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SPECIAL REPORT

EVALUATION OF LOW-COST EXTRUSION COOKERS FOR USE IN LDC'S

Departments of Agricultural and Chemical Engineering
and Food Science and Nutrition
Colorado State University
Fort Collins, Colorado 80523

May 1980

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SPECIAL REPORT

Effect of Extrusion on Calorie Density of Cereal and Cereal/Legume Blends

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May, 1980

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SPECIAL REPORT

Effect of Extrusion on Calorie Density of Cereal and Cereal/Legume Blends

INTRODUCTION

Calorie deficits have been identified in several evaluation studies as the most significant factor in causing protein-calorie malnutrition in developing countries. The effectiveness of a food supplement in overcoming calorie deficits, and deficiencies in other nutrients is partially a function of how much can be eaten in a given meal. Although a number of factors are involved when blended foods are used as gruels, one key variable is the calorie density of the final gruel, expressed as the number of calories per unit volume.

The calorie density of the gruel is dependent on the composition, especially the fat content of the product. Also, the viscosity of the blend would appear to be a key factor. Since gruels are consumed at a given consistency, products which result in a certain degree of thickness at a lower concentration will result in a lower calorie density in the final gruel.

The viscosity of a cereal or cereal/legume blend is primarily dependent on the degree of starch gelatinization and final degree of polymerization. A precooked cereal-type product such as ICSM contains

starch that is by specification completely gelatinized. Such a product is considered to be "instantized" and can be prepared with water or milk and eaten without additional cooking. In contrast, cereal products requiring additional cooking, such as Title II-CSM and Title II-CSB, contain only partially gelatinized starches.

Both the Brady and Insta-Pro are dry-type extruders. One of the most significant differences noted between CSB made on the Brady and a sample of Title II-CSB is that the LEC-CSB results in much higher uncooked viscosities. The importance of the viscosity in determining calorie density in a gruel, as discussed above, is not totally documented. Therefore, it was decided to further investigate the effect of the low-cost extrusion process on the viscosity of corn and corn/soy blends. Gruels were made both by the addition of warm water (uncooked procedure) and by boiling for 10 minutes (cooked procedure). Comparisons were made with CSM, ICSM and two commercial Gerber® baby cereals (instant type) using the following variables:

1) extrusion temperature,
2) extruding corn and soy together or separately,
3) preconditioning with the <u>addition</u> of 9% water,
4) addition, after extrusion, of oil,
5) addition, after extrusion, of sugar,
6) addition, after extrusion, of non-fat dry milk,
7) addition, after extrusion, of amylase.

The complete list of experimental conditions studied is given in Table 1.

Table 1. Proximate Analyses of Extrusion Samples

Sample No.	Description of Sample	Moisture %	Fat %	Fiber %	Ash %	Nitrogen %	Protein %	Carbohydrate %
2-111- 1	70/30 dc/ds[1] (raw)	10.4	9.14	1.56	2.40	2.89	18.1	58.4
2	70/30 dc/ds (raw) 2% oil	9.89	10.9	1.26	2.29	2.81	17.6	58.1
3	70/30 dc/ds (raw) 4% oil	10.0	12.7	1.38	2.28	2.76	17.3	56.3
4	70/30 dc/ds (raw) 10% sugar	9.04	8.23	1.33	2.17	2.58	16.1	63.1
7	70/30 dc (raw)/ds 143°C	8.83	9.13	1.56	2.58	2.99	18.7	59.2
8	70/30 dc 149°C/ds 143°C	5.43	7.95	1.42	2.56	3.04	19.0	63.6
9	70/30 dc 171°C/ds 143°C	4.29	7.79	1.40	2.59	3.07	19.2	64.7
10	70/30 dc 149°C (9% H_2O)/ds 143°C	6.90	7.51	1.35	2.50	3.01	18.8	63.0
11	70/30 dc/ds (149°C)	5.25	8.35	1.38	2.63	3.01	18.8	63.6
12	70/30 dc/ds (149°C) 2% oil	5.29	10.4	1.30	2.55	2.97	18.6	61.9
13	70/30 dc/ds (149°C) 4% oil	5.45	12.1	1.32	2.43	2.98	18.6	60.1
14	70/30 dc/ds (149°C) 10% sugar	4.92	7.55	1.15	2.28	2.73	17.1	66.0

Table 1. Proximate Analyses of Extrusion Samples (continued)

Sample No.	Description of Sample	Moisture %	Fat %	Fiber %	Ash %	Nitrogen %	Protein %	Carbohydrate %
2-111-17	70/30 dc/ds (171°C)	4.11	7.33	1.12	2.47	3.04	19.0	66.0
18	70/30 dc/ds (171°C) 2% oil	4.06	9.18	1.20	2.45	2.95	18.4	64.7
19	70/30 dc/ds (171°C) 4% oil	3.84	11.01	1.08	2.45	2.86	17.9	63.8
20	70/30 dc/ds (171°C) 10% sugar	3.44	6.56	1.14	2.31	2.69	16.8	69.8
21	70/30 dc/ds (149°C) 9% H_2O	7.94	6.32	1.27	2.50	3.10	19.4	63.1
24	70/30 dc/ds (171°C) 9% H_2O	7.33	5.71	1.17	2.60	3.05	19.1	64.1
25	dc (149°C)	5.99	2.87	1.18	1.41	1.55	9.69	78.9
26	dc (171°C)	4.35	2.79	0.96	1.45	1.59	9.94	80.5
27	dc (149°C) 9% H_2O	8.86	1.89	1.10	1.42	1.52	9.50	77.2
28	dc (raw)	11.58	4.87	1.15	1.52	1.48	9.25	71.6
29	Gerber® rice cereal	5.71	1.06	0.04	2.50	1.29	8.06	82.6
30	Gerber® mixed cereal	5.93	1.73	0.43	3.27	2.63	16.4	72.7

[1] dc/ds = dehulled corn/dehulled soy.

METHODS

Extrusion Procedures

Corn and soy were individually dehulled on a Sturtevant scourer-aspirator. The 70/30 blends and the corn were preblended and tempered in a Falcon Model 501 ribbon blender. The final (w/w) of water added in the blender was 9.1% instead of 10% (9.1 g water per 100 g corn or CSB). Mixing times were 30 minutes. Prior to extrusion, a minimum of three hours tempering time was allowed.

The corn and raw CSB were proportioned and milled using the 1/8 inch screen in a Modern Mill Model 600. Water was metered during extrusion at the rate of 86 ml/minute for CSB and 120 ml/minute for dehulled corn except for tests with preconditioned moisture addition. Throughput conditions were as follows:

1)	70/30 low temperature, no preconditioning	6.4 kg/min
2)	70/30 high temperature, no preconditioning	5.4 kg/min
3)	100% corn, high temperature, no preconditioning	5.0 kg/min
4)	100% corn, low temperature, no preconditioning	6.6 kg/min
5)	100% corn, preconditioned 149°C	6.0 kg/min
6)	70/30, preconditioned, 149°C	5.6 kg/min
7)	100% soy, 143°C, no preconditioning	6.6 kg/min

Sample Preparation

The extruded samples were allowed to cool for 1 to 2 hours and were stored uncovered for 16 hours at room temperature until grinding. After grinding each sample was stored in a black plastic bag at room temperature.

All samples were first ground on the Fitz Mill through a 0.127 cm screen, and then through a 0.0686 cm screen. Extruded soy was ground in the Sturtevant pin mill (one pass). Raw soy was ground on the Fitz Mill with a 0.0838 cm screen (one pass). Raw corn was ground two times on the Fitz Mill, first using a 0.127 cm screen and then a 0.0686 cm screen. The samples of Gerber® cereals were ground on a laboratory cyclone mill using a 100 mesh screen. Proximate analysis and particle size were determined on all samples and the results are listed in Tables 1 and 2, respectively.

The final mixing and preparation of CSB samples to be used in the calorie density experiment was done in a Hobart mixer. Oil, sugar and non-fat dry milk (NFDM) were added as a percentage of the final weight (i.e., 2% oil, 98% product, etc.). The finished samples were then packed in plastic bags and stored at 4°C.

Viscosity Measurements

Bostwick values, cooked and uncooked, were determined for all samples in the calorie density study using the standard Title II procedures. Note: the higher the Bostwick values, the lower the viscosity. The Title II standards for CSB, CSM, and ICSM are given in Table 3 for comparison.

Viscosity studies using the Brookfield viscometer provided a means for determining the calorie density of the gruels as prepared in two ways: 1) an "instant" procedure similar to that used to prepare gruels in the Thriposha program in Sri Lanka, and 2) a cooking procedure where the gruels were boiled for 10 minutes.

Table 2. Particle Size Distribution of Samples[1]

Sample No.	Description of Sample	% Retained					
		#20	#40	#60	#80	#100	In pan
2-111- 1	70/30 dc/ds[2] (raw)	3.79	84.0	10.5	0.7	0.3	0.70
2	70/30 dc/ds (raw) 2% oil	32.2	65.4	2.5	--	--	--
3	70/30 dc/ds (raw) 4% oil	46.6	51.0	2.3	--	--	--
4	70/30 dc/ds (raw) 10% sugar	0.6	43.1	43.1	7.89	0.9	4.43
7	70/30 dc (raw)/ds 143°C	35.6	63.5	0.9	--	--	--
8	70/30 dc 149°C/ds 143°C	70.9	28.6	0.3	0.1	--	--
9	70/30 dc 171°C/ds 143°C	76.0	23.7	0.4	--	--	--
10	70/30 dc 149°C (9% H_2O)/ds 143°C	21.4	68.7	8.5	1.0	0.5	--
11	70/30 dc/ds (149°C)	53.0	46.0	1.0	--	--	--
12	70/30 dc/ds (149°C) 2% oil	56.0	43.0	1.0	--	--	--
13	70/30 dc/ds (149°C) 4% oil	42.2	55.2	2.5	--	--	--
14	70/30 dc/ds (149°C) 10% sugar	58.5	40.5	1.0	--	--	--

Table 2. Particle Size Distribution of Samples[1] (continued)

Sample No.	Description of Sample	% Retained					
		#20	#40	#60	#80	#100	In pan
2-111-17	70/30 dc/ds (171°C)	49.1	43.3	7.1	0.2	0.2	--
18	70/30 dc/ds (171°C) 2% oil	96.2	3.8	--	--	--	--
19	70/30 dc/ds (171°C) 4% oil	95.5	4.0	0.5	--	--	--
20	70/30 dc/ds (171°C) 10% sugar	79.0	21.0	--	--	--	--
21	70/30 dc/ds (149°C) 9% H_2O	93.5	5.5	0.7	0.3	--	--
24	70/30 dc/ds (171°C) 9% H_2O	80.5	16.0	3.0	0.5	--	--
25	dc (149°C)	32.5	66.0	1.0	--	0.2	0.2
26	dc (171°C)	8.5	88.5	3.0	--	--	--
27	dc (149°C) 9% H_2O	9.0	75.0	16.0	--	--	--
28	dc (raw)	46.7	52.3	1.0	--	--	--
29	Gerber® rice cereal	7.5	54.7	37.1	0.5	0.2	--
30	Gerber® mixed cereal	1.8	17.4	71.7	8.2	0.2	0.7
2-73-1	Title II-CSM	67.8	30.2	2.0	--	--	--
2-73-2	Title II-ICSM	66.0	33.0	0.7	0.3	--	--

[1]Samples shaken 25 minutes on a Tyler Sieve Shaker with the sieve rotated 90° during shaking.

[2]dc/ds = dehulled corn/dehulled soy.

Table 3. Bostwick Viscosity Values[1]

Sample No.	Description of Sample	Uncooked	Cooked
2-111- 1	70/30 dc/ds[2] (raw)	>24	8.6
2	70/30 dc/ds (raw) 2% oil	>24	11.3
3	70/30 dc/ds (raw) 4% oil	>24	11.4
4	70/30 dc/ds (raw) 10% sugar	>24	11.6
7	70/30 dc (raw)/ds 143°C	>24	8.0
8	70/30 dc (149°C)/ds 143°C	4.2	>24
9	70/30 dc (171°C)/ds 143°C	2.8	>24
10	70/30 dc (149°C) 9% H_2O/ds 143°C	2.9	>24
11	70/30 dc/ds (149°C)	8.3	20.5
12	70/30 dc/ds (149°C) 2% oil	9.0	22.6
13	70/30 dc/ds (149°C) 4% oil	9.8	23.5
14	70/30 dc/ds (149°C) 10% sugar	9.9	>24
17	70/30 dc/ds (171°C)	4.3	>24
18	70/30 dc/ds (171°C) 2% oil	5.6	>24
19	70/30 dc/ds (171°C) 4% oil	4.8	>24
20	70/30 dc/ds (171°C) 10% sugar	5.6	>24
21	70/30 dc/ds (149°C) 9% H_2O	2.5	>24
24	70/30 dc/ds (171°C) 9% H_2O	4.9	>24

Table 3. Bostwick Viscosity Values[1] (continued)

Sample No.	Description of Sample	Uncooked	Cooked
2-111-25	dc (149°C)	1.0	19.6
26	dc (171°C)	< 0.1	>24
27	dc (149°C) 9% H_2O	< 0.1	>24
28	dc (raw)	>24	2.5
29	Gerber® rice cereal	< 0.1	20.0
30	Gerber® mixed cereal	< 0.1	19.8
2-73-1	Title II-CSM	23.5	16.3
2-73-2	Title II-ICSM	10.2	15.2

[1]Title II Standards

	Uncooked (37 g + 100 m H_2O)		Cooked (23 g + 177 m H_2O)	
	Minimum	Maximum	Minimum	Maximum
CSB	--	20	9	21
CSM	--	20	10	22
ICSM	9	--	--	--

[2]Dehulled corn/dehulled soy.

"Instant" Procedure for Making Gruels. Samples were weighed and stirred into 100 ml of 70°C water. The lumps were mashed as well as possible, and the measurement for viscosity made at 45-50°C after a final stirring of the sample. Standard Brookfield conditions were 50 rpm with a #5 spindle, in a 150 ml beaker. Viscosity vs. concentration curves were plotted for all gruels.

Cooking Procedure for Making Gruels. Cold water was added to make a smooth paste followed by the addition of boiled water. The gruel was brought to a boil and boiled for 10 minutes followed by cooling to 50°C. Viscosity was measured at 45-50°C after replacement of the water lost in boiling and a final stirring of the sample. Viscosity was determined as described above and viscosity vs. concentration curves were plotted.

The uncooked viscosity was also measured for sample 2-111-11 after mixing it with Enzeco Fungal Amylase (K4814) from the Enzyme Development Corporation and Rhozyme H39 (a bacterial diastase) from Rohm and Haas. The fungal amylase was added to the sample at a 0.025% level and the bacterial diastase was added at a 0.010% level. Each was mixed with the sample for 30 minutes, and then the standard procedure for both preparations and measurement was followed.

The value of viscosity for a standard sample of Gerber® baby cereal prepared for a 6 month old baby was 1,600 cps using #5 spindle at 50 rpm and 45-50°C. The plots of viscosity (cps) vs. concentration (g cereal per 100 g mixture) were used to establish the concentration for CSB samples with a viscosity of 1,600 cps. This concentration was then used to calculate the calorie density using proximate analysis and density data previously determined. Four to six concentrations were plotted for each sample to establish the viscosity-concentration relationships.

(The calorie densities of the gruels per 100 g and per 100 ml gruel were calculated using composition factors of 4 kcal/g carbohydrate and for protein and 9 kcal/g for fat (shown in Table 4).

RESULTS

Bostwick Viscosity

Bostwick values for all samples are listed in Table 3. "Uncooked" values will be discussed first. Raw samples contained ungelatinized starch and were extremely thin (> 24). Gerber® precooked cereals were completely gelatinized and produced very thick gruels (< 0.1). The difference between CSM and ICSM was apparent with CSM being quite thin (23.5) and ICSM moderately thick (10.2).

In general, the LEC-extruded products gave low Bostwick values. LEC-CSB with the corn and soy extruded together at 149°C gave a Bostwick value of 8.3, similar to ICSM. Raising the extrusion temperature to 171°C and preconditioning with 9% water lowered the Bostwick values to 4.3 and 2.5, respectively. Extruding the cereal separately also resulted in extremely thick gruels with Bostwick values near zero. Addition of oil or sugar had little effect on viscosity.

The "cooked" viscosity values are also given in Table 3. The raw samples and commercial CSM gave Bostwick values in the range of 9 to 16. In contrast, the LEC-extruded products gave Bostwick readings of 20 or greater with many off scale (> 24). The cooked Gerber® cereals and ICSM performed differently with "cooked" Bostwick values in the range of 15 to 20.

Table 4. Calorie Densities of Gruels

Sample Description	Fat kcal/ 100 g	Protein kcal/ 100 g	Carbohydrates kcal/ 100 g	Total kcal per 1 g	"Instant" Procedure		Cooking Procedures	
					Calorie Density kcal 100 g gruel	Calorie Density kcal/100 ml gruel	Calorie Density kcal/100 g gruel	Calorie Density kcal/100 ml gruel
70/30 dc/ds (raw)	83.3	72.4	234	3.89	138.5	153.7	40.8	43.3
70/30 dc/ds (raw) 2% soy oil	98.1	70.4	232	4.01	152.4	169.2	45.7	47.1
70/30 dc/ds (raw) 4% soy oil	114.1	69.2	225	4.09	155.4	174.9	51.9	54.5
70/30 dc/ds (raw) 10% sugar	74.1	64.4	252	3.91	148.6	164.9	54.7	58.0
70/30 dc (raw)/ds (143°C)	82.2	74.8	237	3.94	98.5	106.4	36.6	37.7
70/30 dc (149°C)/ds (143°C)	71.6	76.0	254	4.02	76.4	82.5	68.7	72.1
70/30 dc (171°C)/ds (143°C)	70.1	76.8	259	4.06	81.2	86.1	77.5	80.6
70/30 dc (149°C) 9% H_2O/ds (143°C)	67.6	75.2	254	3.97	67.5	70.9	74.6	78.3
70/30 dc/ds (149°C)	75.2	75.2	254	4.04	76.8	84.4	61.4	64.5
70/30 dc/ds (149°C) 2% soy oil	93.6	74.4	248	4.16	72.0	83.7	71.6	75.9
70/30 dc/ds (149°C) 4% soy oil	108.9	74.4	240	4.23	80.4	84.4	71.9	76.2
70/30 dc/ds (149°C) 10% sugar	68.0	68.4	264	4.00	82.0	86.1	68.8	72.9
70/30 dc/ds (171°C)	66.0	76.0	264	4.06	73.1	76.0	72.3	75.2
70/30 dc/ds (171°C) 2% soy oil	82.6	73.6	259	4.15	87.2	91.6	73.0	76.7
70/30 dc/ds (171°C) 4% soy oil	99.1	71.6	255	4.26	80.9	84.9	77.5	82.2
70/30 dc/ds (171°C) 10% sugar	59.0	67.2	279	4.06	79.2	82.9	82.4	87.3
70/30 dc/ds (149°C) 9% H_2O	56.9	77.6	252	3.87	69.7	73.9	72.4	76.0
70/30 dc/ds (171°C) 9% H_2O	51.4	76.4	256	3.84	71.2	75.5	73.7	77.4
70/30 dc/ds (149°C) 15% NFDM	63.0	80.8	246	3.90	88.1	91.6	73.5	77.9
70/30 dc/ds (171°C) 15% NFDM	55.4	76.8	257	3.89	81.3	84.6	80.8	84.8
dc (149°C)	25.8	38.8	316	3.81	59.8	62.2	57.2	60.6
dc (171°C)	25.1	39.8	322	3.67	60.0	61.2	60.0	63.0
dc (149°C) 9% H_2O	17.0	38.0	309	3.64	51.0	53.0	61.9	65.6
dc (raw)	43.8	37.0	286	3.67	135.8	149.4	29.7	30.3
Gerber® rice cereal	9.54	32.2	330	3.72	46.9	52.6	62.5	66.3
Gerber® mixed cereal	15.6	65.6	291	3.72	55.8	62.5	55.8	59.1
Title II-CSM				3.80	115.9	121.6	54.0	56.1
Title II-ICSM				3.80	76.0	84.1	49.0	51.0
(0.025% K4814) dc/ds (149°C)[1]	75.2	75.2	254	4.04	109.0	115.5	66.3	69.6
(0.010% H 39) dc/ds (149°C)[2]	75.2	75.2	254	4.04	113.0	123.6	76.2	80.1

[1] ENZECO® fungal amylase obtained from Enzyme Development Corporation, 2 Penn Plaza, New York, New York 10001.

[2] Rhozyme H-39 obtained from Rohm-Haas Company, Independence Mall West, Philadelphia, Pennsylvania 19105.

Brookfield Viscosity

"Instant" Gruel Procedure Results. The calorie densities of the Gerber® cereals were 50 to 60 kcal/100 ml gruels. The calorie density of ICSM was 84 kcal/100 ml. The calorie densities of the extruded LEC-CSB's ranged from 71 to 92 kcal/100 ml. The calorie density of the raw corn and corn/soy mixture were much higher (106 to 174 kcal/100 ml), but would not be considered acceptable because of the raw flavors.

Increased extrusion temperatures resulted in slightly lowered calorie density concentrations. Adding sugar, as expected, increased calorie density from 84 to 86 kcal/100 ml for the 149°C sample and from 76 to 83 kcal/100 ml for the 171°C sample. Addition of 2% oil increased calorie density when compared to the material without oil. Addition of 4% oil resulted in a lower calorie density than the 2% oil sample although it was still slightly higher than the product without added oil. This reduction was due to the lower concentration of the gruel needed to achieve the desired consistency; however, the net effect was small.

The use of amylases to partially hydrolyze the starch was the most effective way to increase calorie density of the final blend. Addition of 0.010% amylase H 39 increased the calorie density of LEC-CSB extruded at 149°C from 84 to 124 kcal/100 ml. Addition of 15% NFDM to LEC-CSB extruded at 149°C increased calorie density from 84 to 92 kcal/100 ml. For LEC-CSB extruded at 171°C, NFDM increased calorie density from 76 to 84 kcal/100 ml.

To further compare the viscosity properties of LEC-CSB with commercial CSM and ICSM, the viscosity was measured at two concentrations as a function of shear rate for LEC-CSB extruded at 149°C and 171°C, CSM and

ICSM. The results are shown in Table 5. These results confirm that LEC-CSB is much more like ICSM than CSM (based on viscosity results). The results also reveal that the viscosities of the CSB samples extruded on the Brady were more sensitive to shear rate used for the viscosity measurement than was ICSM.

A comparison was made between LEC-CSB samples, CSM, ICSM and the Gerber® cereals using the effect of cooking time on viscosity. The results are summarized in Table 6.

The raw samples of LEC-CSB respond rapidly when cooked in water. Viscosities measured increased from essentially 0 to 30,000 cps in 15 minutes cooking. After two minutes of cooking, viscosities for the raw samples were higher than any of the other extruded samples except for measurements made on ICSM which had been cooked for 2 to 15 minutes. The extruded samples and the Gerber® cereals exhibited viscosity characteristics much less responsive to cooking time than the raw samples or ICSM.

Cooked Gruel Procedure Results. The calorie densities of cooked gruels are also listed in Table 4. Raw corn soy blend resulted in a calorie density of 43 kcal/100 ml. Extrusion at 149 and 171°C increased the calorie densities to 64 and 75 kcal/100 ml respectively. These values are both greater than the calorie densities of 56 and 51 kcal/100 ml observed for Title II-CSM and ICSM respectively. The beneficial effect of extrusion in increasing calorie density was even more striking when corn was extruded alone. Extrusion of corn at 149° and 171°C resulted in calorie densities of 61 and 63 kcal/100 ml respectively compared to a value of 30 kcal/100 ml for raw corn. Again the extruded corn samples

Table 5. Effect of Shear Rate on Viscosity at Two Concentrations

Sample	RPM	Viscosity (cps)
	20% Concentration Spindle #4	
2-111-11	10	1,807
70/30 dc/ds	20	1,300
149°C	50	861
	100	691
2-111-17	10	2,607
70/30 dc/ds	20	1,767
171°C	50	1,107
	100	1,022
2-73-1	10	0
Title II-CSM	20	27
	50	32
	100	40
2-73-2	10	627
Title II-ICSM	20	467
	50	368
	100	265
	30% Concentration Spindle #7	
2-111-11	10	22,000
70/30 dc/ds	20	14,000
149°C	50	9,120
	100	6,320
2-111-17	10	53,600
70/30 dc/ds	20	33,333
171°C	50	20,133
	100	15,147
2-73-1	10	0
Title II-CSM	20	0
	50	0
	100	200
2-73-2	10	11.733
Title II-ICSM	20	10,000
	50	7,520
	100	5,786

Table 6. Cooking Time--Viscosity Curves 19% Gruels (w/w).

Sample #	Description of Sample	Viscosity in cps[1] 0 time	1/2 minute	1 minute	2 minutes	3 minutes	5 minutes	8 minutes	10 minutes	15 minutes
2-111- 1	70/30 dc/ds (raw)	< 0	4,880	6,213	19,253	--	20,453	--	27,520	30,347
2	70/30 dc/ds (raw) 2% oil	< 0	6,347	17,733	13,360	11,387	36,800	--	24,773	22,960
3	70/30 dc/ds (raw) 4% oil	< 0	--	5,920	9,520	10,880	15,840	--	21,600	17,280
4	70/30 dc/ds (raw) 10% sugar	< 0	3,813	7,200	7,867	14,373	8,160	--	16,747	12,533
11	70/30 dc/ds (149°C)	720	--	--	11,547	--	10,880	12,613	--	13,467
12	70/30 dc/ds (149°C) 2% oil	560	--	--	7,947	--	16,053	10,853	--	13,360
13	70/30 dc/ds (149°C) 4% oil	347	--	--	--	8,107	10,027	14,267	--	14,267
14	70/30 dc/ds (149°C) 10% sugar	187	--	--	--	--	8,960	11,413	--	14,053
17	70/30 dc/ds (171°C)	747	--	--	6,587	--	7,493	7,067	--	10,400
18	70/30 dc/ds (171°C) 2% oil	800	--	--	5,493	--	6,347	6,667	--	8,107
19	70/30 dc/ds (171°C) 4% oil	667	--	--	7,707	--	8,000	7,653	--	6,533
20	70/30 dc/ds (171°C) 10% sugar	720	--	--	3,627	--	4,133	4,427	--	4,080
21	70/30 dc/ds (149°C) 10% H_2O	773	--	--	2,640	--	5,227	5,707	--	5,547
24	70/30 dc/ds (171°C) 10% H_2O	800	--	--	2,853	--	2,613	1,573	--	3,333
29	Gerber® rice cereal	800	--	--	4,293	--	3,547	1,227	--	2,453
30	Gerber® mixed cereal	2,587	--	--	4,933	--	7,147	6,400	--	5,973
2-73-1	Title II-CSM	< 0	--	--	4,347	--	5,893	8,427	--	5,813
2-73-2	Title II-ICSM	1,093	--	11,627	18,960	--	21,147	13,493	--	--

[1] Viscosity measured with a Brookfield viscometer using a #7 spindle at 50 rpm.

were similar in calorie densities to the commercial "instant" baby cereals. The addition of soybean oil, sugar, or NFDM increased calorie densities of LEC CSB, especially at the lower extrusion temperature of 149°C. Preconditioning with water prior to extrusion increased calorie density from 65 to 76 kcal/100 ml at the lower extrusion temperature but had no appreciable effect at the higher temperature.

Gruels prepared in this study were made from ingredients ground as finely as possible in the Fitz Mill. Some of the particle size differences shown in Table 2 are related to oil content which made sieving difficult. Other particle size differences were related to the extrusion conditions which affected the grinding efficiency. Particle size differences are known to influence viscosity. To minimize the particle size-viscosity relationship, the same particle size for all samples should be used. Future studies will be concerned with maintaining uniformity of size from sample to sample.

CONCLUSIONS

The low-cost extrusion process should be considered advantageous for making blended foods that will be used as gruels in supplemental feeding programs. LEC-CSB as manufactured in this study can be considered a precooked or "instant" cereal product that can be made into a gruel by mixing with previously boiled warm water. This has an indirect advantage of saving home fuel. If in a particular application it is traditional to cook the gruel for up to 10 minutes, the LEC process increases the calorie density of the final gruel substantially. For LEC-CSB or LEC-CSM fortified with vitamins and minerals, extrusion not only increases the calorie density of the gruel but also nutrient levels in general.

Extruding at a higher temperature of 171°C appeared advantageous for cooked gruels and extrusion at 143°C was advantageous for uncooked gruels. To the extent possible, addition of sugar and NFDM appear to be desirable additives to LEC-CSB essentially converting this product into LEC-ICSM. Both sugar and NFDM increased the calorie densities of the gruels, and experience suggests that both are helpful in increasing the acceptability of the gruels. The addition of a small amount of an amylase to the dry blend would appear to be of substantial advantage as far as calorie density is concerned if such an enzyme additive is allowable under the food laws in the country of application. Preconditioning of the raw ingredients with 9% water does not appear to have much effect on calorie density.

Results reported by Drs. Graham and McLean (in which nitrogen absorption and nitrogen retention in infants fed LEC-CSB were as high as previously observed in infants fed ICSM) are consistent with the viscosity finding presented above.