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New Extruded Products from Sorghum

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ABSTRACT

Sixteen recipes were suggested in this study to prepare new extruded products from sorghum grains and its flour. The physical, chemical, nutritional and organoleptic properties of these new products were evaluated. The results indicate the importance of both sorghum grain and/or its flour alone, or after mixing with other cereal grains in preparing acceptable extruded products.

INTRODUCTION

According to Creelman *et al.* (1981) sorghum resembles maize and rice and therefore can be popped using a high temperature short time (HTST) roasting process. Gomez and Aguilera (1983) reported that the extrusion process changed the physical properties of the biopolymers, starch, protein and cellulose, reduced vitamins, encouraged Maillard reactions and, to some extent, caused the dextrinization or depolymerization of starch. The aim of

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this investigation was to prepare new extruded products based on sorghum grain. The physical, chemical, nutritional and organoleptic properties of these new products were tabulated.

MATERIALS AND METHODS

Materials

Sorghum grains and flours
Two varieties of sorghum grain (*Sorghum vulgare*); namely, BR and Giza 15, were used. The first was high in tannin (2·9% CE) and obtained from Lippische Hauptgenossenschaft Company, Detmold, FRG. The second was low in tannin (0·19% CE) and obtained from the Ministry of Agriculture, Cairo, Egypt. The grains of both varieties were milled using a Buhler Mill type 220 as described by Anderson *et al.* (1969). Samples of whole, ground grain, flour I and flour II were collected and kept at 4°C in polyethylene bags.

Other ingredients
Soft wheat flour, commercial flour (USA), yellow corn, white rice, defatted soyflour (DSF) with 47% protein and skimmed dry milk (SDM), with 32% protein, sucrose and sodium bicarbonate, were obtained from the Baking Department of Bundesforschungsanstalt Fur Getreide und Kartoffelvorarbeitung, Detmold, FRG.

Extruded products
Figure 1 shows the appearance and the proportion of the ingredients used in preparing sorghum extruded products. The ingredients of each recipe were mixed in an electric mixer and moisture content was adjusted to 16% before extrusion. The screw extruder type BC 45, Co. French Creusot Lovie was used under the following operation conditions:

Temperature	155–156°C
Pressure	30–35 bar
Residence time	40–60 s
Screw operation rate	150 rpm
Feeding rate	350 g/min

Methods

(a) Physical properties
The water absorption index (WAI), water solubility index (WSI), expansion ratio (ER) and specific volume (SV) were determined as mentioned by Anderson *et al.* (1969).

(b) Organoleptic properties
Descriptive tests were utilized to evaluate the sensory characteristics of the extruded products using the scheme of the Standard Methoden Fur Getreide, Mehl und Brot (Arbeitsgemeinschaft Getreideforschung, 1978) and two specialists in these products. The scheme included the following properties:

1. General appearance as:
   excellent (regular form, light colour), good (slightly irregular form, light colour) and satisfactory (slightly irregular form, light colour).
2. Surface characteristics as:
   excellent (smooth), good (moderate, semi rough) and satisfactory (rough).
3. Colour as:
   excellent (light yellow–yellow), good (yellowish brown) and satisfactory (brown, 'dark').
4. Porous texture and distribution as:
   excellent (fine/regular), good (moderate coarse fairly irregular) and satisfactory (course/irregular).
5. Chewiness and Taste as:
   excellent (tender/pleasant), good (nearly tender/little floury taste) and satisfactory (slightly hard floury taste).

(c) Chemical methods
Moisture, crude protein, fat and ash contents were determined before and after the extrusion process according to the Standard Methoden Fur Getreide, Mehl und Brot (Arbeitsgemeinschaft Getreideforschung, 1978). Tannin content was determined as catechin equivalent (g/100 g) as described by Price *et al.* (1978). The amino acid content of the protein hydrolysate was determined using an automatic recording amino acid analyzer, type kontron Anocomp 500.

(d) Nutritional methods
Three experimental diets were prepared from the extruded products. The composition diet is given in Table 1. Twenty-four weanling male Sprague–Dawley rats of equal weight ($65 \pm {\cdot}15$ g) were divided into three experimental groups (eight for each diet). Each animal received approximately 120 mg nitrogen (*c.* 12 g dry matter) daily throughout the adaptation period (4 days) and balance period (4 days). The nitrogen content of the faeces, spilled feed and urine was determined by the Kjeldahl method using an Auto Analyzer (Tecator, GMBH, D-6054 Rodgan). Then the protein content was calculated using 6·25 as a conventional factor. True protein

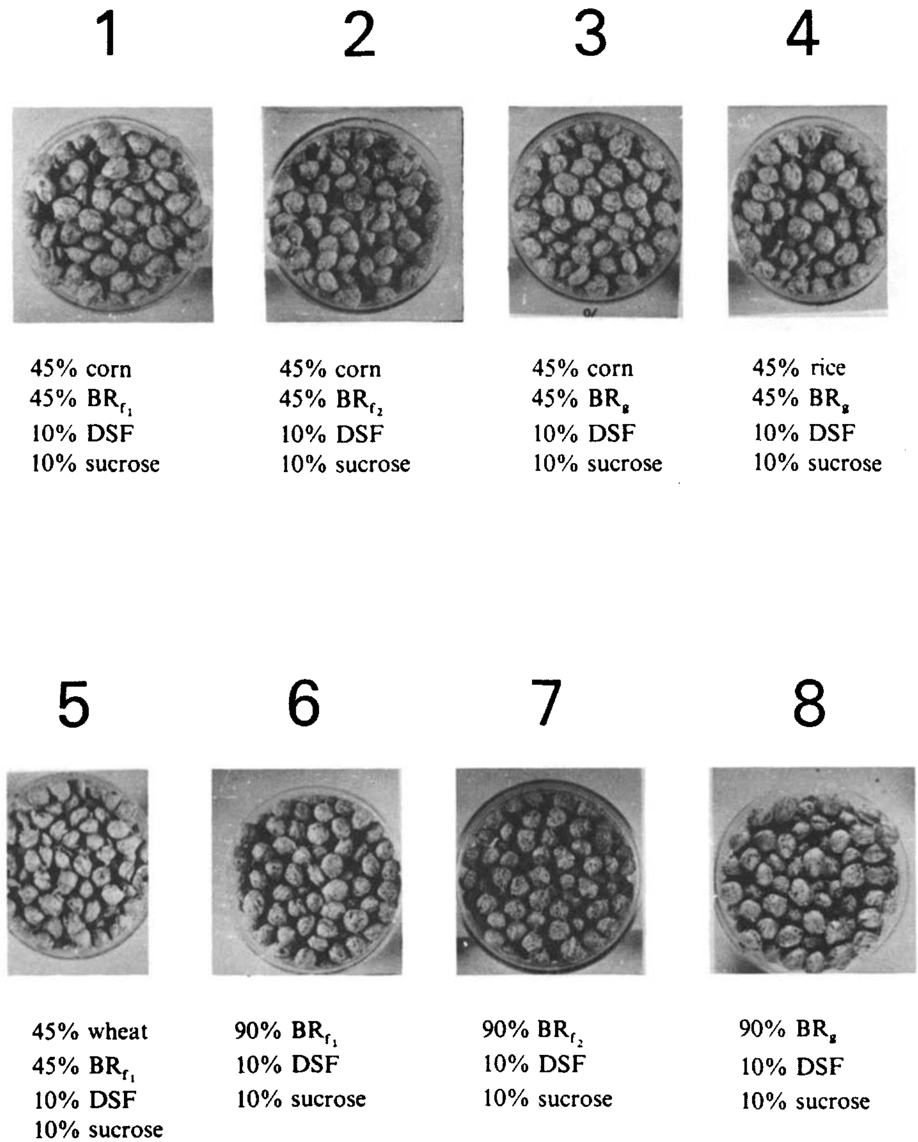

Fig. 1. Appearance of the sorghum extruded products. BR_{f_1} = Flour I (BR variety), BR_{f_2} = Flour II (BR variety), BR_g = Whole ground grain (BR variety), Giza 15_g = Whole ground grains (Giza 15 variety).

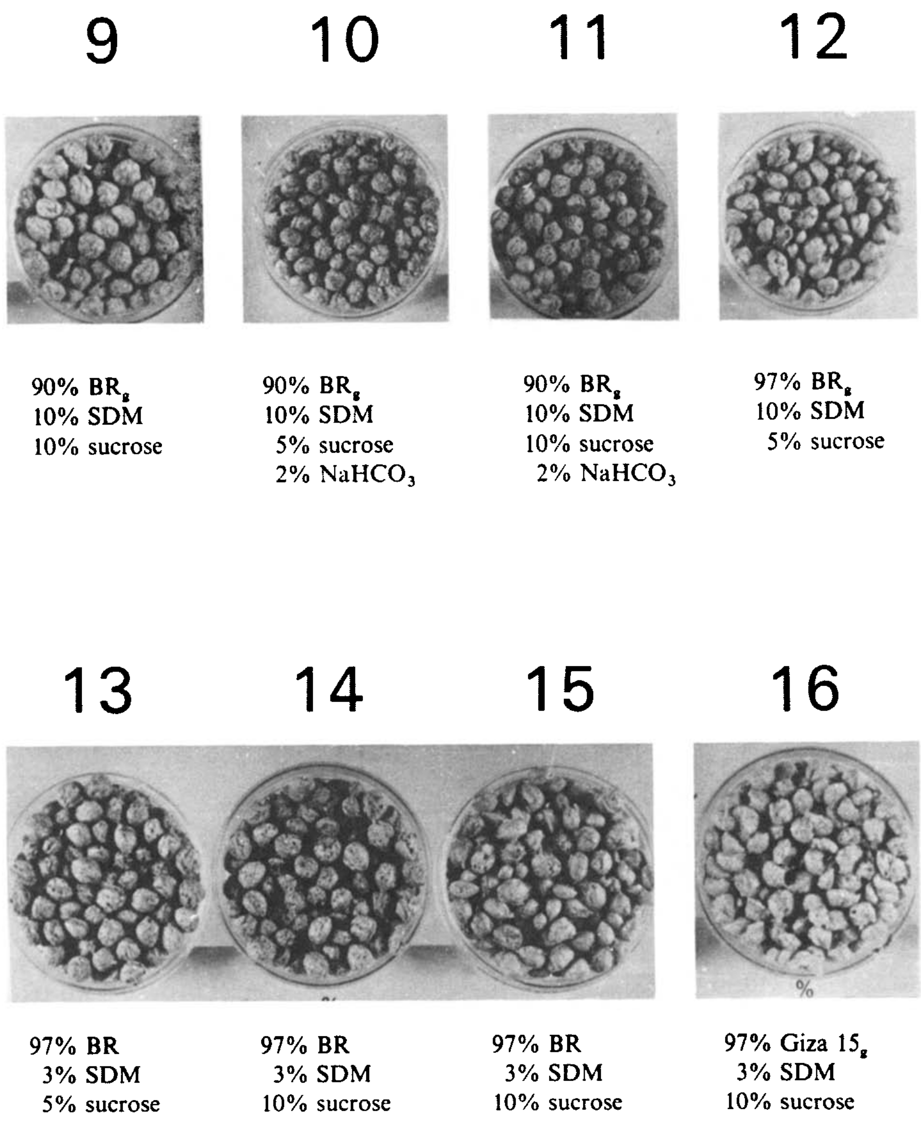
9
90% BR_g
10% SDM
10% sucrose
10
90% BR_g
10% SDM
5% sucrose
2% $NaHCO_3$
11
90% BR_g
10% SDM
10% sucrose
2% $NaHCO_3$
12
97% BR_g
10% SDM
5% sucrose
13
97% BR
3% SDM
5% sucrose
14
97% BR
3% SDM
10% sucrose
15
97% BR
3% SDM
10% sucrose
16
97% Giza 15_g
3% SDM
10% sucrose

Fig. 1.—*contd.*

TABLE 1
Test Diets Composition[a]

Product	*Product tested*	*Sucrose added*	*Total (%)*	*Dry matter*	*Diet protein N × 6·15*
90% whole ground BR sorghum + 10% DSF	77·6	7·4	85·0	94·3	10·4
97% whole ground BR sorghum + 3% SDM	85·0	—	85·0	93·7	10·2
97% whole ground Giza 15 sorghum + 3% SDM	85·0	—	85·0	94·4	9·9

[a] A hundred gram test experimental diet (85 g product tested + sucrose) + 15 g other ingredients (3 g corn oil, 4 g cellulose, 2 g vitamin mixture, 6 g mineral (Altromin, D 4930 lage, Detmold, FRG).

digestibility (PD %), biological value (BV %) and net protein utilization (NPU %) were assessed as described by Njaa (1963). The results were statistically analyzed according to the methods reported by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Organoleptic properties

The results of the evaluation of the organoleptic properties of new extruded products (Fig. 1) reveal that:

(1) The appearance was excellent in the products containing 45, 90, 97% BR_{f_1} and 97% Giza 15_g, satisfactory in that having 90% either BR_{f_2} or BR_g and good in others.
(2) Surface characteristics, texture and distribution of pores were excellent in the extruded products containing from 45 to 97% either BR_{f_1} or BR_{f_2}, good in that including 90 to 97% BR_g or Giza 15_g, and satisfactory in that having both 2% $NaHCO_3$ and 90% BR_g.
(3) The colour was excellent in the products containing 45% of each type of sorghum, 90% BR_f and 97% Giza 15_g, good in that having from 90 to 97% BR_g and satisfactory in that including 2% $NaHCO_3$.
(4) The chewiness and taste were excellent in all the products except that containing 45% sorghum flour and $NaHCO_3$ respectively. The chewiness was good for the former but a strong baking taste was noticed for the latter.

Generally the increase of the proportion of the whole ground grains of the BR variety caused the conversion of the yellow colour to brown, the smooth surface to semi-rough and the fine/regular porous structure to a coarse/irregular one. The darkening of the colour might be attributed to its high content of polyphenols, 'tannin', while the differences in surface characteristics, porous texture/distribution, might be due to the large particle size of the whole ground grains as compared with that of flour.

Physical properties

Table 2 shows that:

(1) Among the products containing more than 90% whole sorghum ground grain, product No. 6 had higher WAI and WSI, followed by products No. 15 and then No. 16. These parameters were nearly similar in the other extruded products.

(2) Within the products containing sorghum flour, product No. 5

TABLE 2
Physical Characteristics of Extruded Products

Product number	*WAI (ml/g)*	*WSI (%)*	*Expansion ratio (ER)*	*Specific volume (cm^3/g)*
1	6·8	28·7	2·06	7·9
2	6·0	22·2	1·42	7·5
3	6·5	26·6	1·83	6·1
4	5·1	24·3	1·63	5·6
5	8·0	37·3	1·98	9·5
6	7·4	31·3	1·63	8·7
7	5·4	20·3	1·32	5·4
8	5·4	25·3	1·38	7·8
9	5·2	24·2	1·36	7·5
10	5·2	25·9	1·43	11·4
11	5·1	24·6	1·38	10·9
12	8·0	34·6	1·67	9·4
13	5·5	27·3	1·83	6·8
14	5·5	29·4	1·75	7·6
15	5·9	30·2	1·88	7·7
16	6·2	33·2	1·83	7·9

WAI = Water absorption index.
WSI = Water solubility index.

$$ER = \frac{\text{Diameter of product (mm)}}{\text{Diameter of die (4 mm)}}.$$

(sorghum/wheat flour, blended 1:1) gave the best WAI, WSI and ER followed by product No. 12 (97% sorghum flour I + 10% DSF).

(3) Both specific volume and expansion ratio decreased when the amount of sorghum increased in the extruded blends. This may be due to the formation of fat–starch complex during the extrusion process and the ability of starch to expand (Linko *et al.*, 1981).

(4) Addition of sodium bicarbonate as a leavening agent increased only the specific volume from 7·6 to 11 ml/g.

(5) Addition of sugar, especially at the 10% level, led to a slight decrease in all the physical characteristics (e.g. products Nos 8, 9, 10, 11, 14 and 15).

(6) Addition of supplemental protein, particularly SDM, improved the physical characteristics of the extruded products.

Generally, the utilization of sorghum flour I in preparing extruded products gave the best characteristics, followed by whole ground grains and flour II, respectively.

Proximate composition

The effect of the extrusion process on the proximate composition of the products was studied. The results are shown in Table 3 and indicate that:

(1) Proximate composition before extrusion differed according to the type and proportion of ingredients used in preparing these products. Generally, the protein, fat and ash ranged from 11·9 to 15·6, 1·5 to 5·3 and 0·8 to 2·5%, respectively. These components were higher in recipes containing sorghum flour II than that having ground sorghum grains and that having flour I. The polyphenols ('tannins') range was 0·02 to 2·69 CE. The value increased with the increase of the proportion of whole ground grains of BR sorghum variety in the recipe composition.

(2) The extrusion process affected only the polyphenols ('tannins') (from 55 to 78% reduction). According to Hulse *et al.* (1980) the extrusion process does affect tannin content. The products containing $NaHCO_3$ (Nos 10, 11) had less tannin than those without $NaHCO_3$. Price *et al.* (1980) found that the amount of assayable tannins was greatly reduced when high tannin sorghum grain was cooked in dilute $NaHCO_3$ rather than in water.

Amino acids and nutritional values

The following extruded products were selected to study the effect of tannin

TABLE 3
Effect of Extrusion Process on the Proximate Composition of Extruded Products (% on dry weight basis)

Recipe number	*Moisture*		*Protein (N × 6·25)*		*Fat*		*Ash*		*Polyphenols (Tannin)*[a]		*Total carbohydrates*[b]	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
1	16	7·4	12·9	12·8	2·3	2·2	1·3	1·3	0·42	0·10	83·1	83·6
2	16	6·8	14·0	14·0	3·0	2·9	1·8	1·8	0·50	0·15	80·7	81·2
3	16	7·0	13·0	12·9	2·5	2·3	1·1	1·1	1·36	0·53	82·2	84·1
4	16	6·9	12·6	12·5	2·0	1·9	1·3	1·3	1·33	0·60	82·8	82·7
5	16	7·6	13·8	13·7	1·5	1·5	1·1	1·0	0·45	0·13	83·2	83·2
6	16	7·2	12·4	12·2	3·3	3·2	1·7	1·6	0·90	0·41	81·7	81·7
7	16	7·2	15·1	15·0	5·0	5·0	2·4	2·3	1·01	0·53	76·5	76·5
8	16	7·4	14·5	14·4	3·0	2·9	1·7	1·6	2·62	0·91	78·2	80·2
9	16	7·2	14·4	14·0	3·1	2·9	1·6	1·6	2·59	0·80	78·3	80·7
10	16	6·9	13·7	13·5	3·0	2·9	2·3	2·3	2·52	0·71	78·5	80·5
11	16	6·8	13·6	13·5	3·1	2·9	2·2	2·1	2·53	0·73	78·6	79·0
12	16	7·0	12·4	12·5	1·8	1·7	0·8	0·8	0·92	0·55	84·1	84·5
13	16	7·0	15·6	15·5	5·3	5·2	2·5	2·5	1·09	0·42	75·5	76·4
14	16	6·5	12·4	12·3	3·0	3·0	1·9	1·9	2·63	1·10	80·3	82·0
15	16	6·9	12·7	12·7	3·0	2·9	1·8	1·8	2·69	1·05	79·8	81·4
16	16	7·6	11·9	11·9	3·8	3·7	1·8	1·8	0·02	0·01	83·6	84·6

A, Before extrusion; B, after extrusion.
[a] Catechin equivalent (g/100 g) using vanillin HCl method.
[b] By difference.

and type of supplemental protein on the nutritional quality of the extruded products.

(a) Product No. 10 (medium in tannins content) (0·71%), having 90% BR_g and 10% DSF.
(b) Product No. 15 (high in tannins content) (1·05%), containing 97% BR_g and 3% SDM.
(c) Product No. 16 (low in tannins content) (0·01%), having 97% Giza 15_g and 3% SDM.

The results in Table 4 show that:

(1) Low tannin products, contained higher values of lysine, methionine, cystine, phenylalanine, histidine, valine and serine and lower values of aspartic acid, glutamic acid and proline than high tannin products. Also NPU, PD and leucine/isoleucine ratio of the low tannin products were higher than that of the high tannin blend. Creelman *et al.* (1981) reported 87·75% PD for yellow sorghum (low tannin) and 78·77% for brown sorghum (high tannin).

TABLE 4
Amino Acids and Nutritive Values of some Extruded Products

Constituent	*Extruded product no.*		
	10	*15*	*16*
Amino acids (g/100 g protein)			
Aspartic	9·70	8·13	7·9
Threonine	2·97	3·03	3·01
Serine	4·19	3·68	3·86
Glutamic	19·11	18·86	18·29
Proline	6·07	6·92	6·38
Glycine	3·42	2·77	2·88
Alanine	8·25	8·34	8·35
Valine	4·33	4·61	4·83
Cysteine	0·39	0·47	0·52
Methionine	1·77	1·34	1·76
Isoleucine	3·47	3·66	3·51
Leucine	11·88	12·50	12·53
Tyrosine	3·13	3·42	3·54
Phenylalanine	4·92	4·23	4·68
Lysine	2·5	1·87	2·20
Histidine	2·95	2·11	2·33
Arginine	4·15	3·68	3·62
NH_3	3·62	3·57	3·6
Leucine/isoleucine ratio	3·40	3·40	3·6
Nutritive values (%)			
PD	80·91 ∓ 0·89	81·5 ∓ 1·2	88·42 ∓ 1·46
BV	50·60 ∓ 2·3	46·67 ∓ 0·67	48·8 ∓ 1·15
NPU	40·93 ∓ 1·63	38·03 ∓ 2·63	43·18 ∓ 2·15

10 = 90% Whole ground sorghum (BR) + 10% defatted soy flour.
15 = 97% Whole ground sorghum (BR) + 3% skimmed dry milk.
16 = 97% Whole ground sorghum (Giza 15) + 3% skimmed dry milk.

(2) The supplementation with DSF led to an increase in lysine, methionine, arginine, histidine, phenylalanine, glycine, glutamic acid, serine, aspartic acid, BV, NPU and a reduction in threonine, cysteine, leucine, isoleucine, valine and tyrosine as compared with addition of SDM. Nearly the same PD and leucine/isoleucine ratio were observed for both products.

(3) Low tannin products containing SDM, had a higher level of total sulfur-containing amino acids and a lower value of lysine as compared with medium tannin products (0·71%) having DSF. Also, the PD and NPU of low tannin products were higher than the other two products. Oswald (1973) reported that lysine was the first limiting factor in grain sorghum diets.

Generally the effect of tannins was more pronounced on lysine, sulfur-containing amino acids, PD and NPU than on BV. Supplementation of the sorghum extruded products with DSF increased the level of lysine and sulfur-containing amino acids and improved BV and NPU, compared with SDM.

In conclusion, sorghum grain and/or its flour can be successfully used alone and/or after mixing with other cereals to prepare, acceptable extruded products.

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