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Final Report

EXTRUSION PROCESSING OF INSTANT NASHA BABY FOOD

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I. BACKGROUND

The Food Research Centre (FRC) of Khartoum, Sudan, has an ongoing effort to promote the use of locally grown sorghum and millet. One of the traditional uses for these grains is a preparation used as a weaning food called Nasha (1).

The traditional preparation of Nasha requires approximately 12-24 hours to complete. Initially, sorghum or millet is decorticated and ground into a flour. The resulting flour is then mixed with water at a ratio ranging between 1:1 to 1:2 (sorghum:water) and allowed to ferment naturally up to 12 hours at ambient temperature. Following fermentation, it is poured and stirred into boiling water through a sieve to remove coarse particles. The mixture is brought to a boil and allowed to simmer for several minutes until it is of suitable viscosity. This latter condition is determined visually and usually differs for each homemaker.

Measurements of the finished product indicate that the resulting gruel has from 5-7% solids and a relatively high viscosity so it can be spoon fed. The cooked product is often flavored with sugar and spices to complement its naturally acidic/fermented flavor.

Because Nasha is time consuming to prepare and has limited nutritional value, FRC has sought ways to produce an easy-to-prepare product of improved nutritional quality that retains the flavor and acceptability of traditional Nasha.

Workers at FRC, Drs. Laila Monawar and Sitt El Nafer M. Badi, have developed a new product called Instant-Nasha (1). The Instant-Nasha is a powder which can be reconstituted to make a ready-to-eat gruel or beverage simply by adding hot water. Decorticated sorghum flour is fermented overnight, followed by the addition of 30% malted sorghum and 20% NFDM. The action of the amylase, which naturally occurs in the malt, reduces the viscosity of the sorghum/water mixture and becomes an aid to drum drying. The mixture is then drum dried and simultaneously cooked to complete the processing. The reconstituted drum dried Instant-Nasha is slightly curdy and has a similar viscosity to the traditionally prepared product. Instant-Nasha is substantially improved nutritionally having approximately three times the caloric density (17% solids) of traditional Nasha (5% solids), as well as greater amounts of protein introduced by the milk. The product has been tested by FRC and found to have good acceptability when compared to traditional Nasha, good storage stability with added BHA, and high protein quality.

The drum dried Instant-Nasha appears to have good potential for sale in retail markets and also for use in government-sponsored feeding programs based on its acceptability. The Sudanese government and private sector commercial organizations are interested in the product and wish to have FRC

proceed with development studies and commercialization activities.

FRC's drum drying process for manufacture of Instant-Nasha is energy intensive and consequently expensive and, if the process for manufacture were used commercially, the resulting product cost would probably limit markets. It is estimated that for every pound of finished product, 3.5 to 4.5 lb of water must be removed. The energy requirement for water removal by drum drying is more than 2000 BTU/lb of water removed. Further, drum driers have high initial capital costs per unit of productive capacity and are expensive to maintain.

In an initial evaluation performed by Crowley (2), it appears that extrusion cooking is a potentially less expensive process for the production of Instant-Nasha. Extrusion cooking is a simple, inexpensive process used in many countries for the production of weaning foods as well as other types of food products. If extrusion cooking can be used for manufacture of Nasha-like products, costs should be low enough for practical use in government feeding programs and to also capture a significant commercial retail market. A factory having a capacity of 700 kg/hr and costing about US$500,000-1,000,000 would have production costs in the range of US$0.55-1.10/kg. A factory such as this would provide the necessary processing capacity to satisfy the above markets.

USAID/Khartoum, in cooperation with the USDA, has agreed to assist FRC in studies and development of lower-cost methods of producing an Instant-Nasha-like product. If a suitable method is found, then a Sudanese

institution, assisted by USAID supplied consultants, will undertake a full feasibility study.

This report summarizes initial work performed at Colorado State University to determine the feasibility of extrusion cooking an Instant-Nasha-like product. Dr. Laila Monawar was present during most of the study period running from October 19 through December 5, 1987.

II. OBJECTIVES

A. To study the technical feasibility of extrusion to make Instant-Nasha.

B. To operate within the following constraints:

1. Raw materials available in Sudan;
2. Codex guidelines (3); and,
3. Process is useable in Sudan.

C. To produce an Instant-Nasha for evaluation in Sudan.

III. METHODS & MATERIALS

A. Extrusion Pilot Plant

Colorado State University recently installed and began operation of an extrusion pilot facility which has the capability of producing representative extruded samples for evaluation and testing. For the tests conducted in this study, the laboratory was configured with the following equipment:

1. Modern Mill Model 600 - for proportioning and milling raw grain materials.

2. Fitzmill Model D-10 Hammer Mill - for fine grinding raw materials and finished products.

3. Anderson Model 4.5" Extruder configured with water applicator, steam injectors, different sized die inserts and cutter - for cooking the grain materials used in the study.

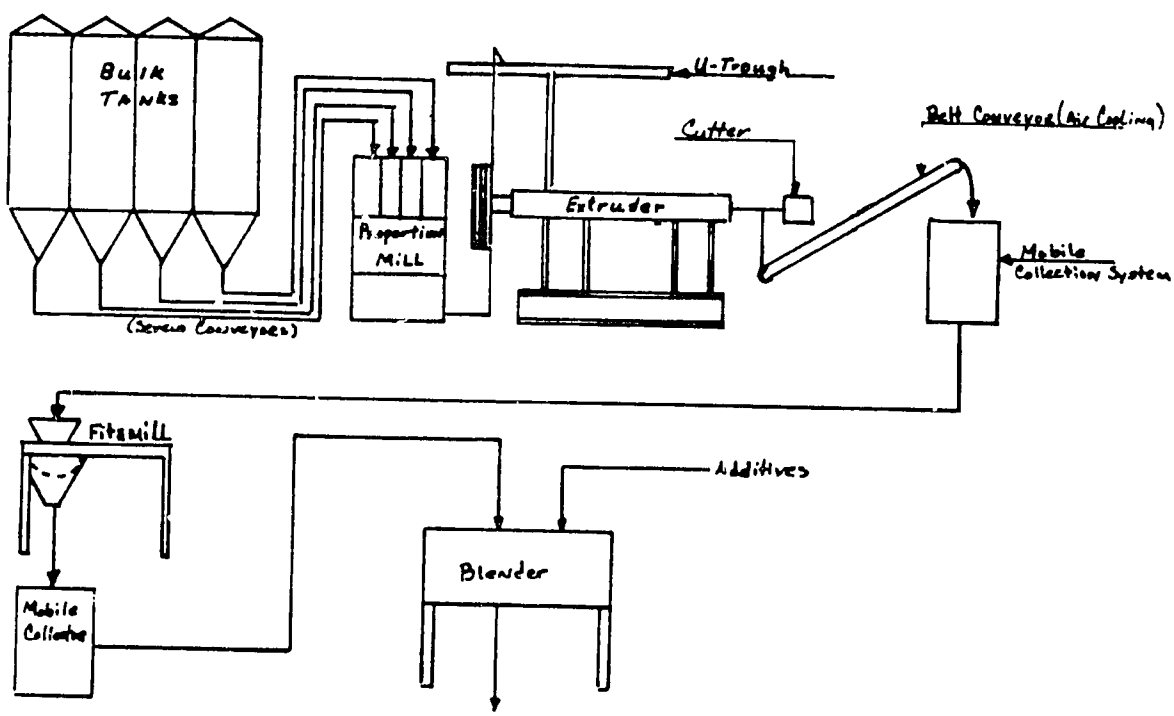
4. B. F. Gump Model 1-JJ Draver Feeder - for feeding the extruder.

5. Falcon Ribbon Blender - for mixing of the extruded ground product with other ingredients.

6. Miscellaneous conveyors - for transport of the materials extruded and raw.

Other miscellaneous equipment was used in support of making the finished product including a steam generator, weighing equipment and water flow meters. A diagram of the facility is given in Figure 1.

FIGURE 1: Diagram of Extrusion Pilot Plant Facility



For a typical production run in the pilot facility, materials stored in bulk tanks enter the proportioner mill for mixing and grinding in a set ratio, followed by conveying to the feeder attached to the extruder. The feeder controls the raw ingredient flow rates to the extruder. During the extrusion process, water and/or steam are added to control the cooking process. Materials leaving the extruder are cut into small collets [expanded pieces ranging from 0.5" to 1.0" (13-25 mm) in diameter] for ease of handling and are conveyed to a belt conveyor where air cooling occurs. Samples are taken from this belt conveyor as required and the remainder is conveyed to a container for disposal. Samples having moistures >19% are collected in trays and placed in a forced air drying oven.

Cooled and dried samples are then ground through a Fitzmill with an appropriately sized screen to achieve the desired finished product characteristics. Following the milling step, the extruded ground product can be blended with other ingredients such as milk powder, vitamins, minerals, and other flavorings or additives to complete the product. Some limited packaging can be done in the plant into 20 kg bags.

B. Production of Extruded Sorghum Samples

Some changes had to be made to the processing sequence described above to accomplish the tests on Instant-Nasha in order to manufacture an acceptable product. Details about the changes made to the processing methods are briefly discussed below.

Due to limitations in material handling equipment when multiple ingredients are used, the steps to prepare the product were done in batches. Raw decorticated sorghum and other ingredients were hand fed into the Modern Mill which was set to give the proper formulation. The Modern Mill was configured with a 0.0625" (1.6 mm) screen in the hammer mill and calibrated to run at a rate of 200 kg/hr. The ground material exiting the Modern Mill was then passed through the Fitzmill configured with a 0.050" (1.3 mm) screen and set to run at a hammer rotor speed of 4500 rpm. The ground raw materials were stored in plastic mobile containers until extruded. This method of preparation resulted in a particle distribution as indicated below:

Percent retained on U.S. #20 - 2%
Percent retained on U.S. #35 - 16%
Percent retained on U.S. #50 - 51%
Percent passing U.S. #50 - 31%

This finely ground material had a tendency to bridge which necessitated manual loading of the extruder feeder to assure constant feed to the extruder. Water and steam injection rates

were adjusted as required to meet processing requirements when the extruder was configured with a single die insert having one round orifice 0.375" (9.5 mm) in diameter.

The discharge temperature of extrusion was measured approximately 8.0" (20.0 cm) before the die or output end of the extruder. A thermocouple attached to a digital readout system with internal reference junction (Omega Model 199 with Type J thermocouple) was used to attain this measurement.

The extrudate was cut into short pieces upon exiting the extruder using a two knife rotating face cutter unit supplied with the extruder. The individual pieces cut measured approximately 0.5" (13 mm) in thickness and were 1.0-1.5" (25-38 mm) in diameter depending on the amount of expansion occurring during extrusion. Samples processed at <19% moisture were allowed to cool and dry naturally and, for those with higher moistures, the pieces were collected in trays and placed into a forced air drying oven until dry.

The dry extruded samples were ground through the Fitzmill using a 0.033" (0.76 mm) screen and a rotor speed of 4500 rpm. Throughput was not controlled for this process step as batch grinding with hand feeding was used. The ground product had the following particle size distribution:

Percent retained on U.S. #20 - 0%
Percent retained on U.S. #35 - 7%
Percent retained on U.S. #50 - 36%
Percent passing U.S. #50 - 57%

The ground product was mixed with other formulation ingredients such as NFDM, lactic acid, vitamins and minerals in batches totalling approximately 100 kg using a Falcon 15 cubic foot ribbon blender.

The product was then placed into plastic bags for storage and transport.

The Anderson extruder was selected for these tests due to its processing and product flexibility. Several variables can be controlled on the Anderson including moisture addition, feed rate, die configuration and steam addition. Typical variable ranges possible on the Anderson extruder are:

1. Extrusion moisture range . . . . 15-30% (wb)
2. Feed rate . . . . . 100-300 kg/hr
3. Die configurations . . . . . 0.25-0.75" (6-19 mm) diameter with up to four die openings possible
4. Steam injection . . . . . Steam injection through three ports located along length of extruder screw

Equipment to measure the quantity of steam was not available and steam addition was calculated based on a moisture balance around the extruder.

Collets (expanded pieces) made on the extruder were homogeneous and typically expanded from two to four times the diameter of the orifice. Higher moisture runs resulted in smaller, more dense collets approximately twice the diameter of the die orifice, while low moisture high temperature products were highly expanded to a size of approximately four times the diameter of the die.

C. Materials

The various raw materials used in the Instant-Nasha extrusion tests are described below:

1. Sorghum - A pearled yellow (amber) sorghum grit made from a number of different varieties of yellow sorghum.

   Purchased from: Grain Products, Inc.
   P.O. Box 400
   Dodge City, Kansas 67801

   Purchase price: US$0.23/kg

2. Peanut - Raw blanched Virginia peanuts consisting of half pieces.

   Purchased from: Bennett Distributing Co.
   190 W. Nevada Place
   Denver, Colorado 80223

   Purchase price: US$2.99/kg

3. Malted Barley - Six row standard malted barley. Specifically balanced for moderate flavor and dextrins.

Purchased from: The Brew-It Co.
129 Remington
Fort Collins, Colorado 80524

Purchase price: US$1.03/kg

4. Vitamins - Watson Vital Mix 139 Vitamin Premix with Antioxidants for Government Program. Composition (specified per label claim for 2 pounds):

Vitamin A (as palmitate)	15,000,000 USP Units
Vitamin D_3 (Cholecalciferol)	1,800,000 USP Units
Vitamin E (di-α Tocopherol Acetate) NF	68,000 I.U.
Ascorbic Acid, USP-FCC	364.0 grams
Niacin, NF-FCC	45.0 grams
Calcium Pantothenate, USP-FCC	25.0 grams
Riboflavin, USP-FCC	3.5 grams
Thiamine Mononitrate, USP-FCC	2.5 grams
Pyridoxine HCl, USP-FCC	1.5 grams
Folic Acid, USP-FCC	1.8 grams
Cyanocobalamin, USP(Vitamin B_{12})	0.036 grams
Butylated Hydroxyanisole	20.0 grams
Butylated Hydroxytoluene	20.0 grams
Corn Starch, USP	To make 2 lbs

Purchased from: Watson Foods Co.
301 Heffernan Drive
West Haven, Connecticut 06516

Purchase Price: US$12.43/kg

5. Minerals - Watson Mineral Premix CSSM-2 with TCP (Watson Code 141-7, Lab No. 83287). Composition (quantities specified are for 2000 lbs of product):

Tricalcium Phosphate	40.00 lbs
Zinc Sulfate, Hydrated ($ZNSO_4 \cdot 7H_2O$)	0.08 lb
Ferrous Fumarate	0.92 lb
Iodized Salt	13.00 lbs

Purchased from: Watson Foods Co.
301 Heffernan Drive
West Haven, Connecticut 06516

Purchase Price: US$1.81/kg

6. NFDM - High Heat Non-fat Dry Milk Powder Extra Grade. Spray process from Mid-America Dairymen, Inc., Springfield, Missouri.

Purchased from: Kraft Food Service
Kraft/Westman FS Denver
4450 Lipan Street
Denver, Colorado 80217

Purchase price: US$1.88/kg

7. Lactic Acid - Spray Dried Lactic Acid Powder, Beatrene 3463.

Purchased from: J. M. Swank
13105 E. 38th Avenue
Denver, Colorado 80239

Purchase price: US$4.18/kg

8. Instant-Nasha - Fermented drum dried product to which malted sorghum had been added to increase caloric density. From proximate analysis, it appears that the Instant-Nasha contains about 20% dried whole milk.

Provided by: Dr. Laila Monawar
Food Research Centre
Khartoum
The Republic of the Sudan

IV. PROCEDURES

A. Phased Tests

Testing was done in three phases:

1. Phase I examined the gross effects of the extrusion conditions required to cook various formulations including sorghum alone, sorghum with the addition of fermented sorghum concentrates, and sorghum with lactic acid. All sorghum used in the tests was decorticated. Laboratory tests were run on the extruded samples to determine functional and nutritional characteristcs. Calculations were made to estimate proximate analysis and nutrient density. Based on results from these tests, new product formulations and test conditions were selected for Phase II of testing.

2. Phase II involved some additional exploration of test conditions clustered around selected products run during Phase I and also included reformulated samples to meet Codex Alimentarius recommendations. These tests further defined the range of products possible with the Anderson extruder and emphasized products directed toward Sudanese conditions and tastes. Samples extruded in this phase included sorghum mixed 4:1 with highly fermented sorghum, sorghum with 10% oil added, and sorghum with 17.4% peanuts.

3. Phase III involved refining the test product and comparing its composition to Codex guidelines. A standard of identity for this product was developed and 50 kg were produced for shipment

to the Sudan for acceptability testing under the direction of FRC personnel.

B. Production of Products

Table I lists specific formulations tested. All raw materials were prepared by first grinding through a Modern Mill with a 0.0625" (1.6 mm) screen followed by milling in a Fitzpatrick hammer mill configured with a 0.050" (1.3 mm) screen.

TABLE I: Formulations for Extruded Components in Test Samples Prepared

Sample No.	Phase	Formulation	
871028-1	I	Decorticated sorghum (amber)	
871028-2	I	Decorticated sorghum (amber)	90%
		Malted barley	10%
871028-3	I	Same as sample 871028-2	
871028-4	I	Decorticated sorghum (amber)	75%
		Fermented sorghum (amber)	25%
		Note: Fermented sorghum used 50% solids plus 50% water and 12 hr hold at 30°C	
871028-5	I	Same as sample 871028-4	
871028-6	I	Decorticated sorghum (amber)	99.5%
		Lactic acid	0.5%
871028-7	I	Same as sample 871028-6	
871105-1	II	Decorticated sorghum (amber)	91.9%
		Soybean oil	8.1%
871105-2	II	Same as sample 871105-1	
871105-3	II	Same as sample 871105-2	
871105-4	II	Decorticated sorghum (amber)	68.9%
		Soybean oil	6.1%
		Fermented sorghum	25.0%
871105-5	II	Same as sample 871105-4	
871105-6	II	Decorticated sorghum (amber)	82.6%
		Peanut	17.4%
871105-7	II	Same as sample 871105-6	
880204-1	III	Decorticated sorghum (amber)	81.7%
		Peanut	18.3%

Table II gives information on the extrusion conditions used with each of the above samples.

TABLE II: Extrusion Conditions Used to Produce Test Samples

Extruded Sample #	Feed Rate kg/hr	Extrudate Moisture* (% WB)	Discharge Temp. °C	Estimated Steam Added kg/hr	Power kW	kW-hr/kg
			PHASE I			
871028-1	246	17.7	130	5	---	---
871028-2	328	21.8	121	10	16.1	.049
871028-3	258	16.3	162	-0-	16.7	.065
871028-4	129	20.0	154	-0-	---	---
871028-5	218	20.0	---	-0-	---	---
871028-6	200	13.6	172	-0-	---	---
871028-7	200	20.0	162	-0-	---	---
			PHASE II			
871105-1	204	13.8	132	-0-	15.3	.075
871105-2	253	16.8	138	-0-	16.4	.065
871105-3	240	19.0	---	-0-	---	---
871105-4	252	20.0	143	-0-	16.7	.066
871105-5	260	23.0	127	10	13.9	.054
871105-6	259	19.3	146	-0-	15.0	.058
871105-7	196	17.2	166	-0-	16.7	.085
			PHASE III			
880204-1	204	18.8	156	-0-	16.3	.080

*Samples with moisture content greater than 19% required drying before further processing.

Most samples were extruded at rates in the range of 200-240 kg/hr and moisture contents in the range of 13-20%. Extrusion discharge temperatures ranged from 138-166°C. The extruder was configured with a 0.375" (9.5 mm) single round die for all of the tests. Some steam was injected directly into the barrel; however, the quantity could only be estimated due to the lack of steam measuring equipment. The steam was injected at a point three-fourths of the way along the barrel length from the feed port. Electrical power draw by the extruder was measured with a BLH Model 12000 torque meter. Specific mechanical energy was calculated by dividing input power by extruded product rate.

In a commercial operation, samples extruded at moistures >19% would require both drying and cooling before grinding. Lower moisture samples would only require cooling before grinding.

C. Analysis

1. Compositional Analysis:

All values of protein, fat, fiber and Kcal were calculated using handbook values. Specific values for frequently used materials are listed in Table III. Values for other materials used as ingredients were obtained from handbooks.

TABLE III: Proximate Analysis for Extruded Instant-Nasha Ingredients

	Decorticated Sorghum	NFDM Regular	Shelled Raw Peanuts
Kcal/100 g	369	362	568
Protein, %	10.0	36.2	26.3
Fat, %	2.6	0.8	48.4
Fiber, %	1.5	0.0	1.9
Reference:	(6)	(7)	(7)

2. pH Procedure:

Ground samples of product were combined with 25°C water to achieve a mixture having 15% solids. Under constant stirring, the pH of the mixture was determined. Equipment used included either a Corning Model 7 pH meter for the laboratory tests reported in Table VII (page 23) or an Orion Research Model 701 digital pH meter for the pH versus lactic acid content tests. It should be noted that pH readings were made using ground extruded product except where noted.

3. Chemical Score:

Chemical scores were calculated for the various blends considered using the FAO reference for older infants and young children. Specifically, these values were:

TABLE IV: Amino Acid Pattern for Preschoolers 2 to 5 Years Old (5)

Amino Acid	Grams Amino Acid Per 100 Grams Protein
Histidine	1.9
Isoleucine	2.8
Leucine	6.6
Lysine	5.8
Methionine + Cystine	2.5
Phenylalanine + Tyrosine	6.3
Threonine	3.4
Tryptophan	1.1
Valine	3.5

Amino acid contents for various Nasha ingredients used in the chemical score calculations were:

TABLE V: Amino Acid Content (Grams AA/100 Grams Protein of Nasha Ingredients

Amino Acid	Decorticated Sorghum	NFDM Regular	Peanuts All Types, Raw
Lysine	1.9	7.9	3.6
Meth + Cyst	2.6	3.4	2.5
Threonine	3.1	4.5	3.4
Tryptophan	0.9	1.4	1.0
Reference:	(8)	(9)	(10)

The protein digestibilities used in the calculations were:

TABLE VI: Protein Digestibilities.
NFDM 95%; Peanuts 95% Ref. source: 5
Sorghum, decorticated and extruded 81% Ref. source: 11

4. Viscosity

Viscosity measurements were made using a Brookfield viscometer configured with a #3 spindle at 50 rpm. Each extruded product was reconstituted at the 15% solids level and compared with Instant-Nasha samples at the same level of solids. The Instant-Nasha was prepared according to Monawar and Badi (1) but did not contain NFDM.

5. Incorporation Tests

Incorporation tests were run to determine the ease and behavior of the extruded flour when mixed with water. The evaluation was done on a subjective level. Evaluations were made by Dr. Monawar and Dr. L. Fapojuwo during Phase I but, neither were available for Phase II evaluations which limits the comparability of these subjective measurements. Each evaluation was done on a scale of 1-10 as indicated below.

a. Effort - The ease with which the flour went into solution. An evaluation of 10 would indicate that a blender is required and 0 would require a minimum amount of stirring.

b. Lumpiness - The degree of lumpy appearance and texture of the rehydrated product. An evaluation of 10 would be similar to cottage cheese in a liquid solution and 0 would be completely smooth and free from lumps.

c. Thickness - The degree of thickness or viscosity of the mixture which does not settle. An evaluation of 10 would be similar to a thick cream and 0 would be watery.

d. Settling - The amount of flour that settled out following incorporation and after one minute settling time. A score of 10 would be similar to placing sand in water while 0 would represent no visible settled material.

V. RESULTS

The results of various extrusion tests are shown in Table VII.

TABLE VII: Results of Quality Tests on Samples

Ext. Sample#	Formulation and Added Ingredients	pH	Fat(c)	Protein(c)	Incorporation(a) Effort	Lumpiness	Thickness	Settling	Viscosity(b)
					PHASE I				
	Instant Nasha	4.4	(3.4)	(13.3)	0	0	5-6	0	340
871028-1	Decorticated Sorghum (130°C)	6.5	1.2	10.0	2	2	5-6	0	0
871028-6	Sorghum Plus Lactic Acid (172°C)	4.5	1.2	10.0	0	1	5	1	0
871028-3	Sorghum Plus Malted Barley (162°C)	6.2	1.3	10.3	0	3	4	0	0
871028-5	Sorghum plus Ferment. Sorghum	5.3	1.2	10.0	0	0	4	0	6
--------	60% #871028-6 30% NFDM, 10% Oil	5.8	10.9	16.9	0	2	3-4	0	0
					PHASE II				
871105-1	Decorticated Sorghum (132°C)	6.5	9.2	9.2	2-3	8-9	5-6	4-5	0
871105-2	Decorticated Sorghum (138°C)	6.8	9.2	9.2	2	4-5	4-5	6-7	0
871105-3	Decorticated Sorghum (High Moist.)	6.4	9.2	9.2	1-2	5-6	5-6	2-3	1
871105-4	Decort. Sorghum Oil, Ferm. Sorg. (143°C)	6.8	7.2	9.4	1	2-3	8	2-3	14
871105-5	# 871105-4 plus steam addition (127°C)	6.1	7.2	9.4	2	2	7-8	2	22
871105-6	Decort. Sorghum plus peanut (146°C)	7.0	9.4	12.8	0-1	2	2-3	4-5	3
871105-7	Decort. Sorghum plus peanut (166°C)	7.0	9.4	12.8	2	7	5-6	5-6	5
					PHASE III				
880204-1	67% D. Sorghum 15% Peanut, 15% NFDM, 2.5% V&M, 0.5% Lactic Acid (156°C)	6.9	8.2 (10.2)	16.1 (16.8)	2	5-6	3-4	1-2	420

a) Tests made using 15% solids solution
b) Brookfield Viscometer, Spindle #3 at 50 rpm, cps
c) Calculated values based on USDA Handbook #8
Note: Number in ( ) represent analytical values

The sorghum formulations processed on the Anderson extruder were fully cooked and free of any raw grain flavor. These products, when incorporated in water, formed a thick gruel with varying degrees of lumping. All the samples showed Brookfield viscosities considerably below those of drum dried Instant-Nasha even though their character and consistency were visually similar as determined by Laila Monawar. This discrepancy was probably due to the large flake-like particles suspended in the Instant-Nasha preparation. It is difficult to estimate slurry viscosities accurately with a Brookfield type viscometer and point to the use of a ring type or Bostwick consistometer as a potentially better quality control standard. The thickness of all samples was judged to be very similar to the Instant-Nasha by Dr. Monawar.

The highest Brookfield viscosities were achieved with extruded samples which consisted of 25% of fermented sorghum mixed with 75% milled sorghum. Higher levels of fermented sorghum were not feasible because the moisture of the blend exceeded practical limits (>30%) for the extrusion operation and would have required extensive drying following extrusion to bring the product to moisture levels for safe storage.

The Phase I samples were exploratory and produced products of marginal acceptability as an Instant-Nasha. The judgement on acceptability was based on the performance of the product when incorporated in water and its organoleptic qualities. The desire to produce a product which had an acidic flavor was not met and appeared difficult to achieve using fermented sorghum. The fermented sorghum contained 50% moisture and, when combined

with dry sorghum, resulted in a mixture having 25% moisture content which reduced the capability of the extruder to cook the product. The addition of 25% fermented sorghum (50% moisture) before extrusion extruded satisfactorily but gave very little of the flavor and acidic characteristic which is typical of Instant-Nasha.

Extruded samples in Phase I were mixed with 10% oil and 30% instant NFDM so their protein and fat content would more nearly meet Codex guidelines. They remained powder-like after the addition of the oil and milk powder, but had increased lumpiness when reconstituted with water. One of these samples is listed in Table VII.

Phase II focused on samples which had oil or peanuts added before extrusion so that an addition of NFDM would make a mixture meeting Codex guidelines. Few problems were experienced when extruding the mixtures tested. The addition of oil or peanuts to the formulation at the levels tested made extrusion at drier moisture contents possible. The presence of oil in the raw ingredients resulted in a denser extrudate (less expanded) than occurred with similar mixtures without oil. The density difference was not significant enough to merit further study; however, it might be possible to expand the ingredients containing oil if a smaller die were used to achieve higher extrudate temperatures.

Table VII also summarizes the results of tests used to characterize these products. Attention was given to the physical behavior of the products as related to ease of incorporation into water and viscosity. In

general, little effort was required to mix the extruded samples with water. Lumping of the flour in water occurred with those samples extruded at lower moistures. Conversely, lumping was less of a problem for the samples extruded at higher moistures. The use of hot water to reconstitute the product reduced the lumping problem and made incorporation, in general, easier.

Samples Nos. 871105-4 and -5 extruded at higher moistures produced a product with higher Brookfield viscosities but only slight increases in thickness as perceived visibly. Settling of some extruded samples was noted after a period of time; however, Dr. Monawar did not feel the degree of settling to be a critical factor in acceptability.

To duplicate the flavor of Instant-Nasha, flavor adjuncts consisting of short-chain fatty acids were added into the dry ground extruded samples. It was found that some degree of flavor similarity to the fermented traditional Nasha could be achieved using this method. The flavors resulting from the addition, however, were not sufficiently representative of traditional Nasha to warrant additional investigation. The addition of dry lactic acid at 0.5% to the extruded base without milk or minerals was found to give the product an acidic flavor. The acidic flavor was found desirable, but lactic acid alone did not give the total array of flavor notes found in traditional Nasha. When 10% NFDM was incorporated in the product and 0.5% lactic acid was added, the pH of the result was only slightly acidic, but the addition rounded out the flavor profile of the product.

Extruded samples made with sorghum and whole peanuts added at 17.4% appeared very promising, since they were judged by Dr. Monawar to have flavor and incorporation characteristics acceptable to the Sudanese people even though they were not acidic like Instant-Nasha. The extruded samples incorporated easily into water and were similar to the viscosity of the Instant-Nasha. The sorghum/peanut combinations were formulated to achieve a fat level of approximately 10% in the extruded portion of the blend. In developing the final formulation, milk powder will be required to improve protein quality and quantity.

Following Dr. Monawar's departure, the extruded sorghum and whole peanut formulations to which NFDM are added were reexamined to assure they met the Codex Alimentarius guidelines for supplementary foods. USDA and Colorado State University collaborated on calculations of protein nutritional quality of various blends for older infants and young children. The reference protein for 2 to 5 year olds as reported by FAO/WHO (5) was used as the standard. Ther specific amino acid standard, the protein and amino acid contents and digestibility of ingredients used in these calculations are given in Tables IV, V and VI in the analysis section. A summary of these calculations on protein quality is given in Table VIII along with data on 100% sorghum for reference.

TABLE VIII: Nutritional Value of Various Mixes of NFDM and Co-Extruded Shelled Peanuts and Decorticated Sorghum (5)

Percent Formulation		Percent Protein Content	Limiting Amino Acid & AA Score	Protein Content Required to Meet Codex Guidelines	Percent Protein Digesti-bility	Protein Content Required to Meet Codex Guidelines & Digestibility Limitation
NFDM	10					
Peanut	20	15.48	Lysine 62.2	19.29	88.95	21.64
Sorghum	67					
Other	3					
NFDM	5					
Peanut	17	13.90	Lysine 55.9	21.47	87.33	24.58
Sorghum	75					
Other	3					
NFDM	20					
Oil	10	13.94	Lysine 86.6	13.86	88.27	15.70
Sorghum	67					
Other	3					
NFDM	15					
Peanut	15	16.0	Lysine 75.0	16.00	89.14	17.95
Sorghum	67					
Other	3					
Sorghum	100	10.0	Lysine 32.8	36.59	81.00	45.17

A blend of 15% NFDM, 15% shelled peanuts, 67% decorticated sorghum and 3% other (lactic acid, vitamins and minerals) has a protein content of 16% and an amino acid score of 75 with lysine limiting. The Codex guidelines require 16% protein when the amino acid score is 75, so the blend just meets Codex guidelines. The guidelines do not take protein digestibility into consideration. The calculated digestibility of the blend is 89% and, if considered, would require the protein content of the blend to be 18% in

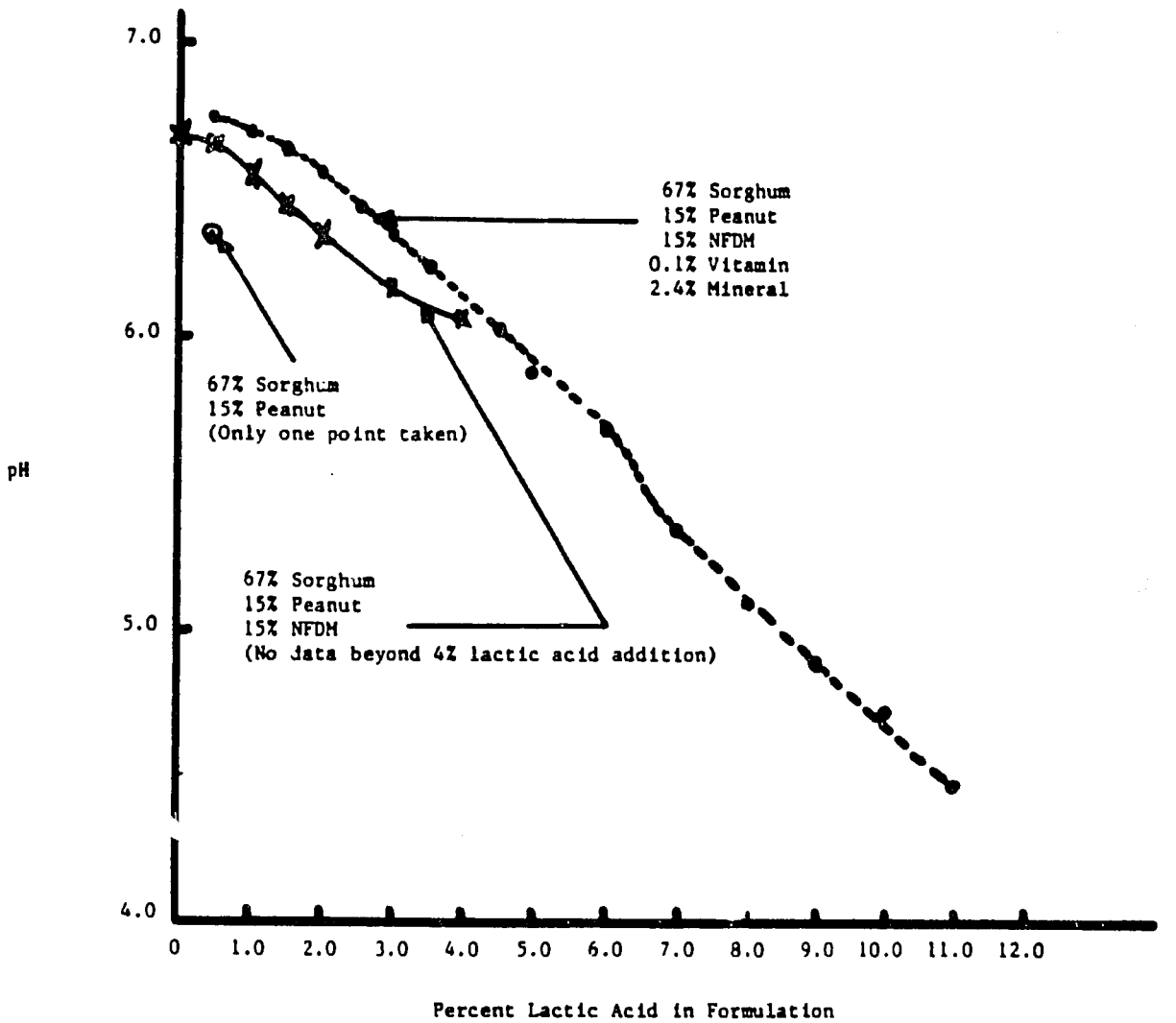
order to satisfy the guidelines. Other essential amino acid scores were calculated and found to exceed FAO/WHO guidelines; the major focus of the formulations was, therefore, based on improvement of the limiting amino acid lysine.

In Phase III, a mixture of 82% sorghum and 18% peanuts was extruded at 156°C discharge temperature. A test product was produced according to the conditions and to the specifications shown in Table II. The product incorporates easily in warm water but forms some lumps which float to the surface of the mixture. A smoother mixture results when the food is mixed in room temperature water and allowed to sit for 5 minutes. A 15% solids gruel is thinner than Instant-Nasha, probably due to the solubility of the NFDM in the mixture at a temperature of 40°C.

The addition of 0.5% dry lactic acid in the formulation gave only a slight acidic note in the reconstituted product. The results of further study on the relationship of pH to dry lactic acid addition are shown in Figure 2. These data show that both the milk and tricalcium phosphate in the mineral mix are effective buffers, making it necessary to add large quantities of dry lactic acid to bring the pH to the 5.0-5.5 range where a distinctly sour but not sharp taste results. These levels of dry lactic acid are deemed impractical and therefore acid at only the 0.5% level was added to the test product giving a pH of 6.7 and rounding out the flavor profile of the product. The Instant-Nasha, which contained 20% WDM, had a pH of 4.4 (Table VII). Apparently, the acid produced by the fermentation step was sufficiently concentrated during drying to give the low pH value

in the product despite the buffering capacity of the added NFDM.

FIGURE 2: Relationship of pH to Dry Lactic Acid Addition



If the acidic flavor is required in the product for acceptability, the proposed formulation will have to be altered. A combination of calcium acid phosphate and calcium carbonate replacing the calcium triphosphate in the mineral mix may have a slight beneficial effect. But, the removal of tricalcium phosphate from the formula may have a detrimental effect on resistance of the sample to insect larvae and this will have to be determined. Using a mineral acid like phosphoric instead of dry lactic acid would reduce the amount of total acid addition to achieve the desired pH. This type of addition is untested and would require handling and incorporation of a potentially hazardous material which, if done improperly, could cause corrosion damage to the blending equipment.

The formulations using >18% peanuts created problems with milling of raw ingredients. The high oil content for the raw blends (approximately 9-10% for a mixture having 18% peanuts) resulted in a material that was somewhat sticky and caused blinding problems in the screens of the Fitzmill. Frequent cleaning of the screen in the Fitzmill was necessary to maintain an acceptable throughput. Cleaning was required after approximately 50 kg of product was milled, at a milling rate of approximately 200 kg/hr. Grinding of the extruded blends presented no problems.

It is essential to have a particle size no greater than that described for raw materials earlier in the report. There is some evidence that a finer grind would permit a higher quality product based on earlier tests with no oil present. It will be necessary to examine in more detail

solutions to milling of the raw materials if and when a decision is made to design and install a plant. One solution might be considering turbo or pin mills, each being more expensive than hammer mills.

Table IX compares the composition of the extruded Nasha to Codex guidelines. Generally, the sample met or exceeded the guidelines. Based on analysis, the fat content of the mixture actually exceeded the standard of 10% although the fat content of the product calculated from handbook compositional data was approximately 1% low in fat. Using the standard USDA Title II vitamin mix resulted in a product which exceeded all vitamin levels in the Codex guideline except for Vitamin D, riboflavin and B_6. The mineral fortified product exceeded all guidelines for Ca, P and Fe, but contained about one-half the I_2 recommended. Surprisingly, the Codex guidelines do not give a recommendation for Zn. Its inclusion should be considered in the final formulation.

TABLE IX:

A. Formulation and Processing Specifications

Raw Materials:

Decorticated sorghum	82%
Raw whole peanuts	18%

Extrusion Conditions:

Moisture	16%
Temperature	156°C
Die	Single 9.5 mm round die
Steam	No steam addition

Grind:

Ground with Fitzmill through 0.050" (1.3 mm) screen

Final Product Blend:

SPB	82.0%
NFDM	15.0%
Vitamins	0.1%
Minerals	2.4%
Dry lactic acid	0.5%

TABLE IX: (continued)

B. Comparison of Extruded Nasha with Codex Guidelines

	Extruded Nasha		Codex Guidelines
Protein	16.04%[a]	16.8%[b]	16.0%
Fat	9.02%	10.2%	10.0%
Crude fiber	1.29%		5.0%
Vitamin content:			
A	497		400 μg
D	5		10 μg
E	5		5 μg
Ascorbic acid	41		20 mg
Thiamine	690		500 μg
Riboflavin	740		800 μg
Niacin	10		9 mg
B_6	550		900 μg
Folic acid	200		100 μg
B_{12}	4		2 μg
Mineral content:			
Calcium	1000		800 mg
Phosphorous	798		800 mg
Iron	19.3		10 mg
Iodine	45		70 μg
Zinc	1.4		-- mg

Protein quality . . . . . 75 (lysine limited)
Caloric density . . . . . 384 Cal/100 g
Percent of calories as protein . . 14%
Percent of calories as fat 21%
pH 6.7
Density . . . . . 0.53 g/cc (33 lb/cubic foot)

[a]Calculated.
[b]Analytical value.

VI. CONCLUSIONS

A. It is technically feasible to extrude in an Anderson 4.5" extruder a combination of decorticated sorghum (82%) and shelled raw peanuts (18%) at moistures less than 20% and discharge temperatures of approximately 156°C to make a precooked base for a supplementary food.

B. The addition of 15% NFDM and 3% other (0.5% dry lactic acid, vitamins and minerals) makes a product which incorporates into water in an acceptable manner and, at 15% solids, is somewhat thinner than Instant-Nasha. Higher extrusion temperatures and moistures improved incorporation characteristics of the finished product.

C. The supplementary food as formulated meets the Codex guidelines for supplementary foods for infants aged 2 to five years old for protein, fat and fiber.

D. The acidic and fermented flavor of Instant-Nasha was not replicated in the extrusion cooked sample. The addition of highly fermented sorghum to the extruder feed material was limited by the resulting excessive feed moistures and gave little improvement in flavor or acidity in the finished product. Further development work may produce formulations which will give the acidic flavor but replication of the fermented flavor appears unlikely.

E. The extrusion process used to produce the Sudanese samples is similar to those which have been successfully operated in other developing countries. To achieve the desired incorporation characteristics, extrusion moistures may have to exceed 20%, which would require some product drying.

F. If the product containing peanuts has unsatisfactory acceptability, an alternate product of sorghum/oil/NFDM should be evaluated.

VII. RECOMMENDATIONS

A. Acceptability tests on Test Sample Product No. 880204-1 prepared by Colorado State University need to be performed in the Sudan to provide feedback to further product development if required.

B. Sudanese decorticated sorghum and shelled peanuts need to be extruded on the Anderson extruder to establish the product characteristics of extruded supplementary foods using indigenous ingredients.

C. An evaluation needs to be performed to determine if afflatoxin-free peanuts are reliably available in the Sudan for use as an ingredient.

D. Rat feeding studies need to be performed to confirm protein quality in the test product.

E. Studies with alternate Ca sources and mineral acids need to be performed to determine the feasibility and procedures for achieving an acidic taste in the finished product.

F. The test product needs to be storage tested to determine packaging requirements and shelf life of the commercial product.

G. Zinc should be added in the final formulation requirement beyond the Codex guidelines.

H. Higher extrusion moistures need to be evaluated to optimize incorporation characteristics of the product.

VIII. REFERENCES

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