Production and Nutritional Value of Weaning Foods from Mixtures of Pearl Millet and Cowpeas[1]

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ABSTRACT

Weaning foods were produced by mixing decorticated and press-dried pearl millet (70%) and cowpea (30%) with and without sorghum malt. Decorticated millet and cowpea flours were cooked into a slurry and press-dried to produce flakes. The heat applied during cooking of the slurry and press-drying was designed to develop proper paste properties for the preparation of porridgelike weaning foods. Sorghum malt hydrolyzed the starch and produced a beverage that contained 17% protein with 90% of the essential amino acids required for infants less than one year old.

Cereal Chem. 70(1):14–18

Cereals and legumes, individually or as composites, are the main source of nutrients for weaning children in developing countries (Aguilera and Lusas 1981, King et al 1985, Morales et al 1988, Malleshi et al 1989). Among cereals, pearl millet (*Pennisetum glaucum*, syn. *P. americanum, P. typhoideum*) is considered to have one of the best protein quality or amino acid scores. The nutritional value of pearl millet is greatly enhanced when mixed with legumes because the latter complement its profile of essential amino acids (Serna-Saldivar et al 1991). Due to their availability and popularity, cowpeas (*Vigna unguiculata*) are an option for use in weaning foods in Africa and India (Guiro et al 1987, Boeh-Ocansey 1989).

Most weaning food technologies, e.g., drum drying and extrusion cooking, are either too complicated or too expensive for low-income families in developing countries. Thus, practical, low-technology processes for production of weaning foods with adequate paste viscosity and nutrient density are needed. Malting, dry roasting, popping, steaming, boiling, and flaking are simple processes proposed for weaning food production (Malleshi and Desikachar 1982, Sefa-Dedeh 1984, King et al 1985, Morales et al 1988, Malleshi et al 1989).

The objectives of this work were: 1) to develop a practical process to produce dehydrated, precooked millet and cowpea flours and 2) to prepare and evaluate the properties and nutritional value of weaning foods from composites of precooked millet and cowpea with and without sorghum malt.

MATERIALS AND METHODS

Raw Materials

Grains used included: pearl millet (grain moisture = 11.3%, density = 1.49 g/cm^3, and test weight = 78.8 kg/hl), grown in Kansas in 1988; commercial cowpea, also called blackeyed peas (moisture = 9.9%, density = 1.46 g/cm^3, and test weight = 71.6 kg/hl), grown in California in 1989; and Dorado sorghum (*Sorghum bicolor*, moisture = 11.6%, density = 1.36 g/cm^3, and test weight = 78.7 kg/hl), grown at Halfway, Texas in 1988. Commercial high-protein (soy-wheat-oat blend) dry baby food (Gerber Products Co., Fremont, MN) was used for comparison.

Decortication Process

Pearl millet (in 5-kg batches) was decorticated for 4.2 min to remove 25% of its weight (75% yield) with an IDRC abrasive mill (International Development Research Centre, Ottawa, Canada) equipped with eight disks 24 cm in diameter. Decorticated kernels were cleaned with a Clipper seed cleaner (Seedburo, model 400-1, Chicago, IL) equipped with round-holed screens, numbers 1/15 (2 mm) and 6 (3 mm). Top and medium fractions were collected and hammer milled (Fitzpatrick hammer mill, model D. Fitzpatrick Co., Chicago, IL) to pass through an 0.8-mm screen. The resulting flours were bagged and stored in a freezer (−10°C). Likewise, cowpeas (5 kg) were decorticated for 1.5 min (75% yield) with an IDRC mill and sieved and aspirated to remove hulls with a Clipper seed cleaner equipped with a number 8 (3.05 mm) round-holed screen.

Press-Drying Process

Millet flour (500 g) was mixed with tap water (1,500 ml, 26°C) and heated for 9 min on a hot plate (325°C surface temperature) with continuous stirring (Fig. 1). The slurry temperature increased linearly (slope = 5.5 C/min) up to 75°C after 9 min of heating. Portions (80 g) of the cooked slurry were spread and pressed with a spatula on a gas-fired griddle (80 × 45 cm) set at a surface temperature of 110°C to produce dry flakes. Hand pressure was applied with a spatula during spreading of the slurry to produce a thin (about 1 mm thick) flake that dried within 15–30 sec.

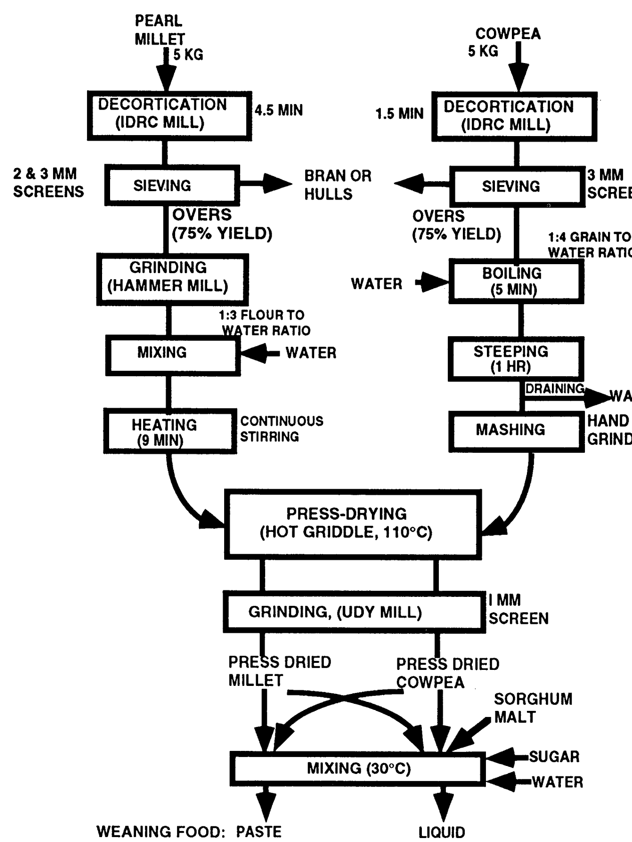

Fig. 1. Experimental procedures for press-drying pearl millet and cowpeas and for preparing weaing foods.

[1]Contribution TA 30057 from the Texas Agricultural Experiment Station.
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Flakes were scraped from the griddle, cooled to room temperature, and stored in a freezer.

Decorticated cowpea (500 g) was boiled (98°C) in 2 L of water for 5 min on a hot plate (325°C surface temperature) and steeped in the same water for 1 hr. The steep water temperature decreased linearly (slope = 0.82°C/min). Steeped cowpeas were washed twice with tap water (26°C) to remove remaining hulls and "black eyes" and then mashed with a hand-operated disk grinder (San Bar, S.A., Mexico). Mashed cowpea was press-dried into thin flakes as previously described for millet.

Sorghum Malt Preparation

Dorado sorghum was steeped for 20 hr, germinated for four days at 28°C, and oven dried at 50°C for two days. Roots and shoots were removed by hand rubbing, and the malted grain was ground in a Udy cyclone mill (Udy Co., Fort Collins, CO), equipped with a 1-mm hole screen.

Weaning Food Formulation

Press-dried millet and cowpea flakes, along with the ground sorghum malt were ground through the Udy cyclone mill to produce two formulations: 1) a paste of press-dried millet (66.5% dry basis), cowpea (28.5%), and sugar (5%); 2) a liquid of press-dried millet (63%), cowpea (27%), sorghum malt (5%), and sugar (5%).

Viscosity

Viscosity at 35°C of raw and press-dried millet flour was measured with a Rapid Visco Analyzer 3C (RVA) (Newport Scientific Pty. Ltd., Sydney, Australia), using slurries with 15% solids. RVA units (stirring numbers) were converted to centipoise, where one stirring number = 10 cP. The viscosity of weaning food composites (based on 20% solids) was determined with the RVA.

To evaluate the effect of grinding method, press-dried millet and cowpea flakes (100 g) were ground with either a Udy mill, a volcanic stone mortar and pestle with a surface area of 1,200 cm^2, or by pounding with a typical African wooden mortar and pestle (30 cm interior diameter and 20 cm deep). The viscosity of the products was then measured using the RVA.

Chemical and Physicochemical Properties

Moisture, ash, and fat of raw and processed grains were determined following standard AACC (1976) procedures. Crude protein (N × 6.25%) was determined using Kjeldahl digestion (AACC 1983) and a Technicon automated nitrogen assay (Technicon 1976). Total and enzyme-susceptible starches were determined after digestion with glucoamylase (Diazyme L-200, Miles Laboratories, Inc., Elkhart, IN) at 60°C (Khan et al 1980) and glucose determination (Technicon 1978). Water absorption index (grams of gel per gram of dry matter) and water solubility index (grams of solubles per 100 g of dry matter) were determined by shaking 1 g of flour in 15 ml of distilled water at room temperature for 30 min (Anderson et al 1969).

Protein Quality

Amino acid composition was determined after acid (Spackman et al 1958) or alkaline (LaRue 1985) hydrolysis. Hydrolysates were analyzed via ion exchange chromatography in a Beckman 121M amino acid analyzer. In vitro protein digestibility and protein efficiency ratio calculated on the basis of both essential amino acid composition and enzymatic digestibility of sample protein (C-PER) were determined according to standard AOAC (1984) procedures.

Sensory Evaluation

A group of 13 African mothers from several countries (Uganda, Mali, Kenya, Burkina Faso, Mozambique, Nigeria, and Guinea) tested the weaning foods using a nine-point hedonic scale (1 = dislike extremely and 9 = like extremely). The weaning food pastes (containing no sorghum malt) and liquefied blends (with malt added) were mixed with tap water (26°C) to 20% solids concentration and offered to the panelists.

Statistical Analysis

A one-way analysis of variance with a completely randomized design was used to evaluate treatment effects. A 2 × 2 × 2 factorial in a completely randomized design with three replications was used to evaluate the effect of ingredients on weaning food viscosity.

RESULTS AND DISCUSSION

Press-Drying: Physical and Chemical Properties

Cooking and press-drying significantly increased the susceptibility of millet starch to glucoamylase hydrolysis (Fig. 2, ESS). Water absorption index and water solubility index also increased (Fig. 2), indicating that starch was gelatinized during processing. Starch granules completely lost birefringence, and the press-dried flours were well suspended in cold water. The physicochemical properties of the press-dried flour were quite similar to the reported properties of flours produced by drum drying of various cereals (Chandrasekhara and Ramanatham, 1983). This method of cooking and drying flours could be very practical in countries where villages have acute needs and do not have access to more developed equipment; wood-fired griddles could most likely be used to prepare the products instead of electric griddles.

Weaning Food Preparation

Use of malted sorghum. Press-dried millet-cowpea blend flours produced high-viscosity pastes when mixed with cold water (Fig. 2, top portion). The addition of 5% sorghum malt reduced the viscosity of the pastes (Fig. 3). Malt (5%) reduced the viscosity of experimental and commercial weaning food pastes (20% solids) by more than 90% after 5 min of stirring at 30°C (Table I). Increased nutrient density can be obtained without increasing the product viscosity by using liquefying malt on a cereal paste of high solids concentration (Malleshi and Desikachar 1982, Malleshi et al 1989; A. N'Doye, *personal communication*, 1989). As a result, children may consume more nutrients per serving. The process of malting sorghum for beer production or other applications is well known in most villages, even in Muslim areas. Therefore, it is practical to include it as a village method for weaning food preparation.

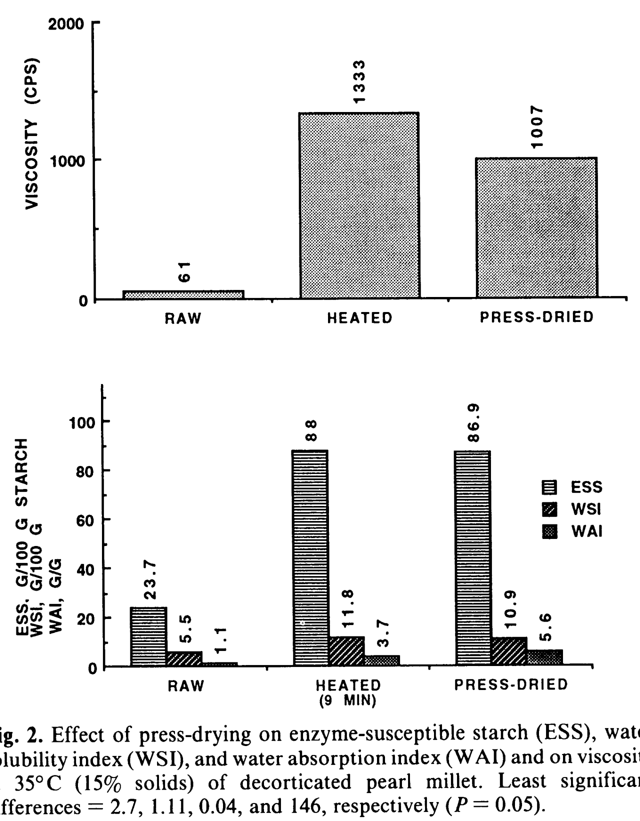

Fig. 2. Effect of press-drying on enzyme-susceptible starch (ESS), water solubility index (WSI), and water absorption index (WAI) and on viscosity at 35°C (15% solids) of decorticated pearl millet. Least significant differences = 2.7, 1.11, 0.04, and 146, respectively ($P = 0.05$).

Effect of grinding method. The viscosity (30° C) of weaning food pastes and liquefied foods was not affected by the method used to grind millet or cowpea flakes (Fig. 4). Hence, either pounding with a wooden mortar and pestle or stone grinding, both commonly used at the village level, would be adequate for use in food preparation.

Sensory Properties

The smooth, viscous textures of press-dried and commercial weaning foods were equally liked ($P < 0.05$) by the African panelists (Table I). Panelists commented that the experimental and commercial weaning foods containing sorghum malt could be easily fed using a bottle, if that was desirable. The color of the experimental weaning food was also well accepted; the white and yellow color was highly desirable for baby foods.

The production rate of press-dried millet flakes was 820 g/hr per person. The cooked slurry became excessively sticky and difficult to spread on the griddle when heated longer than 9 min. Decreasing the solids concentration caused undesirable, violent water evaporation during spreading of the cooked slurry. The production rate of cowpea flakes was 900 g/hr with a yield of about 80% (dry basis) from the raw dehulled cowpea. The 20% loss was due to milling and to solubles lost during cooking, steeping, and washing. Important press-drying parameters such as boiling time and griddle temperature may have to be optimized for particular situations.

Chemical Composition and Nutritional Properties

Decortication of pearl millet caused losses in percent of protein, fat, ash, lysine, and tryptophan (Tables II and III) due to loss of pericarp and germ tissues (Eggum et al 1983; S. O. Serna-Saldivar, C. Clegg, and L. W. Rooney, *unpublished data*). Cowpeas contained almost twice as much protein, ash, and lysine as pearl millet and sorghum. The essential amino acid (EAA) composition of cowpeas was similar to that reported by Mosse and Pernollet (1983). Malting of sorghum did not affect the amount of total organic nitrogen (protein) but increased the amount of the limiting amino acid lysine and the soluble protein significantly (Tables II and III). This has been documented previously (Wang and Fields 1978, Wu and Wall 1981, Bhise et al 1988).

The press-dried millet and malted sorghum protein provided about 55% of the lysine requirement for infants. Consequently, these cereals had low C-PER's (Table III). The limiting amino acids for press-dried cowpeas were methionine and cystine.

The combination of 70% press-dried millet and 30% press-dried cowpeas improved the C-PER due to the upgraded EAA composition. The press-dried blend supplied about 79% of the lysine and >100% of all other EAAs. The millet-cowpea press-dried blend had slightly lower protein digestibility but a similar C-PER compared to commercial baby food (Table III). The C-PER of the press-dried blend was equivalent to that of casein (C-PER = 2.5). The experimental press-dried blend had higher contents of valine, leucine, and isoleucine and slightly lower lysine and threonine than values reported for a millet-milk weaning food produced in Senegal (A. N'Doye, *personal communication*, 1989). The levels of all EAAs were similar to those in several milk-based infant formulas, except that lysine was slightly lower (Sarwar et al 1985).

Press-Drying Applications at the Village Level

These millet-cowpea formulations, with or without sorghum malt, do not have the optimum nutritional value that is most desirable for a weaning food. However, it must be understood that in many areas of the world trace minerals, vitamins, and

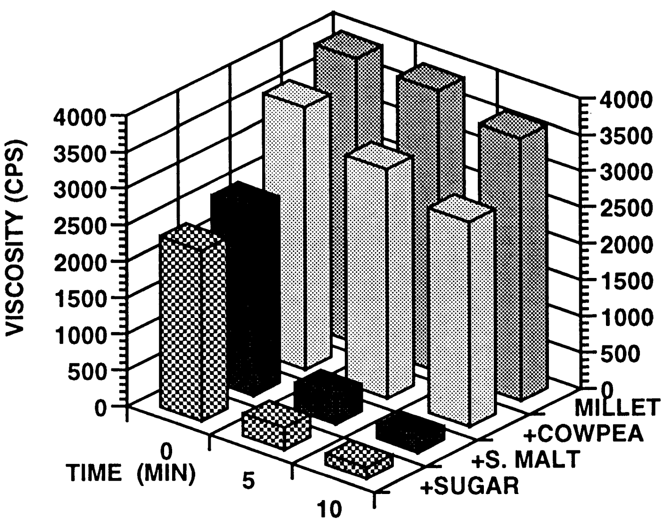

Fig. 3. Viscosity of slurries (20% solids) of press-dried pearl millet and cowpea blends, sorghum malt, and sugar, added sequentially and stirred for 10 min at 30°C. Least significant differences = 550 cP for 0 min, 431 cP for 5 min, and 309 cP for 10 min ($P = 0.05$).

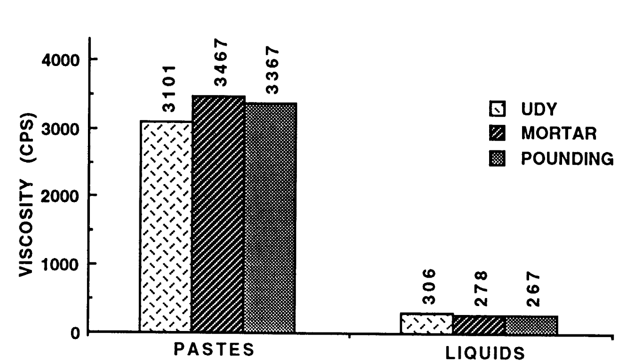

Fig. 4. Effect of grinding method and sorghum malt addition on viscosity of weaning foods after 5 min of stirring at 30°C. Liquid and paste foods were treated with and without sorghum malt, respectively. Least significant differences for liquids = 87 and for pastes = 470 ($P = 0.05$).

TABLE I
Cold Viscosity (30° C) and Organoleptic Properties of Weaning Food Slurries (20% solids)[a]

Formulation[b]	Cold Viscosity, cP			Organoleptic Property[c]		
	0 min	5 min	10 min	Texture	Color	Acceptability
Experimental samples						
Press-dried millet (66.5%), cowpea (28.5%), sugar (5%)	3,329	3,085	2,714	7.1	7.0	7.6
Press-dried millet (63%), cowpea (27%), sorghum malt (5%), sugar (5%)	2,351	306	150	8.0	7.0	7.7
Commercial samples						
Soy-wheat-oat (95%), sugar (5%)	3,195	2,693	2,251	8.0	8.3	8.4
Soy-wheat-oat (90%), sorghum malt (5%), sugar (5%)	929	208	150	8.6	8.1	8.0
LSD[d] ($P < 0.05$)	214	171	129	NS[e]	NS	NS

[a] Viscosity and organoleptic values are means of three and 13 observations, respectively.
[b] Proportion of ingredients given in parentheses are on a dry basis.
[c] Ranked on a nine-point hedonic scale, where 1 = dislike extremely and 9 = like extremely.
[d] Least significant difference.
[e] Not significantly different.

lysine are not available or cannot be purchased by those families that are most in need. These results suggest that mixing millet with cowpeas can produce a significantly improved food for young children and that the addition of malted sorghum can enhance the ease with which the children can consume the product.

The ingredients and processing techniques to produce the flour blends are currently available in villages. Existing cooking devices (flat pans or metal bowels, etc.) can be modified to produce the press-dried material for use by individual families. Sorghum malt is commonly produced in local villages throughout Africa. Thus, all the necessary inputs are available for initiation of these efforts, and in some cases, programs have already begun. For example, in Mali, porridges are made for use as weaning foods using one part cowpea and three parts millet flour. The information reported here provides a rationale for continued efforts to do what is practical, realizing that a nutritionally complete weaning food is economically impossible. The precooked flours are difficult to produce, but they certainly approach practicality, whereas the use of extruders, drum dryers, etc., is impossible in many areas.

TABLE II
Proximate Composition of Pearl Millet, Sorghum Malt, and Cowpeas[a]

Grain	Moisture (%)	Protein (N × 6.25)	Ash (%)	Starch (%)	Fat (%)
Pearl millet					
Whole	10.7	15.4	1.7	70.8	5.2
Decorticated (75% extraction)	10.1	13.9	1.2	78.7	3.9
Press-dried	1.3	14.0	1.3	76.5	3.4
Cowpeas					
Whole	9.5	23.6	3.7	58.6	1.9
Decorticated (75% extraction)	8.4	24.4	3.6	62.8	1.7
Press-dried	4.4	26.0	1.8	62.2	2.0
Sorghum					
Whole	10.6	10.5	1.6	79.1	3.4
Malted[b]	5.6	10.5	1.5	71.9	2.8
Weaning food blends					
Press-dried millet (70%), cowpeas (30%)	3.9	17.9	1.6	72.9	3.2
Commercial soy-wheat-oat[c]	5.0	37.2	8.2	41.0	6.4
LSD[d] ($P < 0.05$)	0.6	1.2	0.2	2.7	0.3

[a] Values are expressed on dry matter basis and are means of three observations.
[b] Germinated for four days and oven dried at 50°C.
[c] Sample from Gerber Products Co.
[d] Least significant difference.

CONCLUSIONS

A composite of press-dried millet flour (70%) and cowpea flour (30%) had high nutritional quality, low moisture content, and the ability to form smooth pastes upon hydration with tap water. Weaning food pastes were liquefied by treatment with sorghum malt (5%) to produce an increased solids concentration and higher nutrient density.

Press-drying is a practical technique to process millet and cowpeas into dry flakes with acceptable physicochemical, nutritional, and storage characteristics. Presumably, other cereals and grain legumes might also be press-dried. Utilization of simple utensils, such as a pot for boiling, a griddle for drying, and a spoon for spreading, makes this process suitable for low-income families living in rural areas in developing countries. However, press-drying, like many other home processes, involves tedious work that users need to learn.

Increased nutrient density and dry matter intake can be obtained by the addition of sorghum malt. Presumably, other malt sources can be used. Supplementation with lysine, vitamins, and minerals can result in a more nutritionally complete weaning food, but it is often beyond the buying capabilities of low-income families in developing countries.

ACKNOWLEDGMENTS

This research project was supported in part by grant AID/D5A/XII/6-0149 from the Agency for International Development, Washington, DC 20523. We thank Bill Stegmeier, Kansas Agricultural Experiment Station, Ft. Hays, KS, for the pearl millet.

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TABLE III
Amino Acid Composition (g/100 g of protein) and Protein Quality of Pearl Millet, Cowpeas, Sorghum Malt, and Weaning Foods[a]

	Amino Acid											
Product	Lys	Met + Cys[b]	Thr	Ile	Leu	Val	Phe + Tyr	Trp	His	Amino Acid Score[c] (%)	Protein Digestibility[d] (%)	C-PER[e]
Pearl millet												
Whole	3.2	3.8	4.4	5.3	12.9	6.8	10.2	3.9	2.6	55.1	77.2	0.73
Decorticated and press-dried (76% extraction)	2.5	3.8	4.2	5.2	12.7	6.5	9.8	1.8	2.4	43.1	81.4	0.77
Cowpeas												
Whole	7.8	2.1	4.3	5.0	8.9	5.9	10.3	1.1	3.5	84.0	76.5	1.44
Decorticated and press-dried (75% extraction)	7.9	2.1	4.3	5.3	9.4	6.2	13.5	1.1	3.7	84.0	89.6	1.72
Sorghum												
Whole	2.5	3.4	3.6	4.9	15.9	6.0	10.9	0.9	2.4	43.1	72.6	0.68
Malted	3.0	3.4	3.7	5.1	15.6	6.3	10.9	1.1	2.5	51.7	78.7	1.00
Weaning food blends												
Press-dried millet (70%), cowpeas (30%)	4.6	3.2	4.0	5.1	10.9	6.2	10.0	1.5	2.8	79.3	85.0	2.50
Commercial soy-wheat-oat	6.5	3.6	4.2	5.1	8.5	5.4	9.8	1.4	2.8	100.0	89.4	2.50

[a] Values are means of two to three observations. Amino acids are expressed on a dry matter basis.
[b] Values of Cys for millet-cowpea mixtures were calculated from the composition of raw materials obtained from FAO (1970). Values for Cys and Trp of soy-wheat-oat mixtures were obtained from the manufacturer (Gerber Co. 1990).
[c] Values are percentages of the FAO/WHO/UNU (1985) suggested pattern of amino acid requirements for two-year-old children. Lys (g/100 g of protein) = 5.8, Met+Cys = 2.5, Thr = 3.4, Ile = 2.8, Leu = 6.6, Val = 3.5, Phe+Tyr = 6.3, and Trp = 1.1.
[d] In vitro protein digestibility, determined according to AOAC (1984).
[e] Protein efficiency ratio, calculated from both essential amino acid composition and enzymatic digestibility of sample protein.

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[Received May 10, 1991. Revision received June 8, 1992. Accepted June 9, 1992.]

Sensory and Physical Properties of Cakes with Bovine Plasma Products Substituted for Egg[1]

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ABSTRACT

Cereal Chem. 70(1):18–21

The sensory and physical properties of cakes in which egg products were replaced with bovine plasma products were studied. Dried egg whites were replaced by dried plasma in high-ratio, white layer cakes at five different levels (0, 25, 50, 75, and 100%). Egg whites could be replaced by dried plasma without reducing cake volume. Cake symmetry was altered by substituting plasma for 75 or 100% of the egg. Substitution altered the colors of both crust and crumb. Cakes with plasma replacing 25% of the egg had decreased L and Θ values compared with those of the control cakes. Cakes with plasma replacing egg were softer, more moist and gummy, and slightly sweeter than the controls. A blend of hydrolyzed plasma and beef stock could replace 50% of the egg in devil's food cake without affecting symmetry or shrinkage and with only a slight decrease in volume. Consumer panels indicated that cakes made with plasma products were as well liked as the control cakes.

Low-cost egg and milk protein substitutes are desired by the baking industry because egg and milk products are relatively expensive ingredients. Egg and milk substitutes, however, must possess functional properties appropriate for the products in which they are used. Spray-dried bovine plasma has functional properties similar to those of egg whites and is believed to have the potential to replace egg whites in cakes (Brooks and Ratcliff 1959, Johnson et al 1979, Khan et al 1979). In recent years, high-quality, food-grade, spray-dried plasma protein concentrates have been produced, and they are currently marketed as food protein ingredients at a cost only about one-third that of spray-dried egg whites. A previous study (Lee et al 1991) showed that nearly equivalent cake quality was achieved by replacing 1.0 part of egg white protein with 1.1 part of plasma protein. Few significant differences in

[1]Journal paper J-14595 of the Iowa Agriculture and Home Economics Experiment Station, Ames 50011. Project 0178, supported by the Center for Crops Utilization Research, the Iowa Beef Industry Council, and the Iowa Agriculture and Home Economics Experiment Station.
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