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Effects of Long-term Storage on Quality of Wheat Packaged in No. 10 Cans

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ABSTRACT

Sensory and select nutritional quality parameters of thirteen samples of hard red wheat (including 5 duplicates) were evaluated. Samples, which were obtained from donors, were packaged in hermetically sealed No. 10, ranged in age from <1 to 32 years, and were stored at ambient temperatures. Can headspace oxygen varied from atmospheric to <2%. Kernel moisture content ranged from 4.50-9.96% and CIE L* value ranged from 43.93-54.37. Protein content ranged from 13.08-16.43%. Overall acceptability hedonic scores (9-point scale, 50-member panel) ranged from 6.5-7.3. Can headspace oxygen, moisture content, protein content, and lightness/darkness were not correlated with any of the sensory parameters. Flavor and overall acceptability did show a slight decline with age. However, all wheat samples maintained >70% acceptance for use in a regular diet and >97% acceptance for use in emergency situations, with no significant decline with age. Free fatty acids ranged from 0.897 to 11.8 µEq/g, and increased significantly with sample age. Thiamin ranged from 3.74 to 5.50 µg/g, and bread loaf volume and firmness ranged from 422 to 536 cc and 425 to 775 g, respectively, with no significant decline over time. Results indicate that, regardless of headspace oxygen level, wheat stored in No. 10 cans retains nutritional quality and makes bread that is acceptable to a majority of consumers after 32 years of storage at ambient temperatures.

INTRODUCTION

There is interest in the long-term storage of food for applications such as space flight, military rations, and disaster relief. Wheat is a major component of the American diet and is therefore important to include in food storage settings. The changes that occur in wheat during storage have been reviewed previously (Wang and Flores 1999; Pomeranz 1988). Under the proper conditions, wheat stores extremely well (Pixton and others 1975). Lipid hydrolysis being the most rapid chemical change over time (Halverson and Zeleny 1988).

While there are numerous studies on the storage properties of wheat, studies on the sensory properties of wheat stored long-term have been largely ignored. The purpose of this research was to examine the effects of long-term storage on the sensory and nutritional quality of wheat packaged in No. 10 cans and held at ambient temperatures up to 32 years.

METHODOLOGY

Samples

Thirteen samples (and duplicates from the same lot of sample aged <1, 8, 9, 13, and 14 years) of hard red wheat kernels packaged in No. 10 cans in reduced oxygen atmospheres were obtained from donors. Samples ranged in age from <1-32 years and were stored at ambient temperatures (approximately 13-27 ºC). Samples <1-10 had oxygen absorbers; all other samples were nitrogen flushed.

Can Analysis

Can headspace oxygen was measured using a 3500-Series Headspace Oxygen Analyzer. Can seams were evaluated using the SeamMate System to measure the following seam dimensions: thickness, width, body hook, cover hook, and overlap. Seam tightness was rated subjectively by an experienced technician on a scale of 0-100%, <50% being indicative of a poor seam.

Wheat Kernel Analysis

Kernel moisture was determined according to Approved Method 44-19 (AACC International 2000). CIE L* value was measured on a HunterLab ColorFlex spectrophotometer. Protein was determined using the Dumas method, with a conversion factor of 5.7 (Chang 2003). Free fatty acids were extracted by grinding wheat in a UDY cyclone mill equipped with a 0.8 mm mesh opening. Fifteen ml of hexane was added to 1.5 g of the ground wheat, and placed on an orbital shaker for 30 min at 140 rpm. The hexane was decanted through Whatman No. 1 filter paper into a round bottom flask. The extraction was repeated twice, and the pooled hexane extractions were evaporated on a rotary evaporator at 40ºC. Extracted lipids were redissolved in isooctane, mixed with a cupric acetate/pyridine reagent, and free fatty acids were quantified spectrophotometrically (Kwon and Rhee 1986). Thiamin was measured according to Ndaw and others (2000) using an autoclave followed by takadiastase digestion method. After conversion to thiochrome, samples were quantified using an HPLC equipped with a fluorometric detector .

Baking Quality

Wheat was ground using a Quadramat Jr. laboratory mill, and aged in closed paper bags for two weeks. Bread was then made according to AACC Method 10-10B (AACC International 2000), omitting all optional ingredients. Optimal water absorption was determined subjectively according to Finney (1945), and optimum mixing time was defined as the time it took for a test dough to cling to both planetary and fixed mixing pins. Fermentation time was 90 min, and proofing time was 33 min. Baking temperature was reduced to 200ºC to prevent burning. After cooling, loaf volume was determined by rapeseed displacement. Bread firmness was determined on two 1 cm slices of bread taken from the center of the loaf according to AACC Method 74-09 (AACC International 2000), except strain was decreased to 25% and trigger force increased to 10 g.

Sensory Analysis

Wheat was ground at 4 °C using a K-Tech electric stone mill and allowed to age in closed paper bags at room temperature for two weeks. Bread was made from this flour by combining 967 g flour, 15 g salt, 120 g sugar, 60 g shortening, 26 g yeast, and 580 ml of water in a Kitchen Aid mixer. Dough was mixed for 10 minutes on low speed with a dough hook, and then fermented at 30ºC and 85% relative humidity with punching down after 52, 77, and 90 min. Dough was shaped into loaves, and proofed for 33 minutes in a 10 × 20 cm loaf pan. Loaves were baked for 24 min at 200ºC in a rotary oven, and then cooled for 1 hr before slicing using a bread slicing guide and electric knife. Bread was stored in plastic bags until serving to panelists the following day.

Acceptability of the bread was determined by a sensory panel consisting of 50 panelists. The sensory panel was conducted at the Brigham Young University Sensory Laboratory using standard procedures. Panelists evaluated all samples in four sessions over a two day period. Panelist were asked to evaluate aroma, texture, flavor, and overall acceptability using a 9-point hedonic scale. Acceptance for use in a regular diet and in an emergency was assessed by asking panelists if they would consume the product in those situations.

Data Analysis

Data were analyzed using Statistical Analysis System software (SAS Institute, 1999) using a mixed model analysis of variance (PROC MIXED). The Tukey-Kramer procedure was utilized to determine significant differences among means. Correlation was assessed using regression analysis (PROC REG). Significant differences were defined as $p<0.05$.

Table 1. Initial measurements of stored cans (headspace oxygen and seam tightness score) and wheat (moisture, L* value, and protein).

Sample Age (yr)	<1	5	8	9	10	12	13	14	17	24	27	29	32
Headspace Oxygen (%)	7.60	0.790	0.735	0.825	1.25	20.75	1.62	20.6	20.6	<0.001	1.98	0.010	<0.001
Seam Tightness Score (%)	93	90	75	90	80	95	85	0	0	95	95	95	95
Moisture (%)	7.95	8.61	7.51	9.55	6.65	8.68	8.45	7.88	8.46	7.08	7.47	8.50	8.67
L* Value	49.7	49.4	48.2	49.4	46.5	46.2	48.6	50.4	50.5	46.4	43.9	54.4	45.7
Protein (%)	13.8	15.1	15.7	13.7	14.5	15.8	15.1	14.0	14.3	15.7	13.2	12.7	13.1

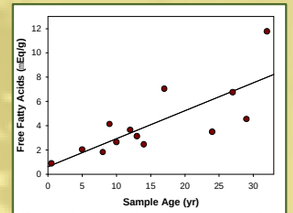

Figure 1. Free fatty acids in wheat kernels stored up to 32 years.

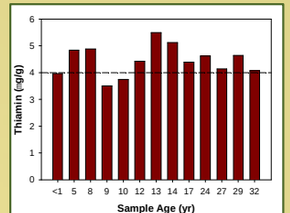

Figure 2. Thiamin in wheat kernels stored up to 32 years. Dashed line shows the literature value for thiamin in wheat (United States Department of Agriculture 2005).

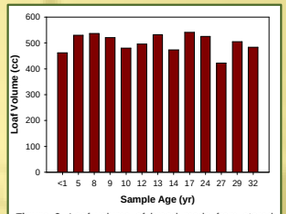

Figure 3. Loaf volume of bread made from stored wheat.

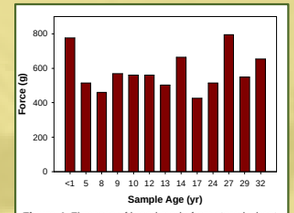

Figure 4. Firmness of bread made from stored wheat.

Table 2. Mean hedonic scores (9-point scale) of bread made from stored wheat. Like superscripts in the same row indicate no significant difference ($p>0.05$).

Sample Age (yr)	<1	5	8	9	10	12	13	14	17	24	27	29	32
Aroma	6.9^{ab}	7.1^{a}	7.0^{ab}	7.0^{ab}	7.1^{a}	6.9^{ab}	7.1^{a}	7.0^{ab}	6.7^{b}	6.7^{b}	6.9^{ab}	7.1^{ab}	7.1^{a}
Flavor	7.0^{abc}	7.2^{a}	7.1^{abc}	7.1^{abc}	7.2^{ab}	7.0^{abc}	7.0^{abc}	7.0^{abc}	6.8^{c}	6.8^{c}	6.4^{d}	7.1^{abc}	7.0^{c}
Texture	7.0^{b}	7.4^{a}	7.4^{a}	7.4^{a}	7.2^{ab}	7.2^{ab}	7.2^{ab}	7.2^{ab}	7.2^{ab}	7.1^{ab}	6.5^{c}	7.1^{ab}	7.0^{b}
Appearance	7.1^{a}	7.4^{a}	7.4^{a}	7.4^{a}	7.2^{a}	7.3^{a}	7.3^{a}	7.4^{a}	7.4^{a}	7.2^{a}	7.1^{a}	7.1^{a}	7.3^{a}
Overall Acceptability	7.0^{abc}	7.3^{a}	7.3^{a}	7.2^{a}	7.3^{a}	7.1^{ab}	7.1^{ab}	7.1^{ab}	6.9^{bc}	6.8^{bc}	6.6^{c}	7.1^{ab}	7.0^{ab}

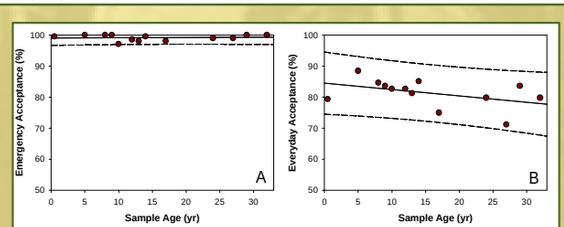

Figure 5. Wheat age compared to percentage of panelists who would use each sample of flour in an emergency situation (A) and an everyday situation (B). Dashed lines represent 95% prediction interval.

RESULTS AND DISCUSSION

Can Analysis

Table 1 shows the initial measurements made on the storage cans. Headspace oxygen was maintained below 2% in all cans with good seams (tightness score of >50%), except sample 12, and was not correlated with sample age.

Wheat Kernel Analysis

Wheat moisture content was low enough in all samples to prevent mold growth (Table 1) (Wang and Flores 1999). CIE L* values for wheat kernels ranged from 43.93-54.37. The L* scale ranges from zero (black) to 100 (white). Protein content ranged from 13.08-16.43%, indicating all samples were hard wheat. Moisture, L*, and protein content were not correlated with sample age. Figure 1 shows the relationship between free fatty acid content and age. Free fatty acids increased significantly from 0.897 to 11.8 µEq/g over time. This is consistent with other studies on the long term storage of wheat (Pomeranz 1971). Figure 2 shows the thiamin content in wheat of various ages. The results indicate that thiamin in whole wheat kernels was not effected by age. This may have been a result of the variation in thiamin content in wheat between crop years, cultivar type, and growing region, as samples were obtained from multiple donors and may not have come from the same source. However, the results were consistent with a previous study of whole wheat (Pixton and others 1975), which found no appreciable decrease in thiamin during 16 years of storage.

Baking Quality

Flour milled from the stored wheat resulted in bread that ranged in loaf volume from 422 to 536 cc (Figure 3) and did not decline with age, indicating it maintained good breadmaking ability. Force required to compress bread by 25%, an indicator of bread firmness, ranged from 425 to 775 g (Figure 4), and also was not correlated with wheat age. These results may be due to the use of wheat from different sources, although Fifield and Robertson (1959) also found no decrease in loaf volume of bread made from wheat stored up to 33 years.

Sensory Analysis

Table 2 shows the average hedonic scores for aroma, flavor, texture, appearance, and overall acceptability of bread made from the stored wheat. All samples maintained a 6.5-7.5 hedonic score (like slightly to like moderately), indicating a high degree of acceptability; however, regression statistics indicated that flavor and overall acceptability did decline significantly with age. Figure 5 shows the acceptance of samples for emergency and everyday use. All samples maintained >97% acceptance for use in emergency situations. All samples maintained >70% acceptance for use in a regular diet.

CONCLUSIONS

As expected, during the storage of wheat, some aspects of kernel (increase in free fatty acids) and bread quality (decrease in flavor and overall acceptability) deteriorated. However, sensory results indicated that bread made from stored wheat maintained a high degree of acceptance for use in emergency and everyday situations. Baking quality, as measured by loaf volume and bread firmness, did not decrease with age, nor did thiamin content. These results show that whole wheat stores extremely well under the proper conditions, and is therefore useful to include in food storage regimens.

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