Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 9 Article 12

Fall 2008

Effects of storage temperature and duration on the milling properties of rice

Tanya Pereira
University of Arkansas, Fayetteville

Nora Cooper
University of Arkansas, Fayetteville

Terry Siebenmorgen
University of Arkansas, Fayetteville

Effects of storage temperature and duration on the milling properties of rice

Tanya Pereira[*], *Nora Cooper*[†], *and Terry Siebenmorgen*[§]

ABSTRACT

To maximize rice quality, it is essential to quantify the various factors that affect milling properties of rice. Rice aging, a process during which rice undergoes a series of chemical and physicochemical changes, affects head rice yield (HRY) and the rate at which HRY changes with degree of milling (DOM). This study examined effects of storage duration (0, 2, and 4 months) and storage temperature (4, 21, and 35°C) on milling properties of 'Wells' (long-grain) and 'Jupiter' (medium-grain) rice cultivars. In general, HRY increased with storage duration, most significantly for Wells cultivar. Millability curves were developed by plotting HRY vs. surface lipid content (SLC) of milled rice. Millability curves of Wells had greater slopes, 11.3 pp decrease in HRY for every 1.0 pp decrease in SLC, than those of Jupiter, 8.5 pp decrease in HRY per 1.0 pp decrease in SLC.

[*] Tanya Pereira is a senior majoring in biological engineering.

[†] Nora Cooper is a program associate in the Department of Food Science.

[§] Terry Siebenmorgen, faculty mentor, is a university professor in the Department of Food Science.

MEET THE STUDENT-AUTHOR

Tanya Pereira

I graduated from Indian School Muscat in Oman in 2004 and enrolled at the University of Arkansas in the fall as a biological engineering major. Since my freshman year at the university, I have been involved with on-campus organizations. I have been a Resident Assistant on campus since 2006 and have served on the International Students Organization committee for two years. I enjoy participating in community service activities and participated in Alternative Spring Break as a Hurricane Katrina relief work volunteer in 2006 and 2007. I have also participated in several leadership and diversity programs including the Emerging Leader Program, Resident Interhall Congress, and the Diversity Leadership Program. During my junior year, I began working for Dr. Siebenmorgen who got me interested in the rice processing research area. Upon graduating, I plan to attend graduate school and pursue a career in the food processing industry. I would like to give a very special thanks to my research mentor, Nora Cooper, for her support and guidance throughout this project and to my faculty mentor, Dr. Siebenmorgen, for giving me the opportunity to be a part of this exciting project.

INTRODUCTION

Rice, the most widely consumed cereal grain in the world, is typically eaten as a milled, intact kernel. Consumers prefer rice to be white and polished, and thus rough rice is processed to first remove the hull and then milled to remove the germ and bran layers. Head rice yield is the current standard used to measure rice milling quality and is defined as the mass percentage of rough rice that remains as head rice (kernels that are at least three-fourths of the original kernel length) after complete milling (USDA, 2005). The milling rate determines the duration required to achieve a given DOM, or the extent to which the bran layers of brown rice kernels are removed during the milling process. Degree of milling can be rapidly determined by light transmittance or by near infrared (NIR) spectroscopy techniques. Rice bran and germ comprise 15-20% lipids (Juliano, 1985) and thus lipid extraction methods, which are presumably more accurate than rapid methods, can be used to measure SLC of milled rice kernels as a measure of DOM. As rice is milled to greater extents, a greater DOM is achieved, leading to decreased SLC; HRY decreases linearly with decreased SLC (Reid et al., 1998).

Since DOM affects profit for rice farmers and millers in terms of HRY reduction, it is essential to understand the relationship between the various factors that affect milling properties of rice, one of which is aging. Rice aging is a complicated process during which rice undergoes a series of chemical and physicochemical changes caused by interactions between kernel components such as starch, lipids, and proteins. These interactions affect kernel hardness, which influences the rate at which bran is removed during milling (Bhashyam and Srinivas, 1984; Pomeranz and Webb, 1985). Studies on aging of rice have shown that tensile strength, hardness, and resistance to grinding increased after storage (Kondo and Okamura, 1937, Kunze and Choudhury, 1972). Daniels et al. (1998) found that rice required approximately 50% longer milling durations to reach the same DOM as achieved prior to aging, indicating that longer storage durations may yield harder kernels, thus making it more difficult to remove bran during the milling process. The above-mentioned changes occur most rapidly during the first few months of storage at a temperature of 15°C (Perez and Juliano, 1982). Head rice yield increases with storage duration (Daniels et al., 1998; Villareal et al., 1976), however, the effects of storage duration and storage temperature on the rate at which HRY changes with SLC, or the millability of rice, have not yet been quantified. Therefore, the objective of this study was to examine effects of storage temperature and duration on the millability of rice.

MATERIALS AND METHODS

Sample procurement and storage conditions. In fall 2007, rice cultivars Wells (long-grain, 16.6% harvest moisture content (MC)) and Jupiter (medium-grain, 16.7% harvest MC) were harvested from Stuttgart, Ark., and Newport, Ark., respectively. Samples were cleaned (Kicker Grain Tester, MidContinent Industries, Inc., Newton, Kan.) and then dried in a chamber maintained at 26°C and 56% relative humidity, corresponding to a rough rice equilibrium MC of 11.5% (ASAE 2004). When the rough rice MC had reached 12.5–12.9%, determined as the average MC of 50 kernels measured with an individual kernel MC meter (CTR 800E, Shizuoka Seiki, Shizuoka, Japan), each cultivar lot was separated into 56 samples of 150 g each, which were sealed in Ziploc bags. Eight of the samples represented replications 1 and 2 (four samples each) for the month-zero storage duration and were subjected to milling tests without storage duration or storage temperature treatment. The remaining 48 samples of each cultivar were grouped into six lots of eight samples each. The six lots were allocated to chambers maintained at 4, 21 or 35°C with two lots, representing replicates one and two, being allocated to each chamber. After two and four months, four samples were removed from each replication at each storage temperature and subjected to milling tests.

Milling procedure and head rice yield determination. Prior to milling, rough rice samples were removed from storage and, while still in the sealed plastic bags, allowed to equilibrate to room temperature for at least one day. Four samples from each cultivar/storage temperature/storage duration/replication combination were dehulled in a laboratory huller (Rice Machine, Satake Engineering Co., Hiroshima, Japan) with a clearance of 0.048 cm (0.019 in) between the rollers as specified by USDA (1982). The resultant brown rice samples were milled using a laboratory mill (McGill No. 2, RAPSCO, Brookshire, Texas) equipped with a timer. A 1,500-g mass was placed on the mill lever arm 15 cm from the center of the milling chamber. The four samples of each replication were milled for either 10, 20, 30, or 40 s in order to create samples of varying DOM, and then aspirated (Grain Blower, Seedburo Equipment Co, Chicago, Ill.) for 30 s to remove excess bran particles. Head rice was then separated from brokens using a sizing device (Seedburo Equipment Co., Chicago, Ill.) and HRY was expressed as the mass percentage of head rice to initial rough rice mass. Milled rice samples were stored at 4°C until SLC measurement.

Surface lipid content measurement. Head rice samples were removed from cold storage and allowed to equilibrate to room temperature for 1 h prior to SLC determination. The SLC of each head rice sample was measured, in duplicate, using a lipid extraction system (Soxtec Avanti 2055, Foss North America, Eden Prairie, Minn.) following the procedure developed by Matsler and Siebenmorgen (2005). This method used 5 g of head rice weighed into cellulose thimbles (Foss North America, Eden Prairie, Minn.). The thimbles and head rice were first pre-dried for 1 h in an oven maintained at 100°C. Lipid was then extracted from the sample by immersing the thimbles in extraction cups containing boiling 70 mL of petroleum ether (boiling point 35–60°C; VWR, Suwanee, Ga.) for 20 min. The thimbles were then raised above the solvent and the samples rinsed with petroleum ether condensate for 30 min. After rinsing, the extraction cups were placed into an oven maintained at 100°C for 30 min to evaporate any solvent in the cup, then moved to a desiccator where the cups were cooled to room temperature for 30 min before being weighed. The difference between the mass of the cups containing the extracted lipid and the original mass of the cups was then calculated to obtain the mass of the extracted lipid. Surface lipid content was expressed as the mass percentage of extracted lipid to the original head rice sample mass. Duplicate measurements were averaged before data analysis.

Statistical analysis. Using statistical software (JMP 7, SAS Institute, Inc., Cary, N.C.), the means obtained from the HRY and SLC tests were analyzed using least squares regression with milling duration, storage duration, and storage temperature as independent variables. Significance was determined using a student's t-test with an alpha level of 0.05. To compare the effects of HRY vs SLC, a full factorial model was constructed in a least squares regression analysis to determine effects of the independent variables (storage temperature, storage duration, and SLC) on HRY. Regression lines relating SLC and HRY were each constructed using eight data points (four milling durations, two replications).

RESULTS AND DISCUSSION

Figures 1 and 2 show effects of storage temperature and duration on the SLC of Wells and Jupiter rice cultivars, respectively, milled for 10, 20, 30 and 40 s. Surface lipid content decreased with increased milling duration, as anticipated from studies such as Cooper and Siebenmorgen (2007) and Siebenmorgen et al. (2006). After two and four months of storage, SLCs of both Wells and Jupiter (Fig. 1 and Fig. 2) did not vary significantly from those at zero months of storage except at the highest storage temperature of 35°C after 4 months. Storage temperature significantly affected SLCs of Jupiter, but storage duration did not. Both storage duration and temperature significantly affected the SLCs of Wells without an interaction between these independent variables.

Figures 3 and 4 show effects of storage temperature and duration on HRYs of Wells and Jupiter, respectively, milled for 10, 20, 30, and 40 s. Head rice yields decreased with increased milling duration. After four months of storage, (Fig. 3b), HRYs of Wells stored at 35°C were significantly greater than those stored at 4 and 21°C, as well as those with no storage. For this cultivar, storage duration significantly affected HRY, as did interactions between storage temperature and milling duration, and between storage temperature, storage duration, and milling duration. After two months of storage (Fig. 4a), there was no significant difference between HRYs of Jupiter stored at 4, 21 and 35°C and HRYs at zero months of storage. After four months of storage (Fig.4b), HRYs of Jupiter stored at 21°C were significantly greater than at zero months of storage and were not significantly different than Jupiter stored at 35°C. Storage duration significantly affected the HRY of Jupiter; there was also a significant interaction between storage temperature and storage duration.

Millability curves relating HRY to SLC are shown in Figures 5 and 6, which were developed by plotting HRYs vs. the corresponding SLCs of Wells and Jupiter cultivars, respectively, milled for 10, 20, 30, and 40 s after having been stored at 4, 21 and 35°C for 0, 2 and 4 months of storage. Both figures show that HRYs were linearly related to SLC; HRY decreased as SLC decreased. This trend was previously noted by Cooper and Siebenmorgen (2007) and Reid et al. (1998). Slopes of the regression lines of each storage duration/storage temperature combination can be found in Table 1. These slopes indicate the change in HRY that can be expected with a unit percentage point (pp) change in SLC. For example, the HRY of Wells at 0 months of storage changed 12.1 pp for every 1.0 pp change in SLC. Even though there was a distinct upward shift in HRYs after four months of storage (Fig. 5a), the rate of change in HRY with SLC only varied from 10.6 to 11.5 pp per 1.0 pp change in SLC, except for at two months of storage and 4°C storage temperature, when the slope of the regression line was 15.9 (Table 1). The millability slope for this storage temperature/duration combination was significantly different than the other slopes. The average of all Wells slopes was 12.0, though it is suspected that the 15.9 slope for month 2/4°C was an anomaly; if omitted, the average slope was 11.3.

Millability regression line slopes of Jupiter were of a lesser magnitude than those of Wells (Fig. 6, Table 1), which could be attributed to the geometry differences of the long-grain vs medium-grain cultivars. At zero months of storage, HRY changed at a rate of 8.3 pp for every 1.0 pp change in SLC (Table 1). The slopes of all Jupiter storage duration/temperature combinations were not statistically different, however, trends were such that the slope decreased to 7.7 after two months of storage at 4°C, and gradually increased with storage duration and storage temperature until reaching 9.2 after four months of storage at 35°C. On average, the HRY of Jupiter changed 8.5 pp with a 1.0 pp change in SLC.

The average slope of all millability regression lines produced in the current study was 9.9 (Table 1), which is only slightly greater than the average slope of 9.4 found by Cooper and Siebenmorgen (2007). Cooper and Siebenmorgen (2007) included 17 rice samples, including both long- and medium-grain samples, milled for 4 durations and aged for 0, 1, 2, 3 and 6 months. It is possible that further storage may produce samples that mill at a rate similar to that found by Cooper and Siebenmorgen (2007).

Summary. For Wells, storage duration resulted in a significant increase in HRYs after two months of storage at 35°C and after four months of storage at all temperatures relative to the month-zero HRYs. This effect was cultivar-specific as HRY changes due to storage duration or temperature were not observed in the medium-grain cultivar Jupiter. The rate of change in HRY with a change in SLC (millability) was greater in the long-grain cultivar, with an average rate of change of 11.3, than in the medium-grain cultivar, which produced an average rate of change of 8.5. Millability did not change significantly with storage duration or storage temperature, though ongoing research involving longer storage durations could elucidate possible effects of storage conditions on rice millability.

ACKNOWLEDGMENTS

The authors thank the Arkansas Rice Research and Promotion Board and the corporate sponsors of the University of Arkansas Rice Processing Program for their financial and programmatic support.

LITERATURE CITED

Bhashyam, M.K. and T. Srinivas. 1984. Varietal difference in the topography of rice grain and its influence on milling quality. Journal of Food Science 49:393-395, 401.

Cooper, N.T.W. and T.J. Siebenmorgen. 2007. Correcting head rice yield for surface lipid content (degree of milling) variation. Cereal Chem. 84(1):88-91.

Daniels, M.J., B.P. Marks, T.J. Siebenmorgen, R.W. McNew, and J.F. Meullenet. 1998. Effects of long-grain rough rice storage history on end-use quality. Journal of Food Science 63:832-835.

Juliano, B.O. 1985. Rice bran in Rice Chemistry and Technology. B.O. Juliano, ed. AACC International: St. Paul, Minn. 647-688.

Kondo, M. and T. Okamura. 1937. Storage of rice. XVII. Comparative study of unhulled rice and hulled rice in regard to the changes of its qualities during long storage in straw bags. Ber Ohara Inst Agric Biol Okayama Univ (7):483–490.

Kunze, O.R. and M.S.U. Choudhury. 1972. Moisture Absorption related to the tensile strength of rice. Cereal Chem. (49):684–696.

Matsler, A.M. and T.J. Siebenmorgen. 2005. Evaluation of operating conditions for surface lipid extraction from rice using a Soxtec system. Cereal Chem. 82(3):282-286.

Reid, J.D., T.J. Siebenmorgen, and A. Mauromoustakos. 1998. Factors affecting the slope of head rice yield vs. degree of milling. Cereal Chem. 75(5):738-741.

Perez, C.M. and B.O. Juliano. 1982. Texture changes and storage of rice. J. Texture Stud. 12:321-333.

Pomeranz, Y. and B.D. Webb. 1985. Rice hardness and functional properties. Cereal Foods World. 30 (11):784, 786-789.

Siebenmorgen, T.J., A.M. Matsler, and C.F. Earp. 2006. Milling characteristics of rice cultivars and hybrids. Cereal Chem. 83(2):169-172.

Sun, H. and T.J. Siebenmorgen. 1993. Milling characteristics of various rough rice kernel thickness fractions. Cereal Chem. 70(6):727-733.

USDA. 2005. US Standards for Rice. Federal Grain Inspection Service. GPO: Washington, D.C.

Villareal, R.M., A.P. Resurreccion, L.B. Suzuki, and B.O. Juliano. 1976. Changes in the physicochemical properties of rice during storage. Starch/Staerke (28):88-94.

Table 1. Slopes and coefficients of determination (R^2) of the millability linear regression lines of Figs. 5 and 6, relating the head rice yields and surface lipid contents of Wells and Jupiter cultivars stored for 0, 2, and 4 months at 4, 21, and 35°C.

Cultivar	Storage duration (mos)	Storage temperature (°C)	Slope	R^2
Wells	0	NA	12.1	0.98
	2	4	15.9	0.95
		21	10.6	0.96
		35	11.0	0.94
	4	4	11.2	0.91
		21	11.5	0.95
		35	11.4	0.98
Jupiter	0	NA	8.3	0.98
	2	4	7.7	0.94
		21	8.1	0.98
		35	8.4	0.98
	4	4	8.4	0.89
		21	9.1	0.99
		35	9.2	0.99

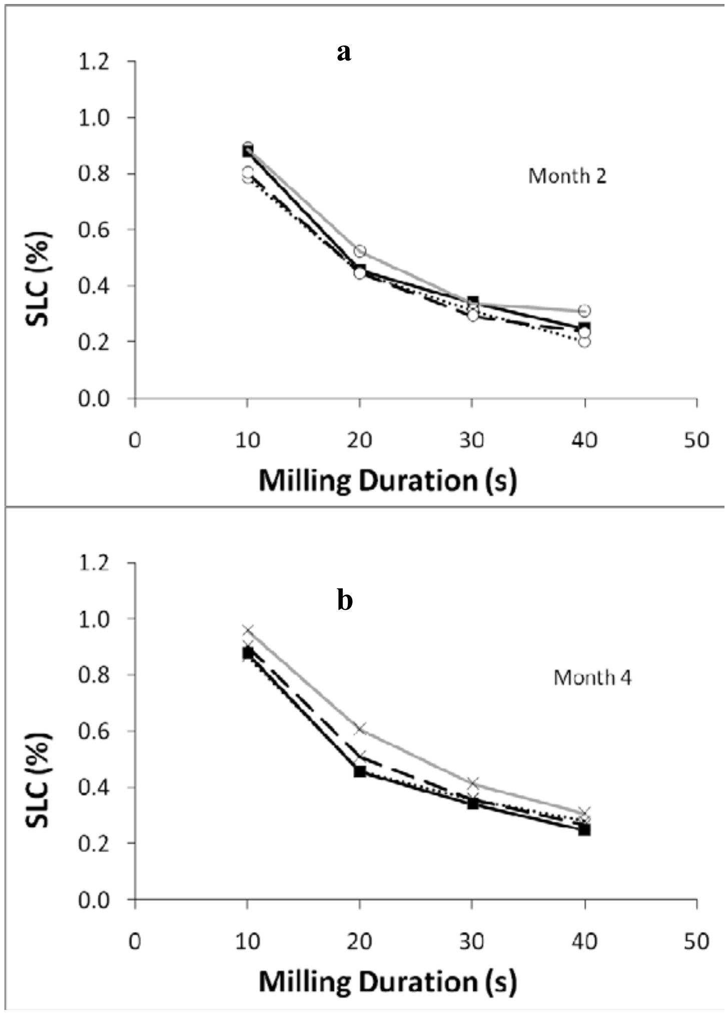

Fig.1. Surface lipid contents (SLCs) of Wells (long-grain) rice cultivar milled for 10, 20, 30, and 40 s after having been stored at 4°C (·······), 21°C (- - - -) and 35°C (——) for a: 0 (■) and 2 (○) months of storage and at b: 0 (■) and 4 (x) months of storage.

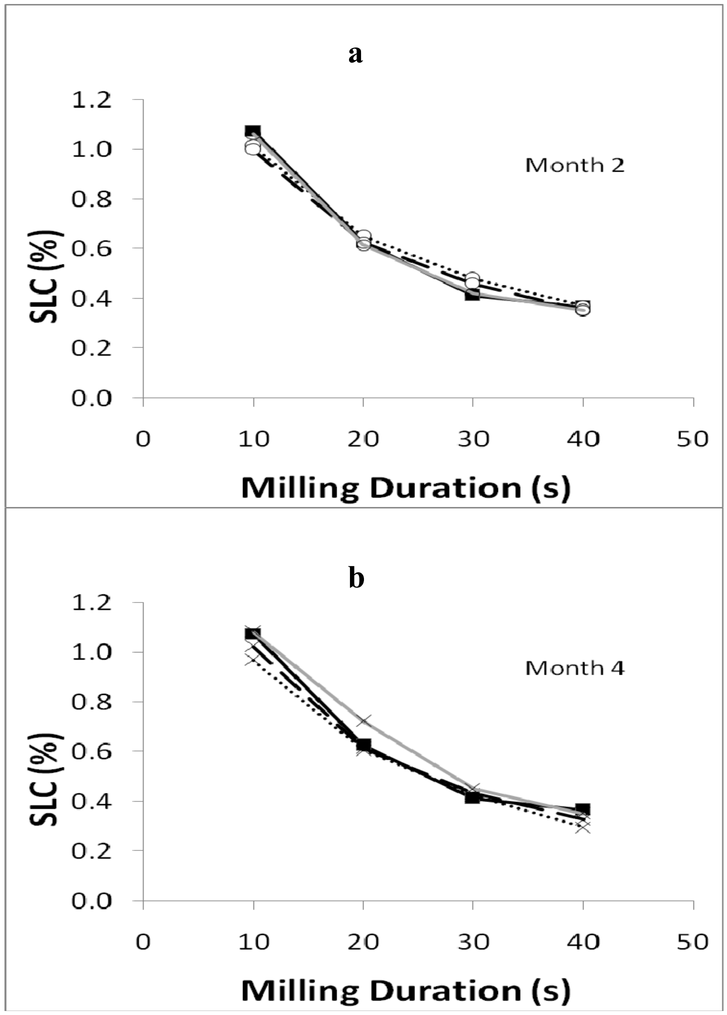

Fig. 2. Surface lipid contents (SLCs) of Jupiter (medium-grain) rice cultivar milled for 10, 20, 30, and 40 s after having been stored at 4°C (·······), 21°C (- - - -) and 35°C (——) for a: 0 (■) and 2 (○) months of storage and at b: 0 (■) and 4 (x) months of storage.

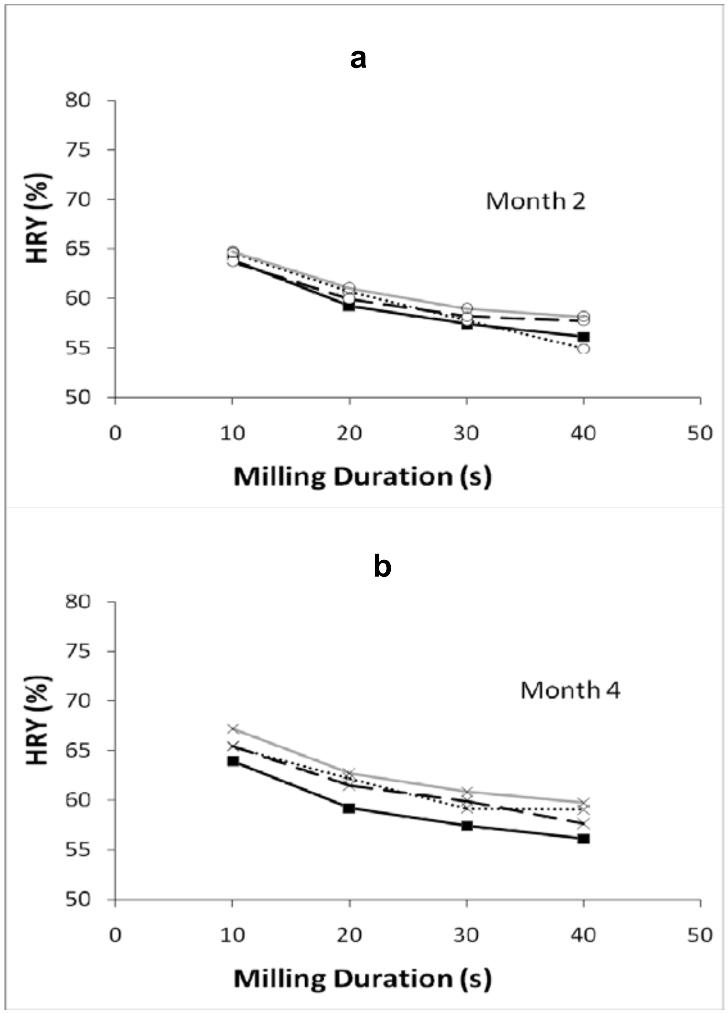

Fig. 3. Head rice yields (HRYs) of Wells (long-grain) rice cultivar milled for 10, 20, 30, and 40 s after having been stored at 4°C (·······), 21°C (- - - -) and 35°C (——) for a: 0 (■) and 2 (○) months of storage and at b: 0 (■) and 4 (x) months of storage.

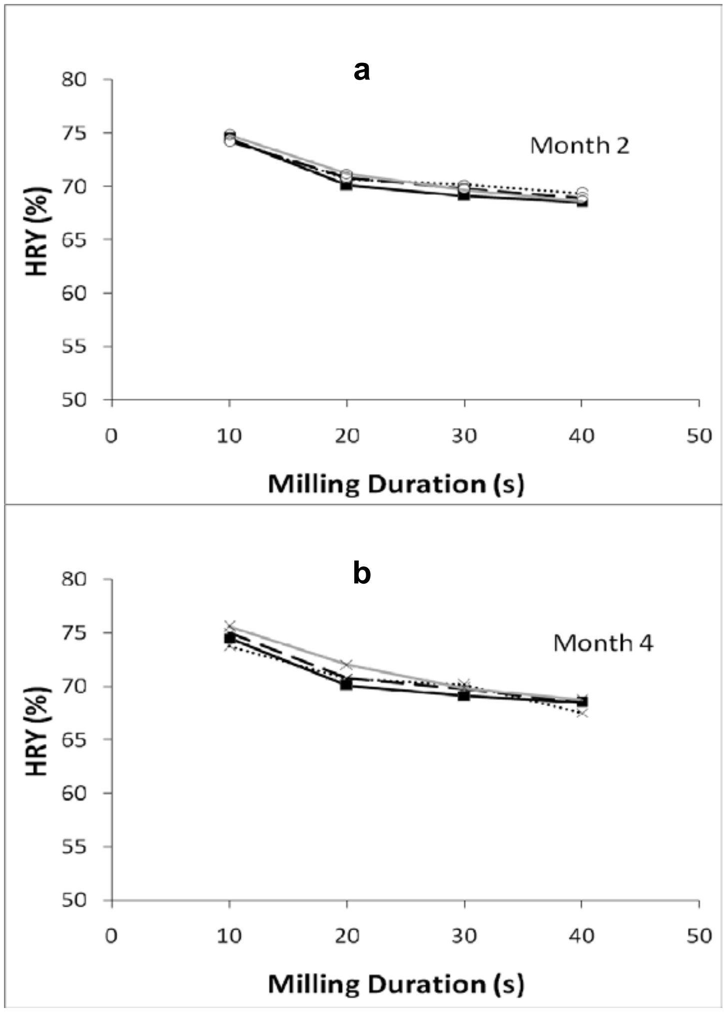

Fig. 4. Head rice yields (HRYs) of Jupiter (medium-grain) rice cultivar milled for 10, 20, 30, and 40 s after having been stored at 4°C (·······), 21°C (- - - -) and 35°C (——) for a: 0 (■) and 2 (○) months of storage and at b: 0 (■) and 4 (x) months of storage.

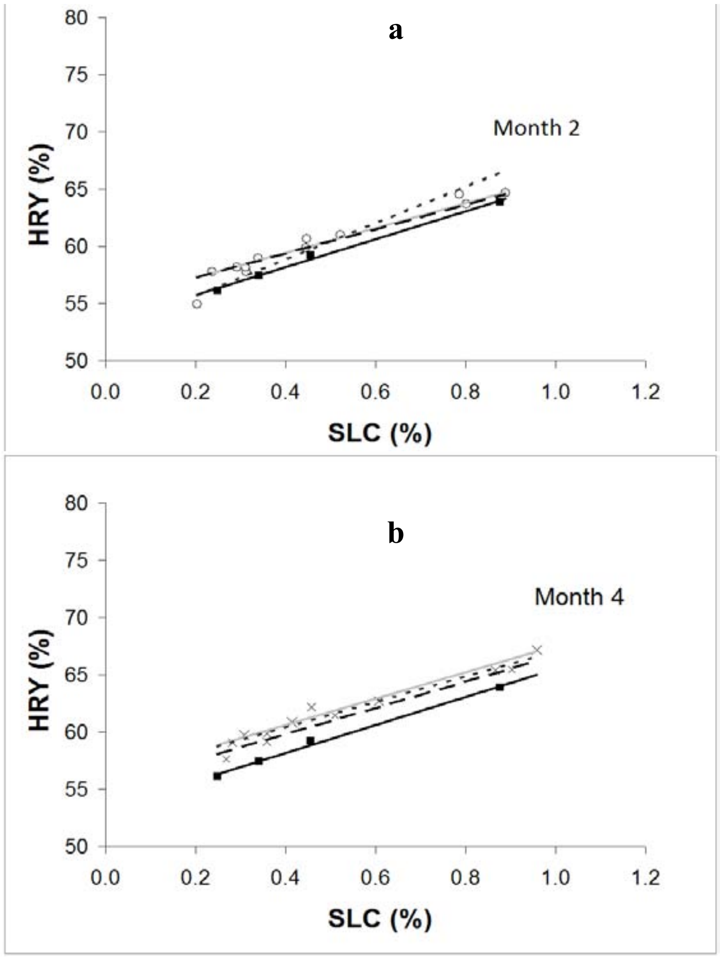

Fig. 5. Head rice yields (HRYs) and corresponding surface lipid contents of Wells (long-grain) rice cultivar milled for 10, 20, 30, and 40 s after having been stored at 4°C (·······), 21°C (- - - -) and 35°C (——) for a: 0 (■) and 2 (○) months of storage and at b: 0 (■) and 4 (x) months of storage.

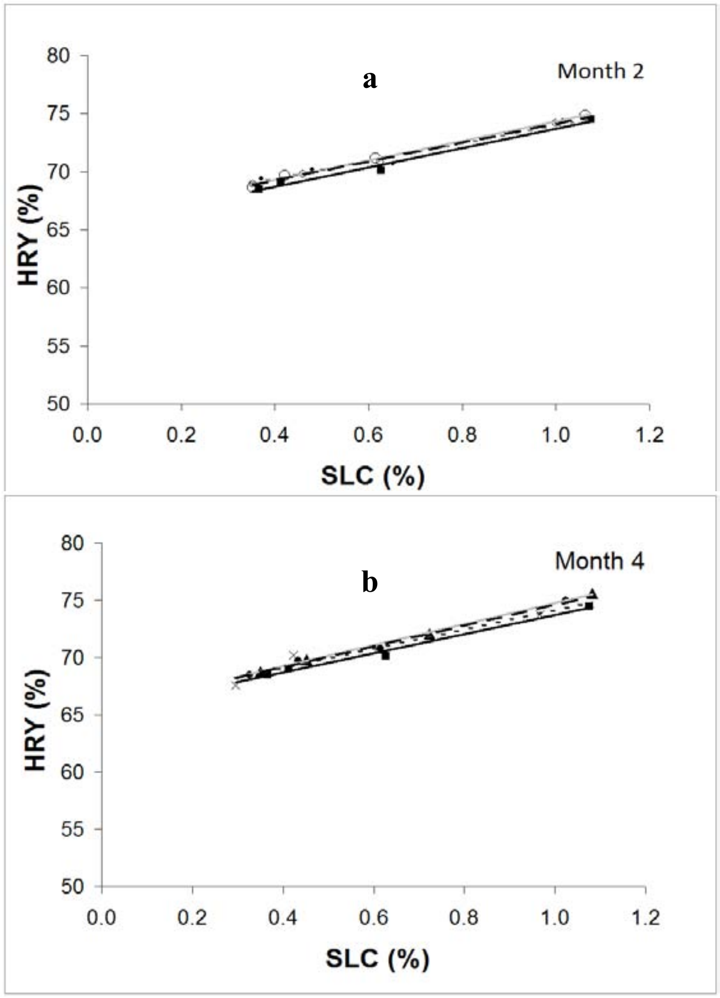

Fig. 6. Head rice yields (HRYs) and corresponding surface lipid contents of Jupiter (medium-grain) rice cultivar milled for 10, 20, 30, and 40 s after having been stored at 4°C (·······), 21°C (- - - -) and 35°C (——) for a: 0 (■) and 2 (○) months of storage and at b: 0 (■) and 4 (x) months of storage.