Relationship Between Milled Rice Surface Fat Concentration and Degree of Milling as Measured with a Commercial Milling Meter[1]

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ABSTRACT

The relationship between surface fat concentration, measured using a standard petroleum-ether extraction technique, and degree of milling, measured using a Satake milling meter, was investigated for 252 milled rice samples of both bulk and thickness-fractionated long-grain rice. Results showed that surface fat concentration was linearly and inversely related to degree of milling with an R^2 value of over 88% for bulk rice samples. There was no statistical difference in the slopes of the equation relating surface fat concentration to degree of milling of bulk rice samples across the three long-grain rice cultivars (Newbonnet, Millie, and Lemont) tested, yet there was a statistical difference between the equation intercepts across the three cultivars.

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Producing a milled, polished rice with minimum breakage is a universal goal of rice mills. Head rice yield and degree of milling (DOM) are the primary factors determining the milling quality of rice. Head rice is milled rice that comprises three-fourths, or more, of a kernel in length (USDA 1979). Head rice yield is the mass percentage of rough rice that remains as head rice throughout milling. DOM is an indicator of the extent to which the bran layer and germ have been removed from kernels during milling.

The Federal Grain Inspection Service grades DOM into four classifications by visual examination: undermilled, lightly milled, reasonably well milled, and well milled (USDA 1979). This subjective, visual evaluation of DOM depends heavily on the skill and experience of personnel.

Petroleum-ether extraction of surface fat from milled rice is a method that has been used to quantify the bran present on the surface of milled rice (Hogan and Deobald 1961, Watson et al 1975, Matthews and Spadaro 1980). Surface fat concentration (SFC) is the mass of surface fat extracted from a sample of head rice expressed as a fraction of either the total dry or wet mass of the milled rice. The more severe the milling, and thus the greater the DOM, the lower the SFC because more aleurone and outer endosperm have been removed (Watson et al 1975). Velupillai and Pandey (1987) determined bulk rice DOM of five cultivars using the extraction method and reported that ~65–73% of the bran was removed in the first 20 sec of milling.

The recently introduced Satake milling meter can be used for rapid measurement of DOM. However, the laborious and time-consumptive petroleum-ether extraction method for measuring SFC is currently a standard method of quantifying DOM. The objective of this study was to determine the correlation between the SFC of milled rice and the associated DOM as measured with a Satake milling meter.

MATERIALS AND METHODS

Experimental Design

Three long-grain rice cultivars, Newbonnet, Millie, and Lemont, were dried to ~12.5% (wb). As a means of estimating the effects of kernel size, bulk rough rice of each cultivar was separated into six thickness fractions using a Carter-Day Precision grader as detailed in Sun and Siebenmorgen (1993): 1) thinner than 1.83 mm, 2) 1.83–1.88 mm, 3) 1.88–1.93 mm, 4) 1.93–1.98 mm, 5) 1.98–2.03 mm, and 6) thicker than 2.03 mm. Subsamples of 150 g of the fractionated rough rice, as well as bulk, unfractionated rice, were milled for durations of 15, 30, 45, and 60 sec in a McGill No. 2 laboratory mill. A total of 252 samples were milled:

(6 thickness fractions + bulk rice) × 3 cultivars × 4 milling times × 3 replicated determinations

The DOM of all 252 samples was measured using a Satake milling meter, model MM-1 B, which utilizes both transmittance and reflectance measurements to determine DOM. DOM is displayed as a value from 0 to 199 where a value of 0 represents a DOM level corresponding to brown rice, and 199 represents a DOM level of snow white rice. Thus, the larger the DOM number, the more thorough or complete the bran removal.

Before the DOM was measured, the milling meter was calibrated using standard white and brown color plates according to the procedure outlined by the Satake instruction manual. After calibration, a milled rice sample, including both whole and broken kernels, was inserted into the sample inlet of the milling meter. Three readings were taken, after which the average value of DOM was displayed.

SFC

The SFC of 504 (252 rice samples × 2 replicate determinations) samples were determined using a Labconco Goldfisch lipid extractor (Hogan and Deobald 1961). Before extraction, each milled rice sample was separated into head rice and broken rice with a Seedburo sizing machine. A 10-g head rice sample was weighed into a cellulose extraction thimble (22 mm i.d. × 80 mm external length). Surface fat was extracted for 30 min with ~35 ml of petroleum ether (Fisher Scientific, optima grade, boiling point 30–60°C). The SFC was the surface fat extracted expressed as a percentage of the original 10 g of head rice.

RESULTS AND DISCUSSION

DOM Data

Table I shows the change in DOM with kernel thickness and milling time. Milling bulk rice samples from 15 sec to 60 sec resulted in DOM ranges of 53–102, 43–95, and 59–107, which corresponded to SFC ranges (data not shown) of 0.15–0.62%, 0.23–0.80%, and 0.25–0.74% for Newbonnet, Millie, and Lemont, respectively. For given thickness fractions, increasing milling time from 15 to 60 sec resulted in differences in DOM values of 40–90 points. Table I indicates that DOM values increased dramatically when milling time was increased from 15 to 30 sec, but further increases in milling time produced progressively less increase in

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TABLE I
Degree of Milling Values Measured by a Satake Milling Meter for Three Rice Cultivars at Different Milling Times (sec)[a]

Thickness Fraction, mm[b]	Newbonnet				Millie				Lemont			
	15	30	45	60	15	30	45	60	15	30	45	60
< 1.83	73 a[c]	109 e	115 i	124 k	0 a	82 f	89 i	95 ij	41 a	94 e	109 i	108 ij
1.83–1.88	54 b	77 f	87 g	96 j	0 a	63 e	74 h	86 g	51 bd	80 fg	86 fh	95 e
1.88–1.93	57 bc	84 fg	92 gj	102 e	38 b	67 e	81 g	92 j	51 bd	77 g	91 eh	101 j
1.93–1.98	63 cd	88 gh	98 j	105 e	48 c	81 g	94 ij	102 k	45 ab	76 g	93 eh	104 ij
1.98–2.03	69 d	90 g	99 j	108 e	56 d	87 gi	98 j	103 k	57 d	86 fh	103 ij	103 ij
> 2.03	59 bc	81 fh	95 jg	102 e	60 de	87 gi	97 ij	107 k	68 c	92 eh	103 ij	105 ij
Bulk Rice	53 b	78 f	92 gj	102 e	43 c	70 h	83gi	95 ij	59 d	88 eh	101 j	107 ij

[a]Values are the mean of duplicate readings of three subsamples of each milling time and thickness fraction combination.
[b]Sun and Siebenmorgen (1993).
[c]Values within a cultivar followed by the same letter are not significantly different at $P = 0.05$, using Fisher's least significant difference method (LSD = 7.7). Values of 0 were readings of the Satake milling meter.

TABLE II
Coefficients of Linear Regression for Relating Surface Fat Concentration of Various Thickness Fractions and Bulk Rice to Degree of Milling Values Measured by a Satake Milling Meter for Three Rice Cultivars

Thickness Fraction mm[a]	Newbonnet			Millie			Lemont		
	Coefficients			Coefficients			Coefficients		
	A	*B*	R^2 %	*A*	*B*	R^2 %	*A*	*B*	R^2 %
< 1.83	0.982	−0.0069	80.3	NS[b]	NS	NS	0.861	−0.0065	79.6
1.83–1.88	1.377	−0.0114	91.9	1.142	−0.0107	73.0	1.169	−0.0094	70.3
1.88–1.93	1.468	−0.0115	88.7	1.113	−0.0093	86.8	1.25	−0.0099	85.9
1.93–1.98	1.676	−0.0134	94.6	1.287	−0.0102	95.2	1.210	−0.0083	74.7
1.98–2.03	1.445	−0.0106	91.3	1.312	−0.0104	89.7	1.507	−0.0113	88.1
> 2.03	1.141	−0.0086	92.5	1.347	−0.0106	97.6	1.530	−0.0115	89.6
Bulk Rice	1.059	−0.0087	94.5	1.214	−0.0102	95.9	1.282	−0.0093	88.7

[a]Sun and Siebenmorgen (1993).
[b]Nonsignificant at $P = 0.05$.

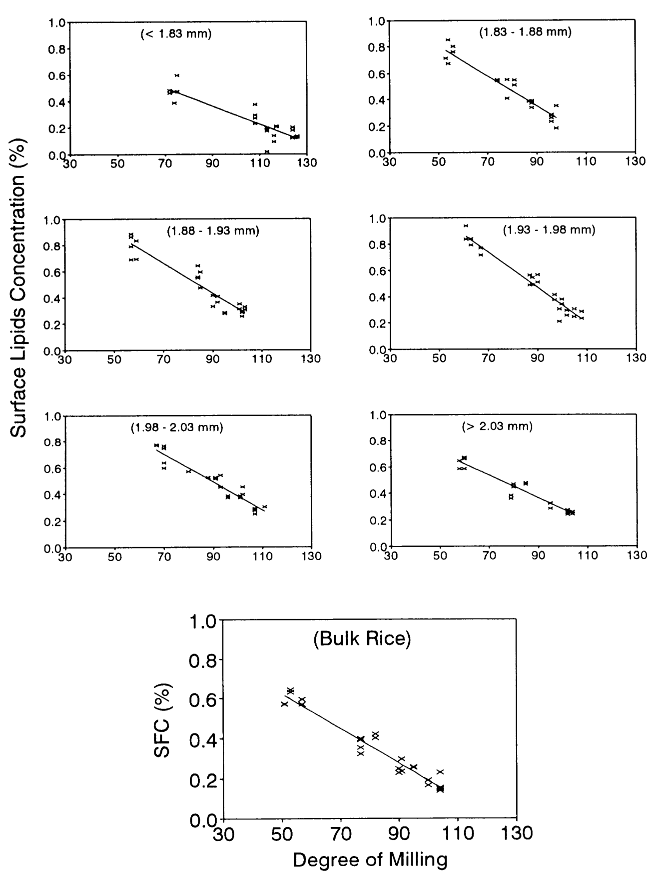

Fig. 1. Surface fat concentrations plotted against corresponding degree of milling values determined with a Satake milling meter for both fractionated and bulk rice samples of the rice cultivar Newbonnet.

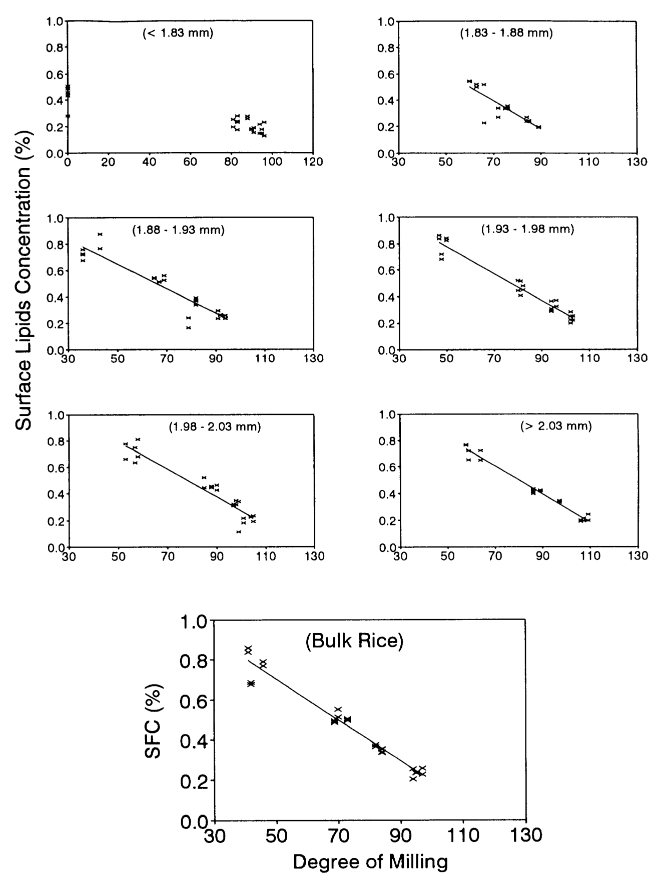

Fig. 2. Surface fat concentrations plotted against corresponding degree of milling values determined with a Satake milling meter for both fractionated and bulk rice samples of the rice cultivar Millie.

DOM, which concurs with the findings of Velupillai and Pandey (1987). Significant differences in DOM (Table I) were found ($P = 0.05$) between the kernel thickness fractions for given milling times using Fisher's least significant difference (LSD) method (MSE = 23.0, LSD = 7.7). Fisher's LSD for the SFC data was 0.069. A complete discussion of the trends in DOM values and the associated sample head rice yields is given by Sun and Siebenmorgen (1993).

Correlation of SFC to DOM

A regression analysis of SFC against DOM was conducted using the linear regression form:

$$\text{SFC}(\%) = A + B \times \text{DOM}$$

where A and B are coefficients. Table II lists the coefficients of this equation for the various thickness fractions and bulk rice for the three cultivars. The R^2 values indicate that most of the variability in SFC was accounted for by DOM readings from the milling meter. Figures 1–3 show the relationships between SFC and DOM for the fractionated and bulk rice samples of Newbonnet, Millie, and Lemont, respectively. The rate of change in SFC with DOM, or the slope of the equation, differed from one thickness fraction to another, suggesting that there were differences in the behavior of the meter due to kernel thickness. However, the trends in relating slope to kernel thickness were inconsistent.

Because the rice industry currently processes nonfractionated bulk rice, it is important to concentrate on the relationship between SFC and DOM of nonfractionated bulk rice. Table II shows that the R^2 values for this relationship were 94.5, 95.9, and 88.7% for Newbonnet, Millie, and Lemont, respectively, indicating a strong correlation between SFC of head rice and readings of the milling meter on milled rice that included both whole and broken kernels. An F-test showed that there was no significant difference ($P = 0.05$) in the slopes of the relationship of SFC to DOM between any of the three cultivars. However, there was a significant difference in the equation intercepts between each cultivar. Millie and Lemont kernels are similar in size, with reported average kernel weights of 18.8 and 19.3 mg, respectively, while Newbonnet is a much smaller kernel with a reported average kernel weight of 16.3 mg (Moldenhauer et al 1989). Thus, it appears that the bulk rice SFC level for a given DOM meter reading, which corresponds to the degree the rice was milled, was partially dependent on kernel size. However, there was no difference in the rate of change in bulk rice SFC as meter readings varied across the three cultivars.

SUMMARY

SFC of head rice was found to be linearly and inversely related to DOM (as measured with a Satake milling meter) of milled rice, which included both head rice and brokens. For bulk rice, the R^2 values for this relationship were over 88% for the three cultivars tested, indicating that the DOM readings from the milling meter explained most of the variability in SFC. There was no statistical difference in the slopes of the equation relating SFC to DOM of bulk rice samples across the three cultivars tested, yet there was a statistical difference between the equation intercepts across the three cultivars.

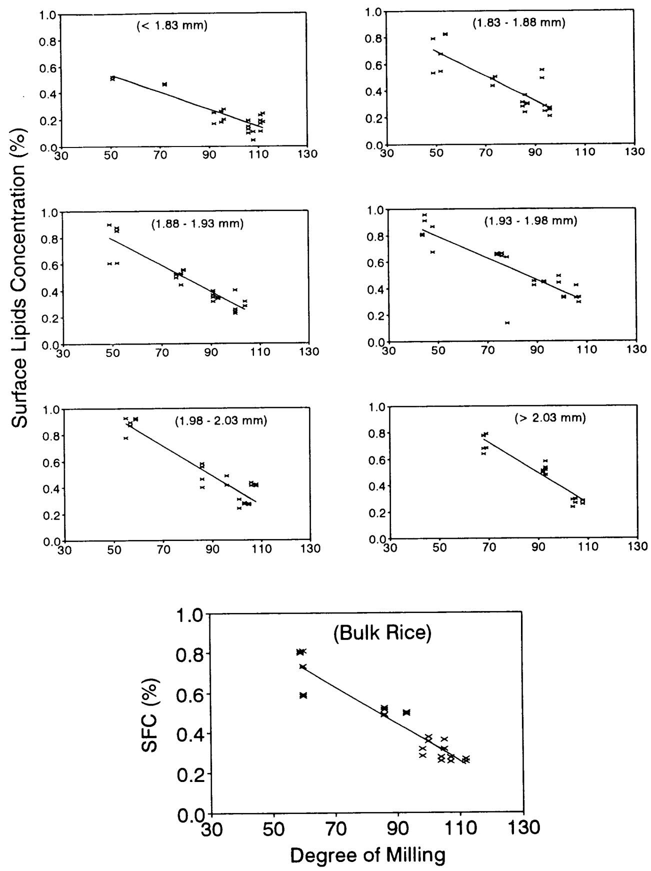

Fig. 3. Surface fat concentrations plotted against corresponding degree of milling values determined with a Satake milling meter for both fractionated and bulk rice samples of the rice cultivar Lemont.

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