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# Quality of cornmeal stored long-term in a low oxygen atmosphere

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## ABSTRACT

The U.S. Department of Homeland Security recommends food be included in efforts to be prepared for natural disasters and other emergencies. Cornmeal packaged in No. 10 cans with a low oxygen atmosphere has been available in the retail market for decades, but the effect of long-term storage on quality is unknown. This study assessed the quality of cornmeal stored up to 33 years at ambient temperatures in a low oxygen atmosphere.

Sixteen samples of cornmeal packaged in No. 10 cans ranging in age from <1 to 33 years were obtained from donors. The cornmeal and products made from the cornmeal (cornbread and cornmeal hot cereal) were evaluated by a 50-member consumer panel using a 9-point hedonic scale for attributes including appearance, aroma, flavor, texture, and overall acceptability. Acceptance for everyday use and emergency situations was also determined. Additional measurements included can headspace oxygen, can seam integrity, color, and water activity.

There was no significant decrease over storage time in aroma, texture, flavor, and overall acceptability in cornmeal, cornbread or cornmeal cereal. Hedonic scores for cornmeal aroma and appearance ranged from 5.2 to 6.3 and 5.6 to 7.0, respectively. Hedonic scores for overall acceptability of cornmeal cereal and corn bread varied from 4.5 to 6.0 and 6.0 to 7.1, respectively. Acceptance of the cornmeal in a regular diet ranged from 44 to 76 % and emergency acceptance ranged from 90 to 99 %. Headspace oxygen ranged from 0.309 to 20.4%. CIE L\*a\*b\* color values ranged from 82.0-86.6, 3.2-10.1, and 26.3-50.8, respectively. Cornmeal appearance hedonic scores correlated with CIE b\* color values (r<sup>2</sup>=0.75). Water activity ranged from .28 to .58.

Cornmeal, especially as an ingredient in a recipe, is capable of retaining a high percentage of consumer acceptance over long periods of time and can be included in long-term food storage efforts.

## INTRODUCTION

The U.S. Department of Homeland Security encourages efforts to be prepared for natural disasters and other emergencies, including the storage of food (Anon. 2006a). The American Red Cross also recommends that food be stored for use in emergencies (Anon. 2006b). Cornmeal packaged in No. 10 cans with a low oxygen atmosphere has been available in the retail market for decades, but the effect of long-term storage on quality is unknown. Storage studies have monitored the quality of ground corn products for one year or less (Madaan and Gupta 1990, Andah 1976). Additional studies have evaluated sensory characteristics of various ground corn products (Cabellero and others 2003, Bangu and others 1994). However, there is a lack of information on the sensory and nutritional quality of retail-packaged cornmeal held at ambient temperatures for an extended period.

## METHODOLOGY

### Samples

Twelve samples of yellow, degermed cornmeal packaged in No. 10 cans were analyzed. Samples ranged in age from <1 to 33 years. Duplicates were obtained from the same lot of sample ages <1, 9, 30, and 33 years. Sample numbers of the same age, but different brands, were designated with the letters A and B. Control samples (<1 year of age) were obtained from a commercial vendor. All the other samples were obtained from donors, and had been stored in private residences at ambient temperatures (approximately 13-27°C).

### Headspace Oxygen, Can Seam, Water Activity and Color

Can headspace oxygen was measured using a 3500-Series Headspace Oxygen Analyzer (Illinois Instruments, Inc., Johnsburg, IL). Can seams were evaluated for thickness, body hook, cover hook, width, and overlap using Seammate System software (Onevision Corporation, Westerville, OH). An overall seam rating and a tightness percentage were determined by an experienced evaluator. Water activity was measured using the chilled mirror technique with an Aqualab CX-2 water activity meter (Decagon Devices, Inc., Pullman, WA). The color of uncooked samples was measured with a Hunterlab Colorflex Spectrophotometer (Hunter Associates Laboratory, Reston, Va., U.S.A.) using the CIE L\*, a\*, and b\* system.

### Sensory Evaluation

Three 50-member consumer taste panels were conducted on cornmeal, cornbread, and cornmeal hot cereal. Cornmeal was evaluated by placing 50 g of cornmeal into plastic cups with lids, which panelists evaluated for appearance and aroma. Cornmeal hot cereal was made by mixing 150 g cornmeal with 240 mL cold water and 5.6 g salt. The mixture was then added to 960 mL boiling water, and simmered for 40 min. Thirty-two grams of sugar were added to each batch. Cornbread samples were prepared according to the following formulation: 107 g cornmeal, 133 g flour, 16 g baking powder, 5 g salt, 240 mL milk, 1 large egg, and 26 g melted shortening. Ingredients were mixed together and baked at 218°C for 20 min. Cornbread samples were made one day before the panel and frozen overnight. Panelists evaluated the prepared cornmeal cereal and cornbread for appearance, aroma, texture, flavor, and overall acceptability using a 9-point hedonic scale. Acceptance of all three samples was determined by asking panelists if they would eat the sample as part of their regular diet and if they would eat it in an emergency situation.

### Thiamin

Thiamin was measured using slight modifications of several methods: AOAC Method 953.17, Arella and others (1996), and El-Arab and others (2004). For the oxidizing reagent, 1.0 mL of 1% (wt/vol) K<sub>2</sub>Fe(CN)<sub>6</sub> was brought to a total volume of 25 mL with 15% (wt/vol) NaOH. Fifteen mL of isobutanol was used for extraction of thiochrome. Results were adjusted to reflect a recovery rate of 68%.

### Data Analysis

Data was analyzed for significance at α=0.05 using Statistical Analysis System software (SAS Institute, Cary, NC). Analysis of variance (PROC GLM) was used to analyze color and nutrition data. Sensory data was analyzed using a mixed model repeated measures analysis of variance (PROC MIXED). Both models used the Tukey-Kramer procedure to determine significant difference among means. Regression analysis (PROC GLM) was performed to determine if sensory attributes significantly correlated with age, water activity, and headspace oxygen.

## RESULTS AND DISCUSSION

### Headspace Oxygen, Can Seams, Water Activity, and Color

Headspace oxygen exhibited extreme variation, ranging from 0.309 to 20.4% (Figure 1). Can seams varied widely in quality. Some seams may not have been sufficient to maintain a hermetic seal. Water activity ranged from 0.28 to 0.58 (Figure 2). This corresponds to a moisture content for cornmeal between 7-12% (Iglesias and Chirife 1982) and is similar to a literature value (Teoh and others 2001).

CIE L\* values ranged from 82.0 to 86.6 (Table 1). CIE a\* values ranged from 3.2 to 10.1. CIE b\* values ranged from 26.3 to 50.8. L\* values significantly increased with time. Both b\* and a\* values significantly decreased overtime, meaning the cornmeal became significantly less yellow and less red during storage.

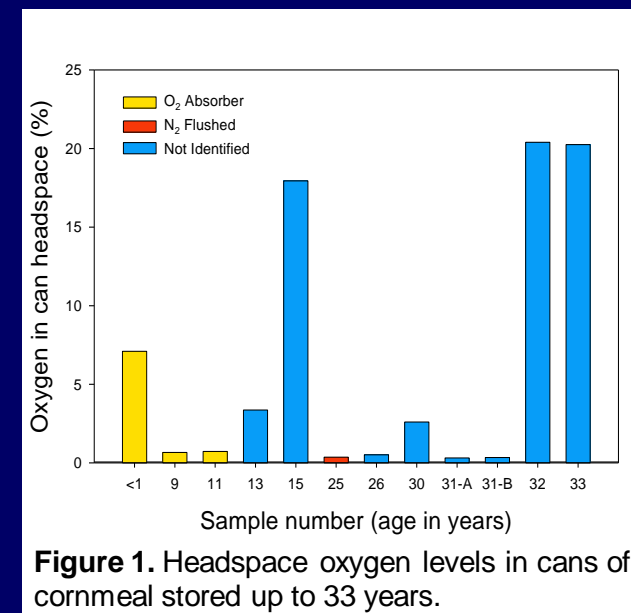


Figure 1. Headspace oxygen levels in cans of cornmeal stored up to 33 years.

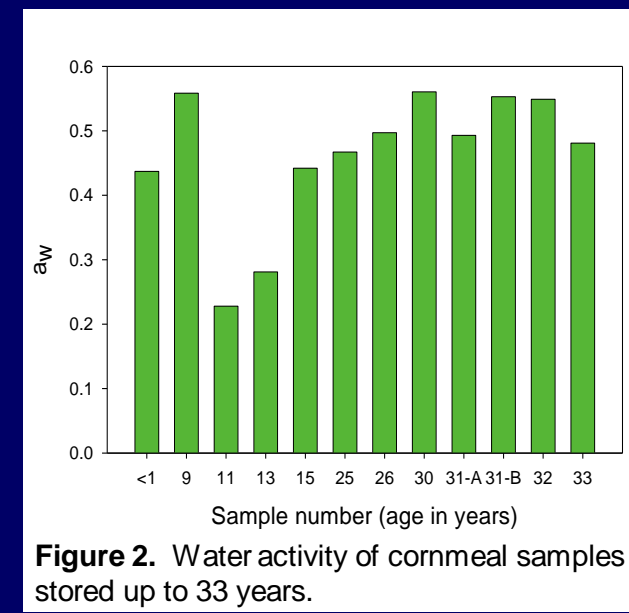


Figure 2. Water activity of cornmeal samples stored up to 33 years.

Table 1. CIE L\*a\*b\* color values for cornmeal stored up to 33 years.

Age (years)	L*	a*	b*
<1	82.45	9.68	46.02
9	83.60	8.07	41.02
11	84.66	7.83	42.08
13	82.63	10.06	50.82
15	84.01	4.19	30.78
25	81.98	9.89	47.53
26	84.51	6.33	36.37
30	83.39	9.01	43.70
31-A	85.33	5.29	32.76
31-B	83.42	6.96	38.50
32	86.56	3.18	26.25
33	85.88	3.69	29.91

Table 2. Mean hedonic scores of cornmeal, cornmeal hot cereal, and cornbread. Common superscripts in the same column indicate no significant difference. p>0.05

Sample Number (age in years)	Cornmeal		Cornmeal Hot Cereal				Cornbread					
	Aroma	Appearance	Overall Acceptability	Aroma	Flavor	Texture	Appearance	Overall Acceptability	Aroma	Flavor	Texture	Appearance
<1	5.9 <sup>abc</sup>	6.6 <sup>c</sup>	4.5 <sup>c</sup>	5.4 <sup>b</sup>	5.0 <sup>d</sup>	4.3 <sup>c</sup>	4.9 <sup>c</sup>	7.0 <sup>a</sup>	6.6 <sup>ab</sup>	6.9 <sup>a</sup>	7.2 <sup>ab</sup>	7.0 <sup>b</sup>
9	6.3 <sup>a</sup>	6.8 <sup>bc</sup>	5.8 <sup>a</sup>	5.9 <sup>a</sup>	6.0 <sup>a</sup>	6.0 <sup>ab</sup>	6.0 <sup>a</sup>	6.8 <sup>a</sup>	6.7 <sup>ab</sup>	6.7 <sup>a</sup>	7.2 <sup>ab</sup>	7.0 <sup>b</sup>
11	6.0 <sup>abc</sup>	7.0 <sup>a</sup>	4.9 <sup>c</sup>	5.7 <sup>ab</sup>	5.4 <sup>bcd</sup>	4.7 <sup>c</sup>	5.2 <sup>c</sup>	7.1 <sup>a</sup>	6.6 <sup>ab</sup>	7.0 <sup>a</sup>	7.3 <sup>a</sup>	7.4 <sup>a</sup>
13	6.0 <sup>abc</sup>	6.9 <sup>ab</sup>	5.7 <sup>a</sup>	5.5 <sup>ab</sup>	5.7 <sup>abc</sup>	6.1 <sup>ab</sup>	5.7 <sup>ab</sup>	7.1 <sup>a</sup>	6.7 <sup>ab</sup>	6.8 <sup>a</sup>	7.3 <sup>a</sup>	7.5 <sup>a</sup>
15	5.4 <sup>d</sup>	5.6 <sup>e</sup>	5.0 <sup>c</sup>	5.4 <sup>b</sup>	5.0 <sup>d</sup>	5.7 <sup>b</sup>	6.0 <sup>a</sup>	6.0 <sup>b</sup>	6.0 <sup>c</sup>	5.9 <sup>b</sup>	6.7 <sup>c</sup>	6.2 <sup>e</sup>
25	6.1 <sup>ab</sup>	6.9 <sup>ab</sup>	5.4 <sup>b</sup>	5.6 <sup>ab</sup>	5.2 <sup>cd</sup>	6.1 <sup>ab</sup>	5.6 <sup>b</sup>	7.0 <sup>a</sup>	6.7 <sup>ab</sup>	6.9 <sup>a</sup>	7.2 <sup>ab</sup>	7.5 <sup>a</sup>
26	5.9 <sup>abc</sup>	6.4 <sup>c</sup>	5.8 <sup>a</sup>	6.0 <sup>a</sup>	6.1 <sup>a</sup>	6.0 <sup>ab</sup>	5.7 <sup>ab</sup>	6.9 <sup>a</sup>	6.6 <sup>ab</sup>	6.8 <sup>a</sup>	7.0 <sup>abc</sup>	6.7 <sup>bcd</sup>
30	6.1 <sup>ab</sup>	7.0 <sup>a</sup>	5.7 <sup>a</sup>	5.3 <sup>b</sup>	5.8 <sup>ab</sup>	6.0 <sup>ab</sup>	5.4 <sup>b</sup>	7.0 <sup>a</sup>	6.7 <sup>ab</sup>	6.9 <sup>a</sup>	7.3 <sup>a</sup>	7.5 <sup>a</sup>
31-A	5.6 <sup>cd</sup>	6.2 <sup>d</sup>	6.0 <sup>a</sup>	5.7 <sup>ab</sup>	5.9 <sup>ab</sup>	6.3 <sup>a</sup>	6.2 <sup>a</sup>	7.0 <sup>a</sup>	6.8 <sup>a</sup>	6.9 <sup>a</sup>	7.1 <sup>ab</sup>	6.8 <sup>bc</sup>
31-B	5.2 <sup>d</sup>	6.8 <sup>bc</sup>	5.8 <sup>a</sup>	5.9 <sup>a</sup>	5.7 <sup>abc</sup>	6.4 <sup>a</sup>	6.3 <sup>a</sup>	6.7 <sup>a</sup>	6.6 <sup>ab</sup>	6.7 <sup>a</sup>	7.0 <sup>abc</sup>	6.7 <sup>bcd</sup>
32	5.8 <sup>bcd</sup>	5.7 <sup>e</sup>	5.1 <sup>b</sup>	5.3 <sup>b</sup>	5.0 <sup>d</sup>	6.0 <sup>ab</sup>	5.9 <sup>a</sup>	6.1 <sup>b</sup>	6.2 <sup>bc</sup>	5.9 <sup>b</sup>	6.8 <sup>bc</sup>	6.4 <sup>de</sup>
33	5.5 <sup>d</sup>	5.9 <sup>e</sup>	5.2 <sup>b</sup>	5.3 <sup>b</sup>	5.1 <sup>d</sup>	6.2 <sup>ab</sup>	6.2 <sup>a</sup>	6.2 <sup>b</sup>	6.3 <sup>bc</sup>	6.1 <sup>b</sup>	6.9 <sup>bc</sup>	6.6 <sup>cd</sup>

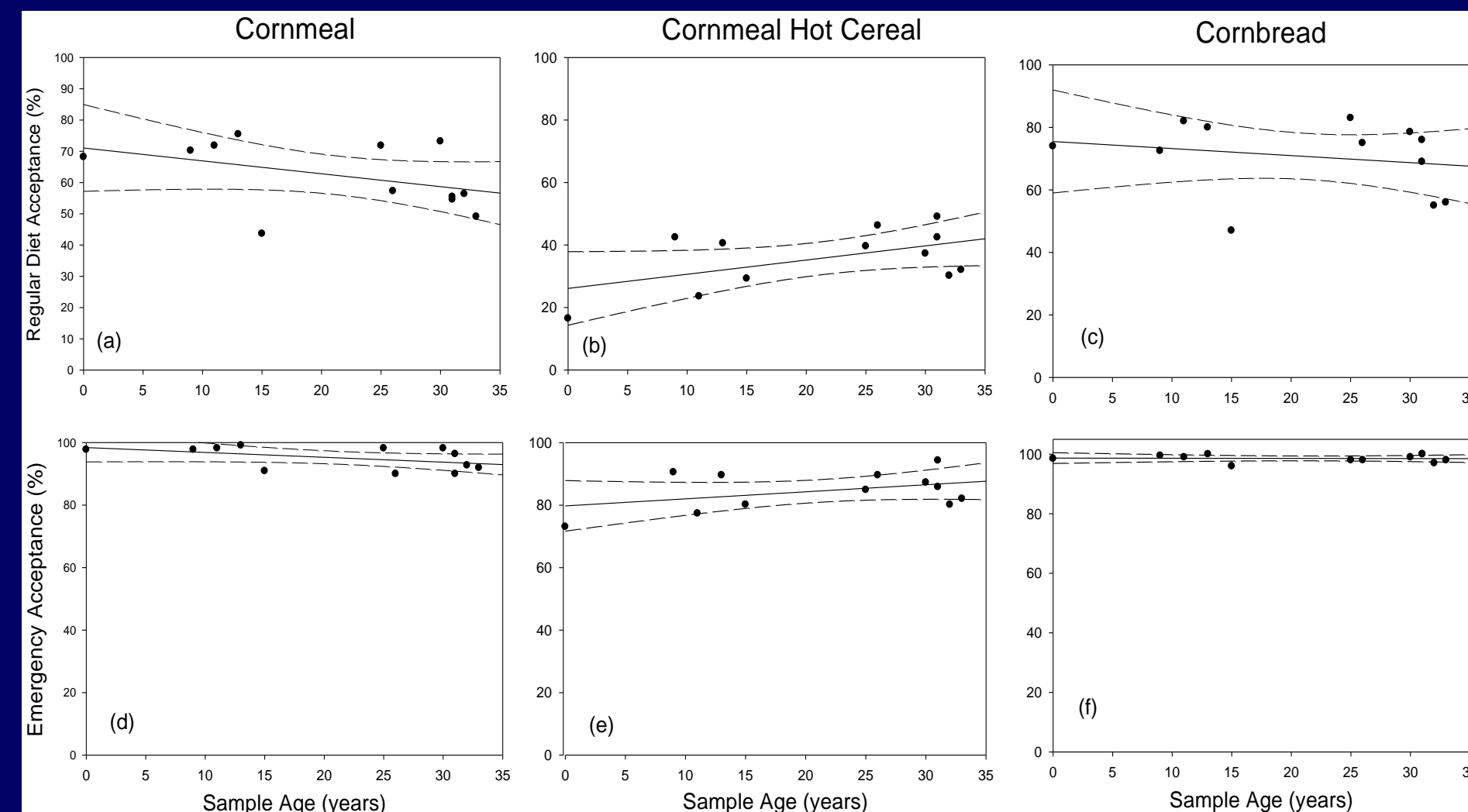


Figure 4. Percentage of panelists that would eat cornmeal as part of a regular diet (a), (b), (c) and in emergency situations (d), (e), (f) when evaluating cornmeal, cornbread, and cornmeal cereal. Dashed line represents 95% confidence interval.

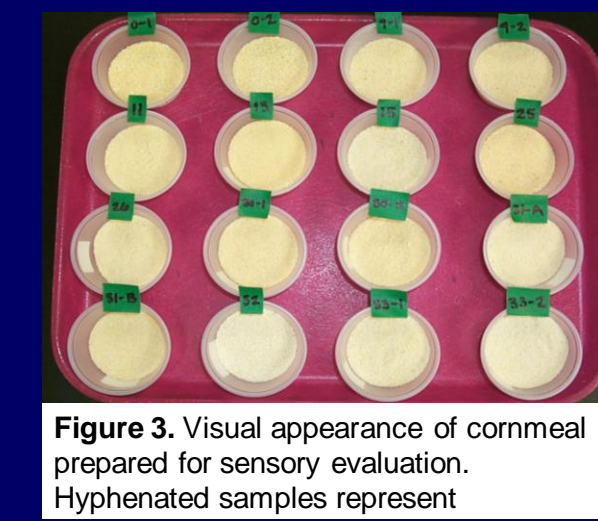


Figure 3. Visual appearance of cornmeal prepared for sensory evaluation. Hyphenated samples represent duplicates.

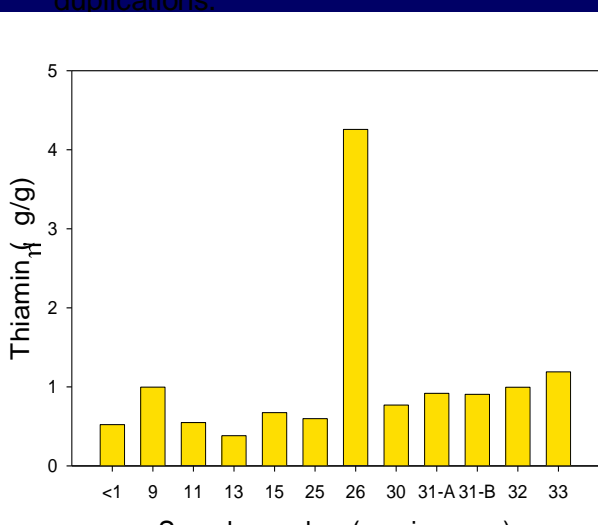


Figure 5. Thiamin in cornmeal stored up to 33 years.

### Sensory Evaluation

As shown in Table 2, ranges of hedonic score means for cornmeal were: 5.2 to 6.3 and 5.2 to 7.0 for aroma and appearance respectively. Cornmeal appearance hedonic scores correlated with CIE b\* color values (r<sup>2</sup>=0.75). Figure 3 is a photograph of the cornmeal prepared for sensory evaluation which shows the difference in color among samples. Hedonic score means for cornmeal hot cereal ranged from 4.5 to 6.0 for overall acceptability. Cornbread hedonic score mean range from 6.0 to 7.1 for overall acceptability.

There was no significant decrease over storage time in aroma, texture, flavor, and overall acceptability in cornmeal, cornbread or cornmeal cereal. Emergency acceptance of cornbread was above 95% for all samples, whereas everyday acceptance of cornbread ranged from 47 to 83%. Emergency acceptance of cornmeal hot cereal ranged from 73 to 90%, and everyday acceptance from 17 to 49% (Fig. 4).

### Thiamin

Cornmeal thiamin values ranged from .38 to 1.2 µg/g except for Sample 26 which contained 4.3 µg/g (Fig. 5). Thiamin content did not significantly decrease with increasing sample age. According to CFR 21 137.260, enriched cornmeal is required to have between 4.4 to 6.6 µg of thiamin per gram. Three sample labels declared that the cornmeal was enriched and two of the samples (<1 and 26) had actual label values; according to thiamin results, none of the samples reached the required fortification level, and only one reached the value stated on its label. Other samples did not have label values.

## CONCLUSIONS

There was a loss of color in cornmeal stored in restaurant-sized No. 10 cans, throughout the time period studied. However, even after 33 years of storage all samples were considered acceptable for use in an emergency situation by at least 92% of panelists for cornmeal, 73% of panelists for cornmeal cereal, and 96% of panelists for cornbread. Also, thiamin content was found to remain stable over time. Cornmeal can be an important part of a long-term food storage plan because of its stability when properly packaged and stored.

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