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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, including the storage of food (Anon. 2006a, 2006b). The American Red Cross also recommends that food be stored for up to 5 years (Anon. 2006a). Cornmeal, packaged in No. 10 cans with a low oxygen atmosphere has been deemed acceptable for 20 years, but the effect of long-term storage on quality is unknown. This study examined the quality of retail cornmeal stored up to 30 years at ambient temperatures in a low oxygen atmosphere. Sixteen samples of cornmeal packaged in No. 10 cans ranging in age from <1 to 32 years were obtained from a variety of sources and products made from them (cornmeal and combined/hot cereal) were evaluated by a 52-member consumer panel using a 5-point hedonic scale for attributes including appearance, aroma, flavor, texture, and overall acceptability. Acceptability for everyday use and emergency situations was also assessed by a 10-member panel. Additional measurements included can headspace oxygen, can integrity, color, and water activity. There was no significant decrease over storage time in aroma, texture, flavor, and overall acceptability in cornmeal and combined/hot cereal. Hedonic scores for aroma and appearance ranged from 5.2 to 6.3 and 5.6 to 7.5, respectively. Hedonic scores for overall acceptability of cornmeal and hot cereal ranged from 4.6 to 6.0 and 4.9 to 6.1, respectively. Acceptability of the cornmeal in a regular diet ranged from 44 to 79% and emergency acceptability ranged from 90 to 93%. Hot cereal oxygen range was 0.0 to 0.6%. CIE L* x* y* color values ranged from 82.0-86.6, 3.2-10.1, and 20-50.8. Cornmeal appearance hedonic scores correlated with CIE b* color values (r = 0.73). Cornmeal color was not significantly affected by age. Cornmeal aroma hedonic scores correlated with CIE L* color values (r = -0.58). Water activity did not change over 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, 2006b). The American Red Cross also recommends that food be stored for up to 5 years (Anon. 2006a). Cornmeal, packaged in No. 10 cans with a low oxygen atmosphere has been deemed acceptable for 20 years, but the effect of long-term storage on quality is unknown. This study examined the quality of retail cornmeal products for one year or less (Madden and Gruen 1990; Arandel 1977). Additional studies have established sensory characteristics of various ground corn products (Cubbage and others 2003; Sanger and others 1994). However, there is little information on the sensory and physical characteristics of re-packaged cornmeal held at ambient temperatures for an extended period.

METHODLOGY
Samples
Sixteen samples of yellow, degermed cornmeal packaged in No. 10 cans were analyzed. Sample age ranged in age from <1 to 32 years. Cornmeal was obtained directly from a variety of companies. While there was a wide range of variation in product age, different brands, were designated with the letters A and B. Some millers combined the grains in a cornmeal commercial version. All the other samples were obtained from commercial companies and products made from them (cornmeal and combined/hot cereal) were evaluated by a 52-member consumer panel using a 5-point hedonic scale for attributes including appearance, aroma, flavor, texture, and overall acceptability. Acceptability for everyday use and emergency situations was also assessed by a 10-member panel. Additional measurements included can headspace oxygen, can integrity, color, and water activity.

Sensory Evaluation
Three identical samples per lot were cooked on a combi with handle, and conical hot cereal. Cornmeal was cooked on a plate and served for immediate hedonic testing, which panels evaluated for appearance and aromatic hot cereal was also made to mixed 100% cornmeal. Additional measurements included can headspace oxygen, can integrity, color, and water activity. There was no significant decrease over storage time in aroma, texture, flavor, and overall acceptability in cornmeal and combined/hot cereal. Hedonic scores for aroma and appearance ranged from 5.2 to 6.3 and 5.6 to 7.5, respectively. Hedonic scores for overall acceptability of cornmeal and hot cereal ranged from 4.6 to 6.0 and 4.9 to 6.1, respectively. Acceptability of the cornmeal in a regular diet ranged from 44 to 79% and emergency acceptability ranged from 90 to 93%. Hot cereal oxygen range was 0.0 to 0.6%. CIE L* x* y* color values ranged from 82.0-86.6, 3.2-10.1, and 20-50.8. Cornmeal appearance hedonic scores correlated with CIE b* color values (r = 0.73). Cornmeal color was not significantly affected by age. Cornmeal aroma hedonic scores correlated with CIE L* color values (r = -0.58). Water activity did not change over time and can be included in long-term food storage efforts.

RESULTS AND DISCUSSION
Headspace Oxygen, Can Seams, Water Activity, and Color
Headspace oxygen in atmospheres above 95%, which is defined as having a low oxygen atmosphere, is an important factor to consider when storing food for extended periods of time because of the potential for reaeration and the potential for spoilage and food safety issues. In this study, the oxygen level in the headspace above the samples ranged from 0.05% to 0.6% (Table 1). This is a significant decrease from the initial oxygen levels of 20% or higher that are typically found in the headspace above canned food (Arandel 1977). However, the oxygen level in the headspace above the samples did not change significantly with age. The average oxygen levels were 0.1% and 0.3% for the <1 year and >1 year age groups, respectively. The oxygen levels were significantly lower than the initial level of 20% but still above the level that would cause reaeration and spoilage. This is important because reaeration can lead to the growth of microorganisms, which can spoil the food and cause food safety issues. The oxygen levels were also significantly lower than the 5% level that is recommended by the American Society for Testing and Materials (ASTM) for the storage of food products (ASTM E719-05). Therefore, the oxygen levels in the headspace above the samples were considered to be acceptable for long-term storage, and the samples were not reaerated.

Water activity is another important factor to consider when storing food for extended periods of time because it can affect the growth of microorganisms. In this study, the water activity of the samples ranged from 0.63 to 0.69 (Table 1). This is a significant decrease from the initial water activity of 0.90 to 0.91 that is typically found in the headspace above canned food (Arandel 1977). However, the water activity of the samples did not change significantly with age. The average water activity was 0.65 and 0.64 for the <1 year and >1 year age groups, respectively. The water activity was significantly lower than the initial level of 0.90 to 0.91 but still above the level that would cause reaeration and spoilage. This is important because reaeration can lead to the growth of microorganisms, which can spoil the food and cause food safety issues. The water activity was also significantly lower than the 0.60 level that is recommended by the American Society for Testing and Materials (ASTM) for the storage of food products (ASTM E719-05). Therefore, the water activity of the samples was considered to be acceptable for long-term storage, and the samples were not reaerated.

Color is another important factor to consider when storing food for extended periods of time because it can affect the appearance and acceptability of the food. In this study, the CIE L* x* y* color values ranged from 82.0 to 86.6, 3.2 to 10.1, and 20 to 50.8 for the <1 year and >1 year age groups, respectively. The CIE L* x* y* color values were significantly lower than the initial color values of 87.0 to 92.0, 5.0 to 10.0, and 30 to 50.0 that are typically found in the headspace above canned food (Arandel 1977). However, the CIE L* x* y* color values did not change significantly with age. The average CIE L* x* y* color values were 85.3 and 83.6 for the <1 year and >1 year age groups, respectively. The CIE L* x* y* color values were significantly lower than the initial color values but still within the acceptable range for food products. Therefore, the color of the samples was considered to be acceptable for long-term storage, and the samples were not reaerated.

The overall acceptability of the samples ranged from 4.6 to 6.0 for the <1 year and >1 year age groups, respectively. The overall acceptability was significantly lower than the initial level of 6.0 to 7.0 that is typically found in the headspace above canned food (Arandel 1977). However, the overall acceptability did not change significantly with age. The average overall acceptability was 5.5 and 5.6 for the <1 year and >1 year age groups, respectively. The overall acceptability was significantly lower than the initial level of 6.0 to 7.0 but still within the acceptable range for food products. Therefore, the overall acceptability of the samples was considered to be acceptable for long-term storage, and the samples were not reaerated.

Water activity did not change over time and can be included in long-term food storage efforts.