

Variation in Corn-Soy Blends for Overseas Distribution

R. P. KONSTANCE,^{1,2} C. I. ONWULATA,¹ E. D. STRANGE,¹ D. LU,¹ M. H. TUNICK,¹
P. W. SMITH,¹ AND V. H. HOLSINGER¹

ABSTRACT

A lack of uniformity in the distribution of vitamin C and other fortificants in the Title II commodity corn-soy blend (CSB) among processors previously was found in a U.S. Agency for International Development-sponsored vitamin C pilot program. Factors influencing fortificant distribution may include stratification in cyclones if the product is moved by air, due to significant differences in particle sizes among some blend ingredients and added fortificants. Determination of variation in particle size, composition, and other properties of CSB between and among processors is essential to ensure a consistent, high-quality food product for overseas distribution. Significant ($P < 0.05$) variations in the gross composition, selected micronutrient levels, and physical properties of samples, both between lots from the same processor and among different processors, were observed. Particle size analyses indicated a bimodal distribution that probably contributes to the nonuniform distribution of micronutrients.

Title II foods are intended to be used to supplement the diets of nutritionally vulnerable populations. The U.S. Agency for International Development (USAID) and U.S. Department of Agriculture (USDA) have routinely fortified Title II foods to prevent nutritional deficiencies among P.L. 480 recipients. Title II commodities include two blended foods: corn-soy blend (CSB) and wheat-soy blend (WSB). CSB and WSB are fortified with a premix of 11 vitamins added separately from a premix of six minerals to avoid adverse chemical reactions between concentrates (1). Significant quantities of these products are designated for overseas distribution in emergency situations, such as refugee-camp food distribution. In 1996, more than 230,000 metric tons of CSB was prepared for distribution (J. Brause, personal communication).

Significant variations in the levels of micronutrients have been found in field samples analyzed by the U.S. Food and Drug Administration. The variation was attributed to 1) premixes that did not contain specified levels of nutrients; 2) nutrients

that were not properly mixed or accurately added to the blended food; and 3) settling within bags that was not compensated for at the time of sampling (1). In response to these findings, CSB was evaluated through the vitamin C and Micronutrient Assessment programs, under the sponsorship of USAID, to better determine the causes of variation. In the vitamin C pilot program study, a lack of uniformity in distribution of vitamin C and other fortificants was observed among some producers (2). The study also noted that vitamin C and iron are relatively stable in both CSB and WSB during transport, shipping, and handling, from production sites to distribution points overseas (2).

CSB is manufactured by a continuous rather than a batch process, which is used for WSB. This means that vitamin and mineral fortificants are metered continuously into the blend during production. The vitamin C study (2) results suggest fortificants are not evenly distributed in the blend and that stratification in cyclones may be due to a significant difference in particle size between some blend ingredients and added fortificants.

Our objective was to evaluate the gross composition (total protein, fat, and moisture); levels of vitamin C, niacin, iron, and zinc; physical properties (degree of gelatinization and water absorption index); and particle size distribution in CSB to determine product variability (lot-to-lot and mill-to-mill). We performed analyses to establish the basis for nonhomogeneous distribution of micronutrients as a result of a particle-size differences.

MATERIALS AND METHODS

Samples of CSB, two lots each, were received from the U.S. Farm Service Agency (FSA). Each sample represented a mix of 10–30 samples taken during a one lot production run of 8–16 hr, representing one to three rail cars. Samples were evaluated ≈30–45 days after receipt. Mills are identified as A, C, D, E, H, and J, each with lots 1 and 2. Each lot from each mill was mixed separately in a V-shaped blender for ≈45 min and immediately sampled for analysis.

Composition

Moisture content was measured by the AOAC (14.003) vacuum oven method in triplicate (3). Fat content was measured by modification of AOAC methods 14.134 and 14.019 in triplicate (3). To determine protein content, samples were sent to a commercial analytical laboratory for duplicate analysis by a modified Dumas method. Chemically available lysine was measured by adapting the dye-binding method of Hurell and co-workers (4). After reaction with propionic anhydride, samples were shaken overnight (16 hr). To determine levels of niacin, vitamin C, iron, and zinc, samples were sent to a commercial analytical laboratory for analysis. Niacin was analyzed by Procedure C, AOAC 981.16 (3), which measures total niacin; vitamin C was analyzed by a microfluorimetric method, AOAC 967.22 (3); iron and zinc was analyzed by atomic absorption after ash digestion in a muffle furnace, AOAC methods 4.8.02 and 968.08 (modified) (5).

Degree of Gelatinization

Samples were analyzed for degree of gelatinization (% gelatinization) with a differential scanning calorimeter (DSC7, Perkin-Elmer Corp., Norwalk, CT). Specimens containing 20.3–20.8% solids were obtained by mixing 2.0- to 2.5-g samples and 10.0–12.5 g of water in volatile sample pans. Samples were heated from 40 to 120°C at 10°C/min. Software supplied with the DSC7 was used to calculate the enthalpies of melting transitions. Data were reported as percentages of peaks of totally ungelatinized material (15.5 J/g), which appeared on thermograms at ≈75°C.

¹U.S. Department of Agriculture, Agricultural Research Service, Eastern Regional Research Center, 600 E. Mermaid Lane, Wyndmoor, PA 19038.

²Corresponding author. Phone 215/233-6600; Fax 215/233-6559; E-mail rkonstance@arserrc.gov.

Water Absorption Index

Water absorption index (WAI) was measured by AACC Approved Method 56-20 as modified by Jin and co-workers (6). Samples were ground and sifted through a 210- μ m sieve, 1 g \pm 0.005 g was placed in a centrifuge tube, and 10 ml of distilled water was added. After standing for 15 min (with intermittent shaking every 5 min), samples were centrifuged for 15 min at 1,000 \times g (Econospin, Sorvall Instruments, Wilmington, DE). Supernatants were decanted, and weight gains in residues were noted. WAI was calculated as:

$$\text{WAI} = (\text{wet weight after decanting}) / (\text{dry weight}) \quad (1)$$

Bostwick Consistency

Samples were reconstituted into porridge according to specifications detailed in FSA Announcement CSBB (7) for CSB. Dry CSB (37 g \pm 0.2 g) was added gradually, while stirring vigorously, to 100 ml of water heated to 25 \pm 0.2°C. The slurry was stirred gently for 3 min to smooth-out lumps. After standing for 2 min to complete hydration, the slurry was stirred gently for 15 sec and poured into the reservoir of a Bostwick Consistometer (CSC Scientific Co., Fairfax, VA). The excess was struck from the reservoir, and after resting for 30 sec, the lever was released, allowing the slurry to flow. The Bostwick reading was taken after exactly 1 min.

Particle Size

Particle size of ground products was determined first by sieving the sample with a no. 60 sieve (250 μ m). Separation was used to ensure that the particles analyzed with an AccuSizer (Model 770, Particle Sizing Systems, Santa Barbara, CA) were small enough to prevent the instrument from clogging. The weights of materials that were larger and smaller than the no. 60 screen were recorded. Samples with particles smaller than 250 μ m were fed into the AccuSizer with a vibratory feeder, and volume-weight means were recorded. Assuming constant particle density, the volume weight means were converted to weight percents. Samples with particles larger than 250 μ m were analyzed with a sieve: nos. 30, 16, and 8 (595, 1,190, and 2,380 μ m, respectively).

Table I. Comparison of Gross Composition of Composite Samples of Title II Corn-Soy Blend^a

Mill	Lot	Moisture (%)	Protein (% db)	Fat (% db)
E	1	6.17cd	16.0de	7.27bc
E	2	6.72bc	16.2c-e	7.07bc
D	1	5.50d	16.5bc-e	7.53a-c
D	2	6.13cd	17.1a-c	7.35a-c
H	1	8.11a	17.7a	7.93ab
H	2	8.65a	17.6a	7.76a-c
A	1	8.57a	17.6a	7.64a-c
A	2	7.66ab	17.0a-d	7.37a-c
J	1	5.68cd	16.0de	6.95c
J	2	6.26cd	17.9a	7.55a-c
C	1	6.15cd	17.4ab	8.24a
C	2	5.67cd	17.4ab	8.24a
Specification		10.00 (max)	16.7 (min)	6.00 (min)

^a Values within a column not followed by common letters are significantly different ($P < 0.05$).

Table II. Comparison of Micronutrient Content (mg/100 g) of Composite Samples of Title II Corn-Soy Blend^a

Mill	Lot	Iron	Niacin	Vitamin C
E	1	15.0cd	4.50de	24.5c-e
E	2	17.0a-c	5.30cd	30.5b-d
D	1	11.7cd	3.35fg	21.5de
D	2	11.4cd	1.95h	7.5fg
H	1	23.8a	6.70ab	31.5b-d
H	2	19.9ab	5.95bc	40.5ab
A	1	11.4cd	4.00ef	18.0ef
A	2	20.2ab	7.30a	42.0ab
J	1	17.2a-c	3.05f-h	9.5fg
J	2	8.1d	2.65gh	1.0g
C	1	16.5a-c	5.80bc	46.0a
C	2	16.8a-c	6.55ab	36.0a-c

^a Values within a column not followed by common letters are significantly different ($P < 0.05$). Values for zinc content were not significantly different.

Table III. Comparison of Physical Properties of Composite Samples of Title II Corn-Soy Blend^a

Mill	Lot	Degree of Gelatinization (%)	Water Absorption Index	Bostwick Consistency
E	1	68.8f	2.67b	20.1a
E	2	70.8ef	2.79b	17.2a
D	1	85.7a-d	2.84b	10.3d
D	2	80.3c-f	2.84b	16.7a-c
H	1	93.7ab	3.87a	1.9e
H	2	95.9a	3.93a	2.1e
A	1	80.8c-f	2.83b	16.8a-c
A	2	73.6d-f	2.73b	19.0a
J	1	86.2a-c	2.60b	21.3a
J	2	82.6bc-e	2.66b	12.7b-d
C	1	79.7cd-f	2.69b	11.8cd
C	2	82.4b-e	2.78b	11.3cd

^a Values within a column not followed by common letters are significantly different ($P < 0.05$).

Statistical Analysis

Statistical analysis of the full model was performed by the general linear method procedure (version 6, volume 2, SAS Institute, Cary NC). Evaluation and differentiation of means were analyzed by the Bonferroni multiple comparison method (SAS). Each analysis was done twice.

RESULTS AND DISCUSSION

Gross Composition

Moisture content varied from 5.50 to 8.65%, and fat content varied from 6.95 to 8.24% among all samples analyzed. There was no lot-to-lot variation, and all samples met specifications for moisture and fat contents (Table I). Four lots contained less than the specified 16.7% protein: mill E, lots 1 and 2; mill D, lot 1; and mill J, lot 1. Samples from mill J showed lot-to-lot variation in total protein contents. Protein contents for samples from mills H and C were significantly higher than those from mill E (Table I). The available lysine for all samples was measured, and there was no significant difference between lots or mills. The average content of available lysine was 57 mg/g of protein ($\alpha = 1.45$, coefficient of variation [CV] = 2.45%).

Micronutrients

Two mills showed lot-to-lot variation in sample iron contents: mills A and J. The average iron content across all samples was 15.7 mg/100-g sample ($\alpha = 4.47$), ranging from 8.0 to 24.0 mg/100-g sample (Table II). Values for zinc essentially were invariable, and the average zinc content for all samples was 2.55 mg/100-g sample ($\alpha = 0.33$). Mills D and A showed lot-to-lot variation in both vitamin C and niacin content. Vitamin C showed the greatest variation among analyses reported. The average vitamin C content across all samples was 25.9 mg/100-g sample ($\alpha = 14.3$; CV = 55%). Mill J samples were significantly lower in vitamin C than most samples. Niacin content also varied widely (average niacin content across samples was 4.76 mg/100-g sample; $\alpha = 1.70$; CV = 35.7%) (Table II).

Physical Properties

Degree of gelatinization (%) is an indication of the extent of additional cooking required before consumption. None of the samples were fully cooked (Table III). There was no lot-to-lot variation for different mills; however, there was differences among mills: samples from mill H exhibited a significantly higher degree of gelatinization than samples from mills A and E.

WAI is a measure of the ability of a sample to absorb water when reconstituted or subjected to high levels of humidity. WAI is an indicator of macromolecular degradation of starch with a related increase in solubility with decreasing ability to absorb water (8). The only significant difference among samples was observed for those from mill H, which had the highest WAI values. Samples from mill H also exhibited the most resistance to flow (firmest porridge) when rehydrated (Table III). The specifications for CSB require a maximum uncooked Bostwick consistency of 20, and some samples exceeded this maximum. Lot-to-lot variations were found in consistency values for mills D and J.

Particle Size

Difference in particle size were found for all samples analyzed. Table IV shows that fewer particles fell in the 150-249 μm range, suggesting particle sizes for all samples were from two different populations. There was insufficient data to declare a statistical degree of significance, but it appears that mill A samples had a greater proportion of particles larger than 595 μm than did any other mill. Although the data need to be evaluated further, the implication of a bimodal distribution of particle sizes could play a significant role in the tendency of CSB to separate during bagging at the mill or settle during storage, resulting in nonuniform distribution of added fortificants.

Table IV. Comparison of Particle Size (Weight %) of Composite Samples of Title II Corn-Soy Blend

Mill	Particle Size (μm)						
	<50	50-149	150-249	250-599	596-1,190	1,191-2,380	>2,381
E	23.4	28.0	1.00	25.1	20.3	2.16	0.040
D	21.5	33.6	1.54	15.9	16.1	11.10	0.300
H	24.2	32.7	1.09	24.2	15.6	2.27	0.010
A	22.6	16.3	0.35	18.9	31.6	10.19	0.010
J	25.4	23.4	0.61	20.8	22.8	6.75	0.250
C	28.8	28.8	0.55	27.3	13.7	3.49	0.190

CONCLUSIONS

Determination of variation, between and among processors, in particle size composition and other CSB properties is essential for ensuring consistent, high-quality food products for overseas distribution. Statistical analysis of CSB samples from six mills showed there was significant variation in all measured variables, except zinc and available lysine. Samples from mill H appeared to be the most uniform in all respects, whereas those from mill A exhibited lot-to-lot variability in many of the variables measured.

Variations in gross composition were a concern only for amount of total protein. Two mills (E and J) delivered products that were below specified protein levels. Although our study used two composite samples for back plant, lot-to-lot variation in micronutrient levels was evident in samples from mills J (iron), D (vitamin C and niacin), and A (iron, vitamin C, and niacin). We could not determine whether these differences were a result of stratification during sampling, less than adequate mixing or blending at the mill, or differences in levels of fortificants added. The implied bimodal distribution of particle sizes found for all samples may contribute to the potential for segregation of components during storage and non-uniform distribution of added fortificants. Differences in physical properties were noted between lots and among mills.

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