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Quality of regular and parboiled rice in long-term storage

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Quality of regular and parboiled rice in long-term storage

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ABSTRACT

There is interest in storing food for long periods of time for such uses as disaster relief efforts, military rations and space travel. Rice hermetically sealed in cans and treated to remove oxygen is available in the retail market, but further work is needed to determine the effects of long-term storage on quality.

The objective of this research was to investigate the quality of regular and parboiled white rice packaged for long-term storage in cans treated to reduce oxygen levels and held at ambient temperature for up to 30 years.

Eighteen samples of white rice (11 regular, 7 parboiled) packaged in No. 10 cans were obtained from donors. Samples ranged in age from 6 to 30 years. Two fresh samples of rice (1 regular, 1 parboiled) were purchased as controls. A 52-member consumer panel evaluated prepared rice for appearance, aroma, texture, flavor, and overall acceptability using a 9-point hedonic scale. Acceptance for use in everyday and emergency situations was also determined. Analyses included can headspace oxygen, can seam integrity, color, water activity, headspace hexanal, and thiamin content.

Aroma, texture, flavor and overall acceptability hedonic scores for regular rice did not significantly decrease with age. Appearance, flavor and overall acceptability scores for parboiled rice did decrease with age. The percentage of panelists who would eat regular rice in everyday or emergency situations did not decrease over time. Both types of rice had greater than 88% acceptance for emergency use at 30 years of storage. There was no correlation between headspace hexanal of uncooked rice and hedonic scores of the cooked product.

Results indicate that polished white rice is capable of retaining a high percentage of consumer acceptance over long periods of time and should be included in long-term food storage efforts.

INTRODUCTION

There is a market for food products that will store for long periods of time, intended for such uses as personal preparedness, disaster relief efforts, military rations, and space travel. Polished white rice hermetically packaged and treated to remove oxygen is available in the retail level, yet little work has investigated the effects of long-term storage on quality. Most storage studies have monitored rice quality for one year or less (Sharp and Timme 1986; Suzuki and others 1996; Widjaja and others 1996; Basunia and others 1997; Perdon and others 1997). A few authors have studied rice stored for 3-5 years (Kondo and Okamura 1929, 1934, 1937; Swamy and others 1978; Calderwood and others 1985). Most of these studies have investigated the storage of rough and brown rice and only a few have studied regular-white or parboiled rice. Evidence indicates that rice will store well for at least five years if the moisture content is low enough (12%), the container is air-tight, and room temperature is not exceeded (Kondo and Okamura 1937; Calderwood and others 1984).

Kondo and Okamura (1933) tested two samples of rice 26 and 28 years in age that had been stored in air-tight tin containers. The rice appeared to be only 3-4 years old, and the loss in Vitamin B content was 45.9% and 16.2%, comparable to the loss in rice stored in straw bags for 2-3 years. The quality of the odor and the stickiness of the rice when cooked decreased somewhat, but the taste and overall sensory quality were satisfactory. They predicted that good quality rice, properly dried (11-13% MC) and placed in air-tight containers, would not deteriorate for at least 30 years.

The objective of this research was to investigate the quality of regular and parboiled white rice packaged for long-term storage in cans treated to reduce oxygen levels and held at ambient temperature for up to 30 years.

METHODS

Samples

Eighteen samples of white rice (11 regular, 7 parboiled) packaged in No. 10 cans were obtained from donors. The cans had been stored in private residences at ambient temperature (≤27°C) and ranged in age from 6 to 30 years. Some of these samples were Duplicate cans (same lot) were obtained for the storage ages of 6, 9, 19, and 24 years. Sample numbers of the same age, but different lots, were designated as A and B. Two fresh samples of rice (1 regular, 1 parboiled) packaged in plastic sacks without oxygen reduction were purchased from a retail distributor and used as controls.

Headspace Oxygen, Can Seam, and Water Activity

Can headspace oxygen was measured using the 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).

Color

The color of 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

A 52-member consumer taste panel evaluated the sensory quality of the rice. Samples were prepared using rice cookers (model RA3A, Salton, Inc., Columbia, MO) and then transferred to steam tables where they were held at 63-74ºC. The panelists evaluated the prepared rice for appearance, aroma, texture, flavor, and overall acceptability using a 9-point hedonic scale. Acceptance was determined by asking the panelists if they would eat the sample as part of their regular diet and if they would eat it in an emergency situation.

Headspace Hexanal

Rancidity was evaluated in uncooked rice samples by measuring headspace hexanal (Fritsch and Gale 1977) using a headspace sampler (Perkin-Elmer Model HS-40XL, Norwalk, CT) and a gas chromatograph (Hewlett-Packard 5890 Series II Plus, North Hollywood, CA) equipped with a flame ionization detector.

Thiamin

Thiamin was extracted from samples, converted to thiochrome, and analyzed using an Agilent Model 1100 high performance liquid chromatograph (Agilent Technologies, Palo Alto, CA) equipped with a C18 reverse phase column (Phenomenex, Inc., Torrence, CA) and a fluorescence detector. Determinations were carried out under subdued light (Ollilainen and others 1993; Ndaw and others 2000).

Data Analysis

Data was analyzed for significance (p<0.05) using Statistical Analysis System software (SAS Institute, Cary, NC). Analysis of variance (PROC GLM) with Duncan's test was used to determine significant differences for headspace hexanal, color data, and thiamin content. Sensory data was analyzed for significant differences using a mixed model repeated measures analysis of variance (PROC MIXED) with Duncan's test. Regression analysis (PROC GLM) was performed to determine which variables (sensory attributes and thiamin) significantly correlated with age, type of rice, water activity, headspace oxygen, and hexanal.

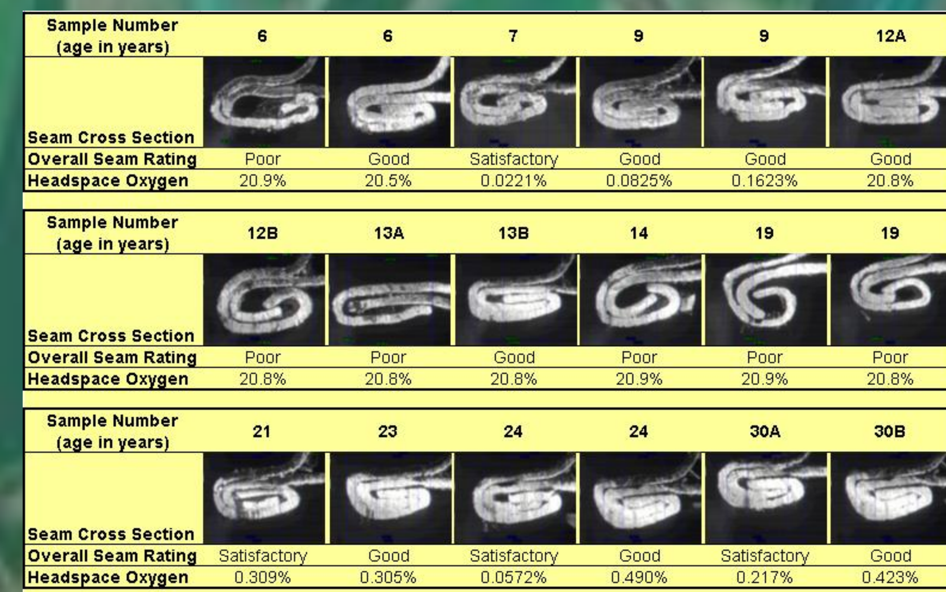

Figure 1: Can seam cross section with corresponding overall seam ratings and headspace oxygen percentages. Identical sample numbers represent samples from the same lot.

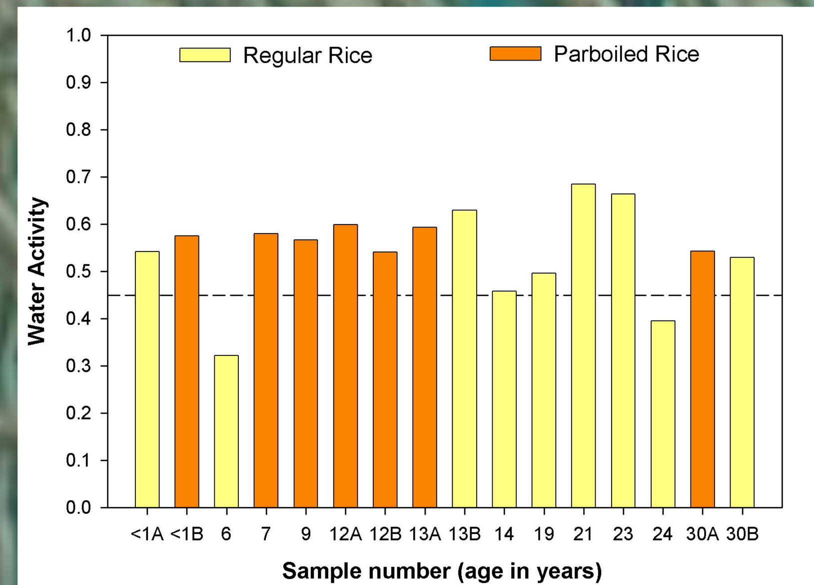

Figure 2: Water activity of regular and parboiled rice of various ages. Dashed line represents suggested a_w (Kondo and Okamura 1934; Calderwood and others 1984; Juliano 1985; Basunia and Abe 2001).

Table 1: Color values of uncooked rice samples stored up to 30 years at ambient temperatures. Data for sample numbers with an asterisk are averages of data from duplicate cans. Like superscripts are not significantly different (p<0.05).

Sample Number (age in years)	Type	L* value (CIELAB)	a* value (CIELAB)	b* value (CIELAB)
<1A	Regular	75.67^{a}	-0.96^{h}	16.17^{g}
6*	Regular	72.16^{bc}	0.66^{efgh}	24.24^{de}
13B	Regular	72.22^{abc}	1.14^{defgh}	19.93^{f}
14	Regular	72.54^{ab}	0.38^{fgh}	20.41^{f}
19*	Regular	70.98^{bcd}	1.55^{defgh}	21.26^{ef}
21	Regular	70.34^{bcd}	2.97^{cdef}	22.61^{ef}
23	Regular	72.38^{ab}	2.38^{cdefg}	21.5^{ef}
24*	Regular	67.60^{d}	1.63^{defgh}	21.33^{ef}
30B	Regular	68.84^{cd}	3.48^{cde}	26.13^{cd}
<1B	Parboiled	63.15^{e}	0.16^{gh}	26.63^{cd}
7	Parboiled	60.29^{ef}	2.68^{cdefg}	26.94^{cd}
9*	Parboiled	59.53^{f}	4.66^{abc}	29.02^{bc}
12A	Parboiled	60.85^{ef}	3.79^{bcd}	28.92^{bc}
12B	Parboiled	59.44^{f}	6.66^{ab}	31.89^{ab}
13A	Parboiled	61.61^{ef}	5.19^{abc}	30.61^{ab}
30A	Parboiled	54.7^{g}	7.45^{a}	33.32^{a}

Table 2: Hedonic scores for the sensory attributes of rice stored up to 30 years at ambient temperatures. Data for sample numbers with an asterisk are averages of data from duplicate cans. Like superscripts are not significantly different (p<0.05).

Sample Number (age in	Type	Appearance	Aroma	Flavor	Texture	Overall
<1A	Regular	7.12^{a}	5.66^{c}	6.56^{a}	6.43^{abc}	6.43^{ab}
6*	Regular	6.64^{a}	5.65^{c}	5.78^{b}	6.10^{c}	5.90^{cd}
13B	Regular	6.62^{ab}	6.30^{a}	6.74^{a}	6.40^{abc}	6.61^{a}
14	Regular	7.10^{a}	6.25^{ab}	6.60^{a}	6.43^{abc}	6.59^{a}
19*	Regular	6.67^{a}	5.89^{abc}	6.25^{a}	6.35^{abc}	6.32^{ab}
21	Regular	7.10^{a}	5.90^{abc}	6.36^{a}	6.36^{abc}	6.30^{abc}
23	Regular	7.10^{a}	5.97^{abc}	6.50^{a}	6.48^{abc}	6.63^{a}
24*	Regular	6.63^{a}	6.20^{ab}	6.32^{a}	6.48^{abc}	6.38^{ab}
30B	Regular	6.03^{cd}	6.12^{abc}	6.47^{a}	6.26^{abc}	6.35^{ab}
<1B	Parboiled	6.46^{bc}	5.90^{abc}	6.44^{a}	6.74^{a}	6.48^{a}
7	Parboiled	6.40^{cd}	5.86^{abc}	6.47^{a}	6.62^{ab}	6.51^{a}
9*	Parboiled	5.92^{de}	5.81^{bc}	6.53^{a}	6.49^{abc}	6.39^{ab}
12A	Parboiled	5.99^{cde}	5.56^{c}	6.51^{a}	6.59^{ab}	6.34^{ab}
12B	Parboiled	4.96^{fg}	5.92^{abc}	6.33^{a}	6.30^{abc}	6.24^{abc}
13A	Parboiled	5.44^{ef}	5.88^{abc}	6.25^{a}	6.18^{bc}	5.95^{bcd}
30A	Parboiled	4.51^{g}	5.58^{c}	5.67^{b}	6.30^{abc}	5.61^{cd}

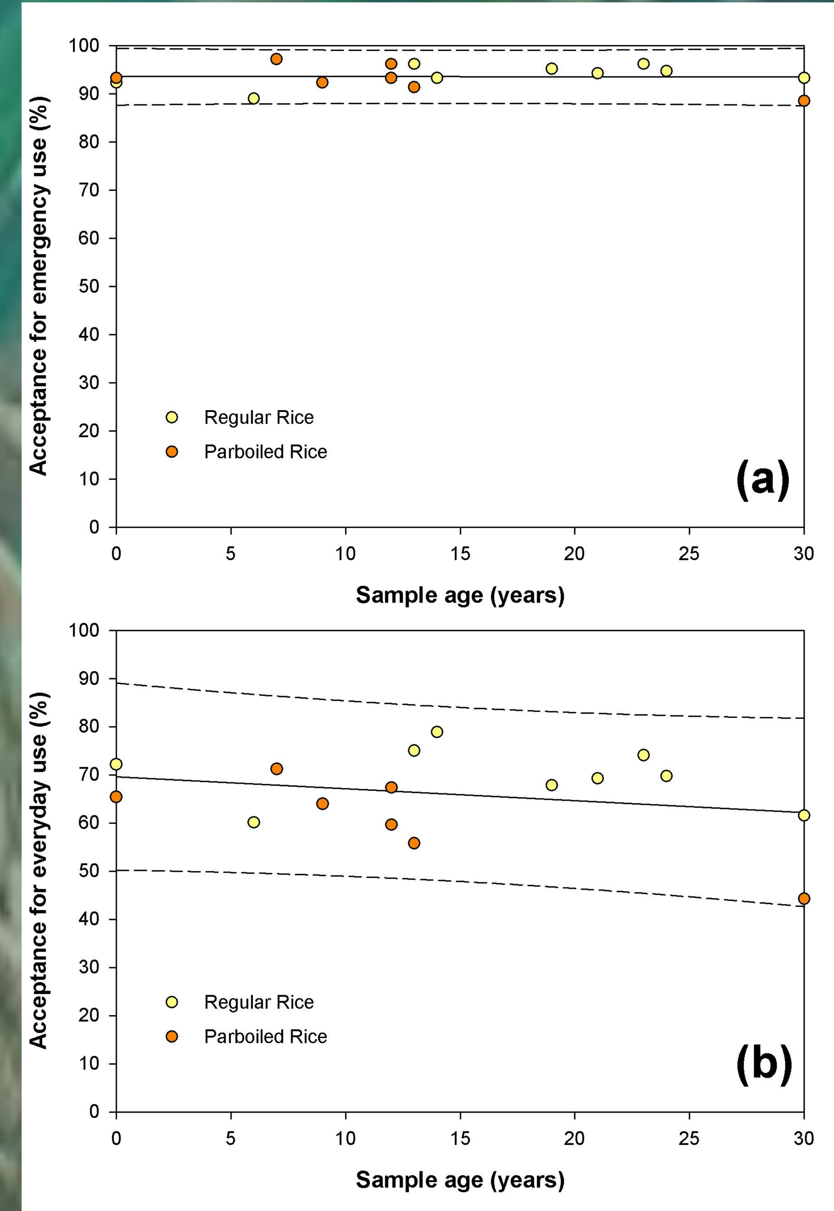

Figure 3: Age compared with acceptance of rice samples to eat in an emergency situation (a) or an everyday situation (b). Dashed lines represent 95% prediction interval.

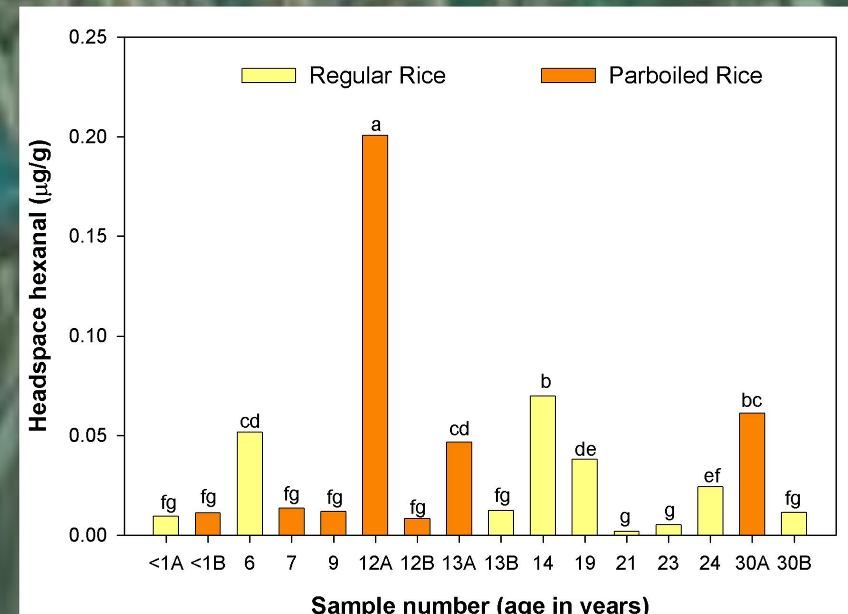

Figure 4: Hexanal content of regular and parboiled uncooked rice of various ages. Like superscripts are not significantly different (p<0.05).

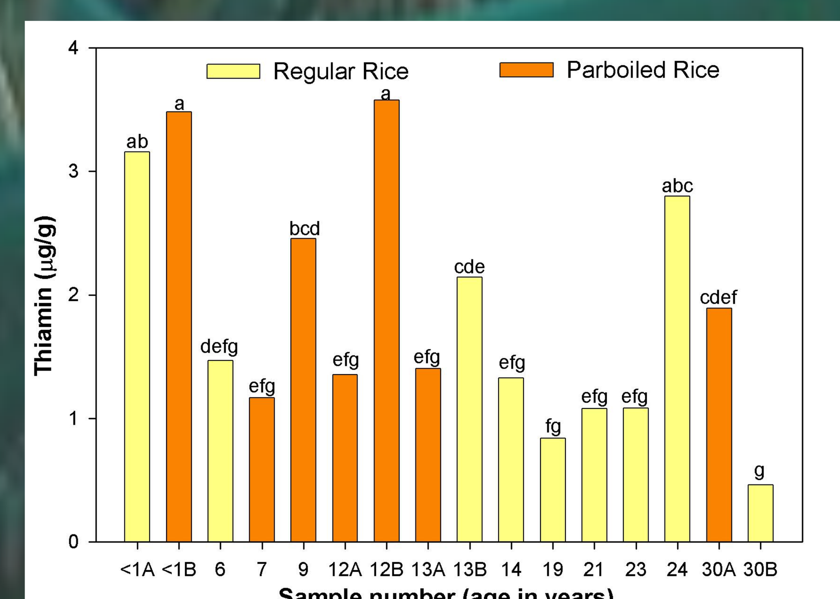

Figure 5: Thiamin content in stored regular and parboiled rice. Dashed line represents the typical level of thiamin in unenriched rice according to the USDA. Like superscripts are not significantly different (p<0.05).

RESULTS AND DISCUSSION

Headspace Oxygen, Can Seam, and Water Activity

The results for the headspace oxygen and seam quality for each can are shown in Figure 1. One third of the can seams were given an overall rating of poor. Headspace oxygen in both regular and parboiled rice was either very high (above 20%) or very low (below 1%). Oxygen percentage for regular rice ranged from 0.06% to 20.9%, with 5 of the 11 cans having >1% oxygen. Oxygen percentage for parboiled rice ranged from 0.02% to 20.8%, with 4 of the 7 cans having >1% oxygen. The high oxygen levels can be attributed to poor can seam quality or lack of proper oxygen removal.

Water activity ranged from 0.54-0.60 for parboiled rice and 0.32-0.69 for regular rice (Figure 2). Previous studies (Kondo and Okamura 1934; Calderwood and others 1984; Juliano 1985) have recommended a moisture content of 12% for rice used in long-term storage, which corresponds to approximately 0.45 aw (Basunia and Abe 2001).

Color

Table 1 lists the color values measured for each sample of rice. Although the color in regular rice did not significantly change over time, the parboiled rice did significantly darken.

Sensory Evaluation

The average hedonic scores for different sensory attributes for each sample are shown in Table 2. For regular rice, the only sensory attributes that significantly decreased in quality over time were appearance and aroma. On the other hand, hedonic scores for parboiled rice significantly decreased over time for appearance, flavor, and overall acceptability.

The slope for age versus overall acceptability for regular rice was significantly different than the slope for parboiled rice, meaning that parboiled rice decreased over time in overall quality more than regular rice. There was no correlation between the amount of oxygen and the sensory quality of the rice. There also was no significant correlation between water activity and the sensory quality of the rice.

Both types of rice had greater than 88% acceptance for emergency use at 30 years of storage, and neither type significantly decreased over time in acceptance (Figure 3). The acceptance for everyday use for parboiled rice did significantly decrease over time while the percentage of panelists who would eat regular rice in everyday situations did not decrease over time.

Thiamin and Headspace Hexanal

No significant trend over time was found for either headspace hexanal or thiamin levels (Figures 4 and 5). Observations made at the time the cans were opened (data not shown) indicated that raw samples high in hexanal also had an off-odor present, but no correlation existed between the headspace hexanal levels and the sensory hedonic scores of the cooked rice. This lack of correlation is likely due to volatiles being driven off during cooking. Variation in thiamin content was not significantly correlated with sample age, rice type, water activity, headspace oxygen, or hexanal levels.

CONCLUSIONS

The quality of rice in long-term storage did not decrease significantly over 30 years of storage at ambient temperature, indicating that rice is capable of retaining a high percentage of consumer acceptance over long periods of time and should be included in long-term food storage efforts.

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