in the average of suitable particle size for extrusion process. On the other hand these results indicated that all grits of yellow corn and white corn flours proceed to be of suitable size for good feeding to extruder for adequate heat treatment during extrusion process. Raw materials used were subjected to screening analysis as shown in table (3).

Table (3): Particle size analysis of raw materials

Fraction	Yellow corn grits flour %	White corn grits flour %
Fraction > 1000 µ	41.60	49.70
800µ < Fraction < 1000 µ	21.90	22.10
600µ < Fraction < 800 µ	18.50	17.90
500µ < Fraction < 600 µ	8.70	3.30
400µ < Fraction < 500 µ	3.70	3.50
315µ < Fraction < 400 µ	3.30	2.30
Fraction < 315 µ	2.30	1.20

Results showed that the particle size of the ground raw materials were greater than 500µ, this means that the flour used were in the average of suitable particles size for extrusion process.

EFFECT OF VARIOUS EXTRUSIONS – COOKING CONDITIONS ON THE EXPANSION RADIO, SPECIFIC WEIGHT AND SHEAR FORCE

Effect of various extrusion-cooking conditions i.e barrel temperature (110 to 170 °C) and screw speed (150 rpm) at four level (15, 17, 20 and 25%) of moisture content an expansion ratio, specific weight, shear force, water solubility index (WSI), water absorption index (WAI) and viscosity of extruded yellow corn and extruded white corn as shown in table (4, 5 and 6).

Results showed that extrusion process caused an expansion of the product. The degree of expansion was varied according to the raw materials used and it affects density, friability, and tenderness of the product. Expansion ratios of the final extrudate were found to increase with every decrease in moisture content of feed material. The optimum conditions obtained for the highest expansion ratio of yellow and white corn grits were 15% moisture content, 150 °C and 150 rpm. The lowest expansion was at 25% moisture content and 130 °C for all tested samples.

A relation between expansion ratio and specific weight of extruded products i.e., the greater the expansion volume, the lower the specific weight. The optimum conditions obtained for the lowest specific weigh of yellow and white corn grits were 15% moisture content, 150 °C and 150 rpm. As the moisture content increased and temperature decreased the extrudate texture was found to increase. The highest shear force value was found at conditions of 25% moisture content. The optimum conditions obtained for the best shear force of yellow corn grits and white corn grits were 15% moisture content, 150 °C and 150 rpm.

Table (4) Effect of various extrusion – cooking conditions on the expansion radio, specific weight and shear force

Moisture %	Temp °C	Expansion ratio		Specific weight		Shear force	
		Yellow corn grits	White corn grits	Yellow corn grits	White corn grits	Yellow corn grits	White corn grits
15	110	3.6	3.2	22.05	25.22	8.2	8.6
	130	3.8	3.74	21.05	22.1	7.8	7.55
	150	4.01	2.99	20	21.05	7	7.1
	170	3.47	3.3	22.7	24.7	8.44	8.4
17	110	3.5	3.05	22.55	26	10.2	10.9
	130	3.6	3.71	22.05	22.53	9.85	9.8
	150	3.79	3.75	21.1	22.29	9.1	9.5
	170	3.29	3.1	23.6	25.8	10.9	10.5
20	110	3.15	2.8	24.3	27.35	12.8	13.7
	130	3.19	3.25	24.1	24.95	12.35	12.3
	150	3.42	3.45	23	23.9	11.6	12
	170	3	2.9	25	26.8	13.4	13.5
25	110	2.7	2.25	26.44	30.25	16.75	17.95
	130	2.8	2.79	26.05	27.4	16	15.75
	150	3	2.95	25	26.55	14.9	15
	170	2.51	2.3	27.5	30	17.8	17.4

EFFECT OF VARIOUS EXTRUSION – COOKING CONDITIONS ON THE WATER SOLUBILITY INDEX AND WATER ABSORPTION INDEX

The water solubility index (WSI) of extrudate was found to increase with every decrease in the moisture content and every increase in temperature.

The best conditions to obtain the maximum WSI was 15% moisture content, 170 °C and 150 rpm for the raw materials used. The minimum WSI at 25% moisture content, 110 °C and 150 rpm. Results showed that the most favorable conditions for obtaining maximum water absorption index (WAI) were 170 °C, 15% moisture content and 150 rpm.

While for obtaining minimum (WAI) the suitable conditions would be 110 °C, 25% moisture content and 150 rpm. Therefore, it could be concluded that the lowest moisture content and highest extrusion temperature caused the highest WAI of the final extrudate.

EFFECT EXTRUSION VARIABLES ON VISCOSITY OF YELLOW AND WHITE CORN GRITS AT SCREW SPEED 150 RPM

The cold-paste viscosity at 29 °C of the extrudate was found to increase with the increase in temperature and moisture content. The highest viscosity was obtained at 25% moisture content, 170 °C and 150 rpm. While the lowest viscosity at 29 °C was obtained at 15 % moisture content, 130 °C and 150 rpm. The higher initial viscosity could be due to a greater degree of gelatinization affected at higher moisture level in the extruder material. The maximum value of hot-paste viscosity at 95°C was obtained at 130 °C and 25% moisture content using 150 rpm. While, the minimum viscosity at 95 °C was observer at 170 °C.25% moisture content and 150 rpm. Viscosity at 95 °C was also found to decrease by increasing the applied temperature especially at 25% moisture content. Viscosity at 50 °C after cooling was found to decrease by increasing the temperature and decreasing the moisture content. The lowest value of viscosity was obtained at 15% moisture level 130 °C and 150 rpm. While the highest viscosity value was obtained at 25% moisture content.130°C and 150 rpm. In general, it could be noticed that white corn grits had the lowest value of cooked-paste viscosity at 50°C after cooling followed by yellow corn grits extrudates.

EFFECT OF EXTRUSION-COOKING ON THE CHEMICAL COMPOSITION

The chemical compositions of the products processed from materials used in this study are reported in table (7). There is no noticeable change in the ether extract, protein, ash, fiber and total carbohydrates contents of the extruded materials than that of the flours (table 7 and 1). However, it was found that the processed samples had less moisture content than the flour. This might be due to the variation of moisture by heat treatment during extrusion.

Table (5) Effect of various extrusion – cooking conditions on the water solubility index and water absorption index

Moisture %	Temperature °C	Water solubility index		Water absorption index	
		Yellow corn grits	White corn grits	Yellow corn grits	White corn grits
15	110	11.98	13.99	6.30	6.97
	130	16.75	17.98	6.50	6.71
	150	18.21	18.90	6.98	7.03
	170	19.50	20.05	7.90	7.10
17	110	10.20	12.09	6.20	5.90
	130	15.05	16.71	6.47	6.70
	150	16.88	17.69	6.81	6.40
	170	18.30	19.00	7.55	7.00
20	110	8.90	9.90	6.05	5.67
	130	13.65	14.80	6.30	6.42
	150	14.97	15.19	6.67	6.60
	170	16.50	16.70	7.18	6.81
25	110	6.19	5.70	5.80	5.40
	130	11.20	10.20	6.18	6.10
	150	13.05	11.10	6.57	6.40
	170	14.10	12.10	6.95	6.65

Table (6) Effect extrusion variables on viscosity of yellow and white corn grits at screw speed 150 rpm

Moisture %	Temperature °C	Viscosity					
		Cold-paste at 29°C		Hot-pate at 95°C		Cooked-paste at 50°C	
		Yellow	White	Yellow	White	Yellow	White
control	control	5	20	490	465	1160	640
15	130	285	300	175	75	170	150
	170	430	460	190	100	200	170
25	130	410	440	410	210	360	320
	170	605	620	140	90	190	180

Table (7) Chemical composition of the extruded products (calculated on dry weight basis)

%	Yellow corn Grits flour	White corn Grits flour
Moisture	5.10	5.15
Ether extract	0.80	0.97
Protein	9.15	9.80
Ash	0.52	0.59
Fiber	2.05	2.00
Carbohydrates	87.48	86.64

Table (8) Mineral contents of the extruded products (mg/100gm dry samples)

%	Yellow corn Grits flour	White corn Grits flour
Iron	3.24	3.09
Sodium	26.77	25.02
Zinc	0.85	1.04
Potassium	178.31	184.05
Calcium	8.19	6.91

EFFECT OF EXTRUSION-COOKING ON THE MINERAL CONTENT

The effect of cooking process on mineral content of processed products was concerned in table (8). The mineral content of the extruded materials showed the same trend as that of chemical composition it was found that no noticeable changes in the mineral content with all products was realized when compared with their raw materials (table 8 and 2).

CONCLUSION

From previous results it could be concluded that the white corn grits instead of yellow corn grits is considered the good instant gruel snacks food because it characterized nearly the same results such as chemical composition, mineral content, Expansion ratio, texture, bulk density, water absorption index, water solubility index and viscosity. The extrudate products were varied according to the raw materials used. Expansion ratio of the extrudate product was found to increase with every decrease of moisture content. 15% moisture content, 150°C and 150 rpm were found to be the optimum conditions for high expansion ratio of both yellow and white corn grits. Also, the yellow corn grits could be considered as white corn grits which are available in extreme quantities in Egypt.

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