# Effects of McGill No. 2 Miller Settings on Surface Fat Concentration of Head Rice[1]

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## ABSTRACT

The surface fat concentration of 384 head rice samples milled with a McGill No. 2 miller was measured with a Goldfisch lipid extractor (Labconco, Kansas City, MO). The data were used to evaluate the effects of moisture content, milling time, pressure applied to the rice, and initial rough rice weight on the degree of milling of two varieties of long-grain rice. Moisture contents ranged from 9 to 14% wet basis; milling time ranged from 15 to 60 sec in 15-sec intervals; and initial rough rice weights were 125 and 150 g. The pressure applied to the rice during milling was adjusted by the position of a 1.5-kg weight on the lever arm and ranged from 6 to 18 cm, in 6-cm increments. Moisture content and milling time were found to be the most significant variables affecting surface fat concentration. Sample size was the least significant variable. Surface fat concentration decreased as moisture content, pressure applied to the rice, and milling time increased. It increased as sample size increased. A varietal difference in surface fat concentration existed. An equation that predicts the surface fat concentration for the various experimental settings was developed. Head rice yield is directly related to surface fat concentration. Equations relating the two at different moisture contents were developed. Milling at lower moisture contents typically produced higher head rice yields, even when differences in surface fat concentration were taken into account.


Degree of milling (DOM) and head rice yield (HRY) are primary factors used to quantify the milling quality of rice. The DOM is an indication of the amount of bran removed from the surface of rice kernels during milling. Head rice is defined as milled rice kernels that are three fourths or more of the original kernel length. HRY is the weight percentage of rough rice that remains as head rice during milling. Maximizing HRY (or minimizing breakage) while producing a desired DOM is a universal goal of rice processors; however, procedures for obtaining these two objectives often conflict.

The Federal Grain Inspection Service (FGIS) of the U.S. Department of Agriculture (USDA) has four DOM classifications: well milled, reasonably well milled, lightly milled, and undermilled (USDA 1976). The FGIS evaluates DOM by visually comparing a sample to interpretive line samples. DOM is also estimated visually in most commercial operations. This visual evaluation of DOM relies heavily on sensory perception and subjective judgment.

Several objective methods have been proposed to determine DOM. One of these methods involves petroleum-ether extraction of surface fats from milled rice (Hogan and Deobald 1961, Watson et al 1975, Mathews and Spadaro 1980). Surface fat concentration (SFC) is the ratio of the weight of surface fats extracted from a sample of milled kernels to the total dry matter weight of the sample. Therefore, the more severe the DOM, the lower the SFC. Velupillai and Pandey (1987) determined the DOM of five rice varieties using a fat-extraction technique and stated that approximately 65-73% of the bran was removed in the first 20 sec of milling.

Several studies have addressed the effects of moisture content (MC) on the behavior of rough rice during milling. Banaszek et al (1989) determined the HRY and DOM of rice ranging from 10 to 16% MC (wb) milled in a McGill No. 2 miller for 30 sec. They stated that, within a range of samples determined to be well milled by the FGIS, MC accounted for a change in HRY of more than 10 percentage points. Webb and Calderwood (1977) stated that HRY of low MC samples was higher than that of the high MC samples, but the difference in HRY between low and high MC samples was greatly reduced or eliminated when the mill settings were changed to obtain the same DOM. Barber and Benedito de Barber (1979) suggested that rice samples should be evaluated for milling quality at an optimum MC range for processing of 13-14%. They stated that caking occurs when MC is too high (above 16%) and breakage is higher when MC is too low (below 12%). The latter finding contradicts the findings of Andrews et al (1992), who stated that HRY increased 7.2 percentage points in Lemont and 6.2 percentage points in Newbonnet when the MC fell from 14 to 9.5% in rice milled to a well-milled DOM in a McGill No. 2 miller.

The USDA rice standards (USDA 1982) specify the use of the McGill No. 3 miller or "an approved miller that produces the same results" for determining HRY. The McGill No. 2 miller is becoming more popular than the McGill No. 3 miller due to a lower initial cost, as well as lower power and sample-size requirements. As the use of the No. 2 miller becomes more widespread, the importance of developing standards for its operation becomes more vital. Andrews et al (1992) reported the effects of sample MC, sample size, milling time, and pressure applied to rice (weight placement) on the HRY of two varieties of long-grain rice milled in a McGill No. 2 miller. They found that MC was the most significant variable affecting HRY; sample size was the least significant. They stated that, when comparing the HRY of rice milled in a No. 2 miller to rice milled in a No. 3 miller, equivalent results, as measured by both HRY and DOM, could be obtained with proper settings of the No. 2 miller. However, no one combination of settings produced equivalent results across all four MCs tested for both varieties. Andrews et al (1992) also reported a wide range of DOM classifications, as determined by FGIS personnel, for samples milled under the settings used.

The objectives of this study were to: 1) measure the SFC of head rice samples milled at various MCs and settings of a McGill No. 2 laboratory rice miller, and 2) quantify the interrelated effects of the variables used in the milling procedure on SFC.

## MATERIALS AND METHODS

Head rice samples were obtained from a study reported by Andrews et al (1992) in which the effects of rice conditions and McGill No. 2 miller settings on HRY were quantified. The details of rough rice sample procurement, cleaning, drying, and shelling are given by Andrews et al (1992). The milling and SFC analysis procedures are given below.

### Experimental Design

A single McGill No. 2 miller was used to mill all samples. The pressure on the rice during milling was controlled by placing a 1.5-kg weight on the lever arm. Positions tested were 6, 12, and 18 cm from the center of the saddle to the center of the weight. Rough rice of two long-grain varieties, Lemont and

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Newbonnet, at MCs of 9.5, 11, 12.5, and 14% were chosen for milling. Rough rice amounts of 125 and 150 g were milled for durations of 15, 30, 45, and 60 sec. Two replications were conducted for all variable combinations. Thus, 384 samples (four MCs × three weight placements × two rough rice weights × four milling durations × two varieties × two replicates) were milled in the No. 2 miller.

As a control for the experiment and a basis of determining MC effects, 40 1-kg samples (five samples from each of the four MCs for both varieties) of rough rice were milled by the FGIS at Stuttgart, AR. The FGIS milled the rough rice samples in a McGill No. 3 miller according to USDA standards (Table I).

### McGill No. 2 Milling Procedure

The No. 2 miller was warmed up by milling approximately 120 g of brown rice in two consecutive 30-sec runs; one run had a 1.5-kg weight on the lever arm and one run did not have the weight. The miller was thoroughly cleaned between each milling by brushing the dust and broken rice kernels from the screen and removing the excess bran from the rotor. White rice weight was recorded after milling. The HRY of milled samples was determined by the FGIS. Samples were then stored at 1°C to await fat extraction.

### SFC Determination

The 424 head rice samples were randomly tested in a Goldfisch lipid extractor (Labconco) using the method of Hogan and Deobald (1961). The surface fats were extracted for 30 min into a clean beaker. The difference between the initial and final beaker weight represented the accumulated surface fats extracted from the head rice. The sample SFC was calculated as:

$$SFC = (FB_{wt} - IB_{wt}) \ / \ DM_{wt} \times 100\% \qquad (1)$$

where $FB_{wt}$ was the final beaker weight, $IB_{wt}$ was the initial beaker weight, and $DM_{wt}$ was the dry matter weight of the head rice sample.

## RESULTS AND DISCUSSION

A best-fit model was created using the PROC REG procedure (SAS 1989) and included a significant linear effect for each of the experimental variables. The model used to predict the sample SFC ($SFC_{pred}$%) was:

$$SFC_{pred} = a0 + a1 \times Vi + a2 \times MC + a3 \times MT + a4 \times WP + a5 \times RRW + a6 \times (MC \times Vi) \qquad (2)$$

where: Vi = variety (1 for Newbonnet or 0 for Lemont); MT = milling time, (sec); WP = weight placement, (cm); RRW = rough rice weight, (g); *a* = regression coefficients (Table II).

The results indicated that 81% of the change in SFC was explained with this model. The four experimental factors (MC. MT, WP, RRW), variety, and the MC × Vi product given in equation 2 and Table II influenced the SFC at the 5% significance level. The sign of the regression coefficients in Table II indicates that, except for the RRW effect, all of the factors indicate a negative linear relationship with SFC. Therefore, as MC, MT, and WP increased, SFC decreased proportionally, indicating a greater degree of bran removal.

Figure 1 illustrates the contribution of each of the four experimental variables on changes in SFC. MT and MC were the most important variables affecting SFC in the Lemont and Newbonnet varieties, respectively. RRW was the least important factor for both varieties. Differences in kernel dimensions are

**TABLE I**
**Data from 40 1-kg Samples Milled Using a McGill No. 3 Miller**

| Variety | Moisture Content (% wb) | Head Rice[a] Yield (%) | Surface Fat[a] Concentration (%) | Standard[b] Deviation (%) |
|---|---|---|---|---|
| Lemont | 9.5 | 64.6 | 0.571 | 0.039 |
| | 11.0 | 62.9 | 0.352 | 0.022 |
| | 12.5 | 60.4 | 0.251 | 0.007 |
| | 14.0 | 57.4 | 0.216 | 0.014 |
| Newbonnet | 9.5 | 67.9 | 0.813 | 0.034 |
| | 11.0 | 65.7 | 0.436 | 0.035 |
| | 12.5 | 64.0 | 0.259 | 0.012 |
| | 14.0 | 61.7 | 0.196 | 0.015 |

[a]Values are the average of five replicates.
[b]Values are the average of five surface-fat concentrations.

**TABLE II**
**Data for Predicted Surface Fat Concentration Equation**

| Coefficients | Standard Error of Estimates | Model Standard Error | $R^{2a}$ |
|---|---|---|---|
| $a0 = 1.0645$ | $s(a0) = 0.1035$ | 0.1325 | 0.8104 |
| $a1 = 1.1875$ | $s(a1) = 0.0959$ | | |
| $a2 = -0.0481$ | $s(a2) = 0.0057$ | | |
| $a3 = -0.0097$ | $s(a3) = 0.0004$ | | |
| $a4 = -0.0209$ | $s(a4) = 0.0014$ | | |
| $a5 = 0.0039$ | $s(a5) = 0.0005$ | | |
| $a6 = -0.0908$ | $s(a6) = 0.0081$ | | |

[a]Coefficient of multiple determination.

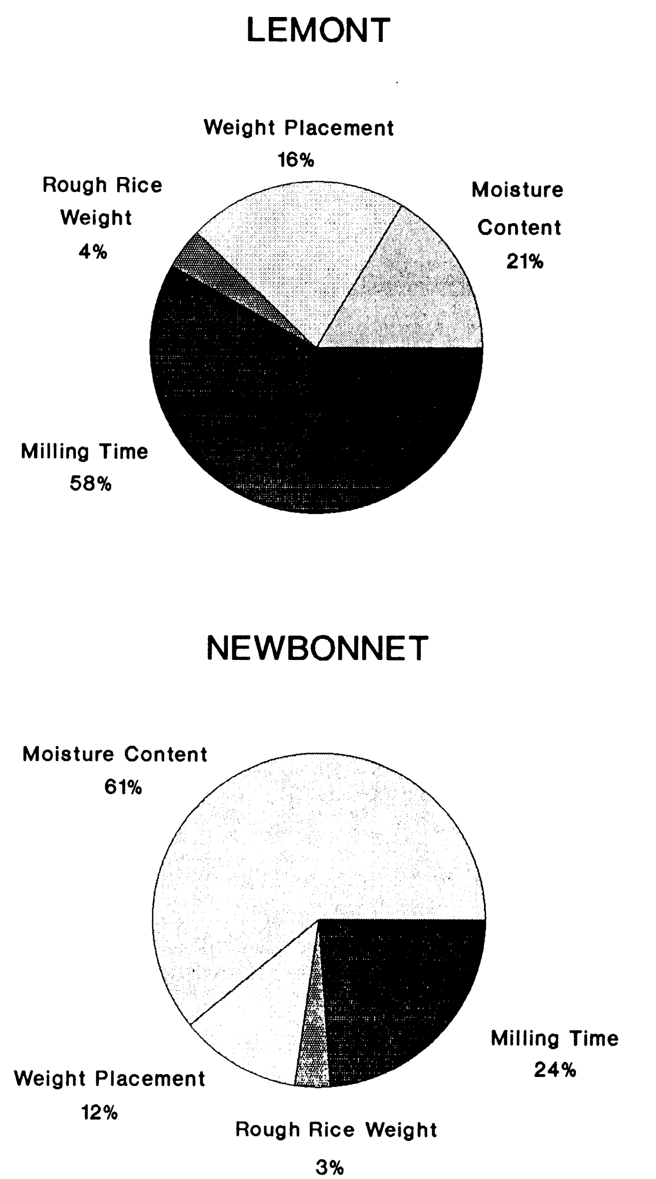


**Fig. 1.** Contributions of experimental variables that account for changes in surface fat concentration as indicated by sum of squares.

one possible source for the differences in experimental variable contributions between varieties. The average length, width, and thickness of 100 rough rice kernels of the Lemont variety were 7.08, 2.35, and 1.73 mm, respectively; the significantly different average length, width, and thickness of 100 Newbonnet rough rice kernels were 6.82, 2.06, and 1.59 mm, respectively (Andrews et al 1992).

Two variables, WP and RRW, are fixed at various levels in the response surfaces of the Lemont and Newbonnet varieties illustrated in Figures 2 and 3, respectively. The contours indicate that surface fat removal became more difficult as MC decreased. Generally, a 1% increase in MC produced a 0.13 and 0.05 percentage point decrease in SFC in Newbonnet and Lemont, respectively. Figures 2 and 3 also illustrate that WP and MT inversely affected SFC. A change in weight placement from 6 to 18 cm accounted for a decrease in SFC of approximately 0.22 percentage point. Similarly, an increase in MT from 15 to 60 sec caused a decrease in SFC of approximately 0.44 percentage points.

Figure 4 illustrates the influence of MC on SFC in the 1-kg samples milled by the FGIS to a well-milled DOM. This graph reveals that SFC is typically higher for low MC samples than it is for high MC samples. An increase in MC from 9.5 to 14% resulted in a SFC decrease of approximately 0.5 and 0.3 percentage points in Newbonnet and Lemont, respectively. Therefore, samples with a low MC have to be milled longer than high MC samples to achieve a desired DOM.

Figure 5 illustrates the relationship between SFC and HRY. Generally, HRY increased as SFC increased; conversely, the DOM decreased as HRY increased. The equation of the model predicting the HRY ($HRY_{pred}$) in Figure 5 is:

$$HRY_{pred} = b0 + b1 \times SFC \quad (3)$$

The regression coefficients $b0$ and $b1$ are given in Table III.

Figure 5 and Table III illustrate that a unit increase in SFC appears to cause a larger incremental change in HRY of 14% MC samples than it does in 9.5% MC samples. For example,

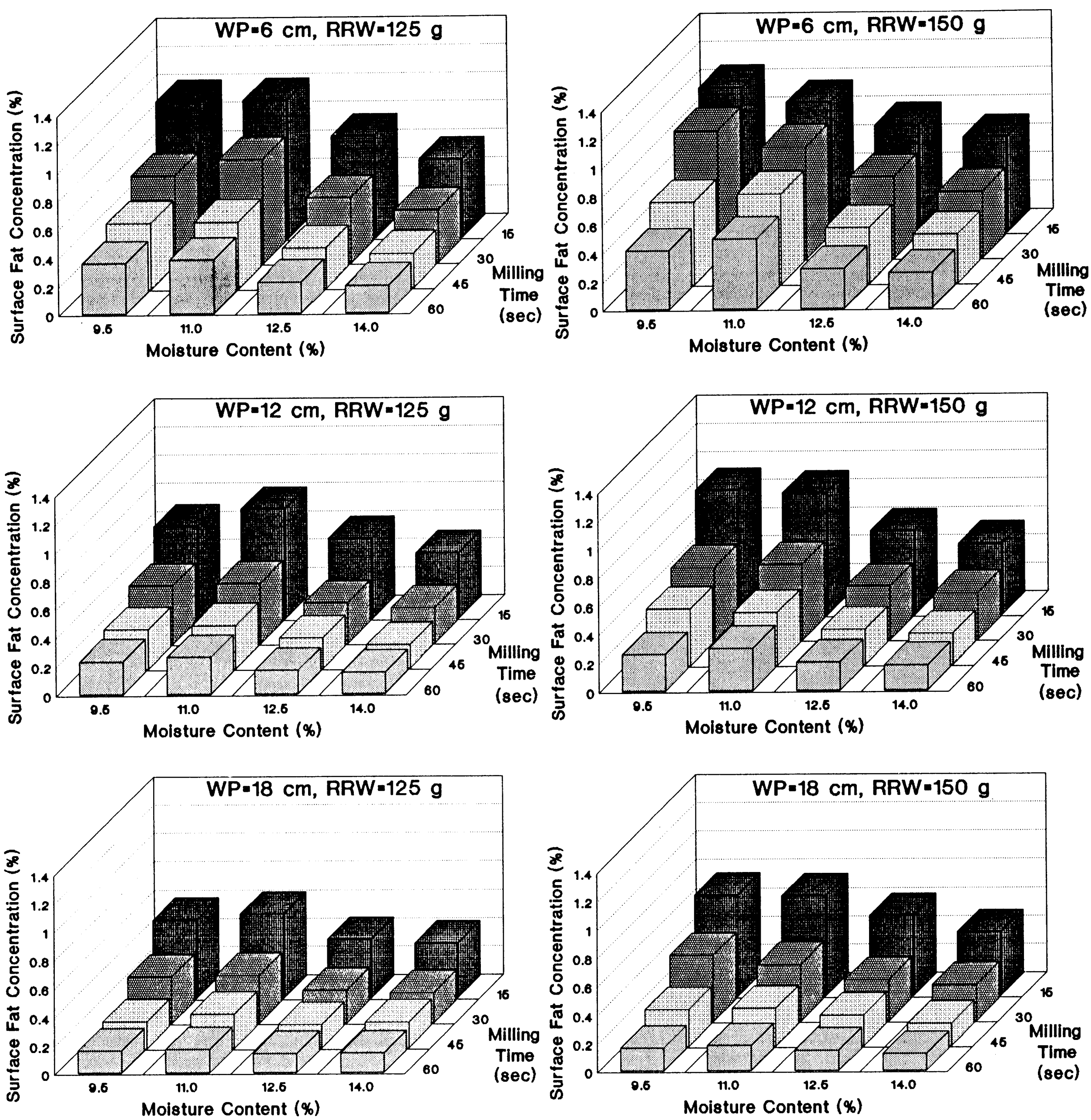


**Fig. 2.** Surface fat concentration response surfaces for Lemont rice milled in a McGill No. 2 miller. (WP = weight placement, RRW = rough rice weight).

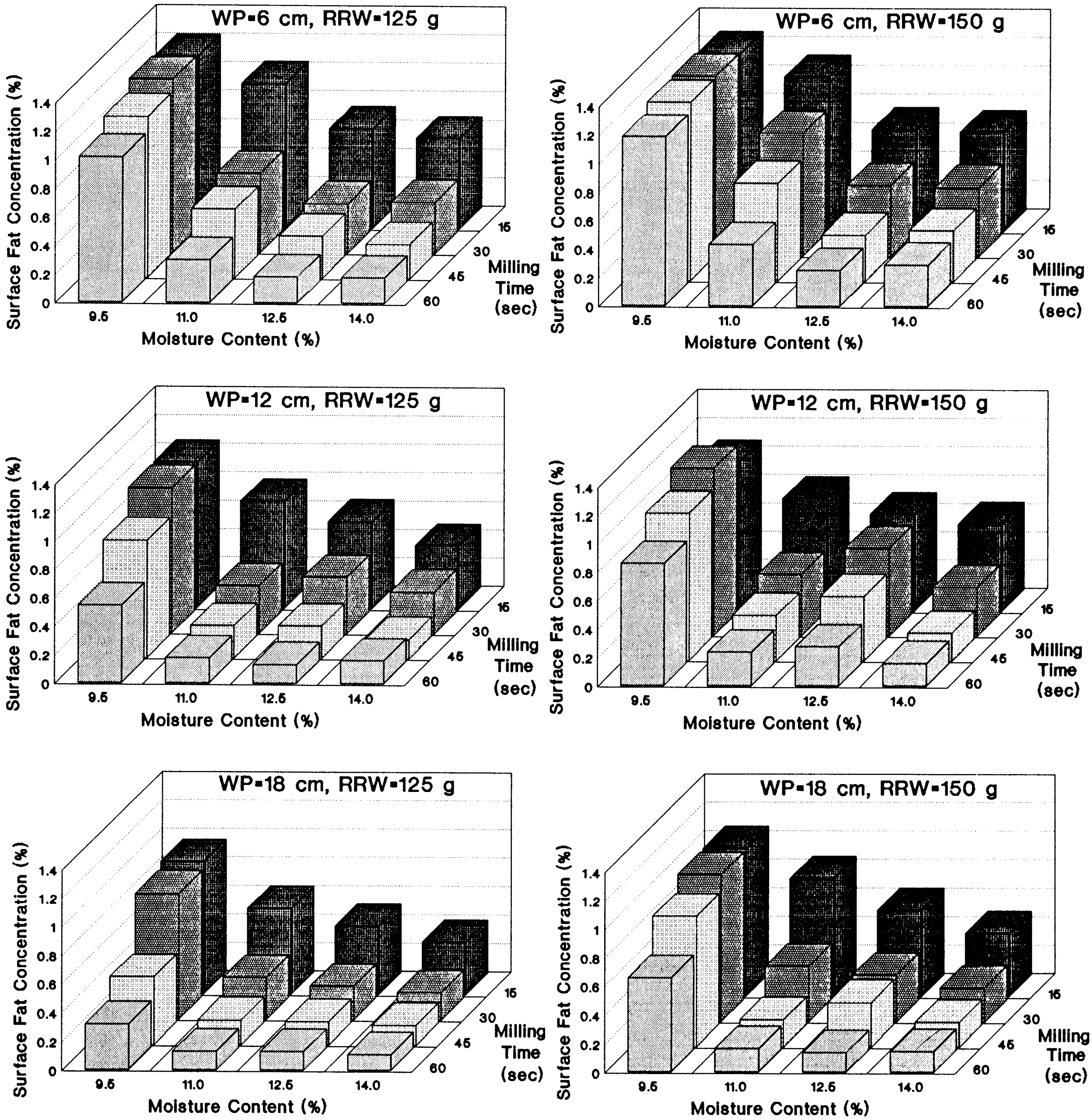


**Fig. 3.** Surface fat concentration response surfaces for Newbonnet rice milled in a McGill No. 2 miller. (WP = weight placement, RRW = rough rice weight).

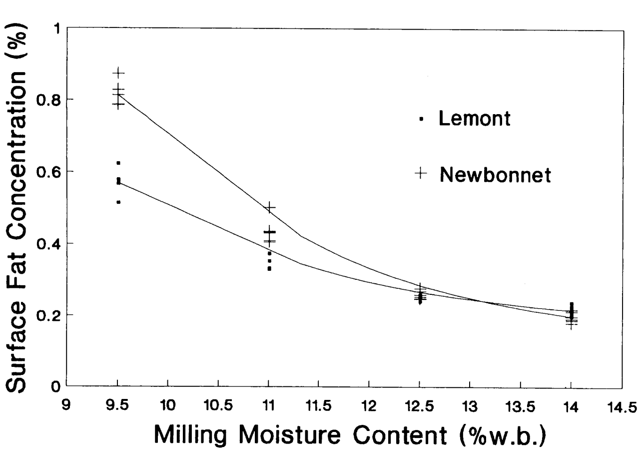


**Fig. 4.** Effects of moisture content on surface fat concentration of rice milled in a McGill No. 3 miller.

increasing the SFC of 14 and 9.5% MC Lemont rice from 0.5 to 0.7% results in an HRY increase of 6.04 and 2.24 percentage points, respectively. The values of *b*1 in Table III reveal that a unit increase in SFC of Lemont causes a larger incremental change in HRY than does a unit increase in SFC in Newbonnet. For instance, a 0.2 percentage point increase in SFC of 9.5% MC rice increased HRYs by 2.24 and 1.57 percentage points for Lemont and Newbonnet, respectively. Figure 5 also illustrates the potential consequences in HRY reduction associated with milling rice to lower SFCs. For example, milling 12.5% MC Lemont rice to a SFC of 0.7 and 0.4% produces HRYs of 63.6 and 58.1%, respectively. Table III reveals that the coefficient of multiple determination, $R^2$, was approximately 0.88 for Lemont at all MCs. However, $R^2$ was considerably lower (0.38–0.87) for Newbonnet.

Figure 5 and Table III also confirm the findings of Pominski et al (1961) that suggest higher HRY can be obtained by milling at low MC, even when rice samples are milled to the same SFC. For example, milling Lemont rice at 9.5 and 14% MC to an

SFC of 0.5% yields an HRY of 63.8 and 57.1%, respectively. These findings appear to contradict part of the research of Webb and Calderwood (1977), which suggests that HRY differences between low and high MC samples were greatly reduced or eliminated when mill settings were adjusted to obtain the same DOM.

## CONCLUSIONS

MC, variety, MT, pressure applied to the rice (WP), and sample size (RRW) significantly affect SFC. MT and MC were the most significant variables affecting the SFC in Lemont and Newbonnet varieties. SFC increased as MC decreased, indicating that bran removal became more difficult as MC decreased. For comparable miller settings, Lemont usually had a lower SFC than that of Newbonnet. MC, MT, and WP had an inverse effect on SFC. The 125-g samples usually had a lower SFC, and thus achieved a greater DOM, than that of the 150-g samples.

High HRYs were obtained in samples that were not as well milled (higher SFC). High MCs typically produced larger incremental changes in HRY for a unit change in SFC than did low MCs. Milling at low MCs typically produced high HRYs, even when differences in SFC were taken into account. Lemont typically had a larger increase in HRY than did Newbonnet for a given incremental increase in SFC. Both SFC and HRY increased as MC decreased.

**TABLE III**
**Data for Predicted Head Rice Yield (HRY) Equation**

| Variety | Moisture Content, % | Regression Coefficients | | $R^{2}$ [a] | Model Standard Error |
|---|---|---|---|---|---|
| | | *b0* | *b1* | | |
| Lemont | 9.5 | 56.6401006 | 11.2228490 | 0.888 | 1.067 |
| | 11.0 | 54.7043210 | 13.3207319 | 0.883 | 1.214 |
| | 12.5 | 50.7254537 | 18.4298269 | 0.865 | 1.390 |
| | 14.0 | 41.9603206 | 30.2129335 | 0.894 | 1.593 |
| Newbonnet | 9.5 | 59.9054196 | 7.86950565 | 0.868 | 0.800 |
| | 11.0 | 54.4919953 | 13.6715251 | 0.735 | 2.411 |
| | 12.5 | 53.6629263 | 13.8380059 | 0.379 | 3.517 |
| | 14.0 | 47.8880219 | 25.1682347 | 0.665 | 3.140 |

[a] Coefficient of multiple determination.

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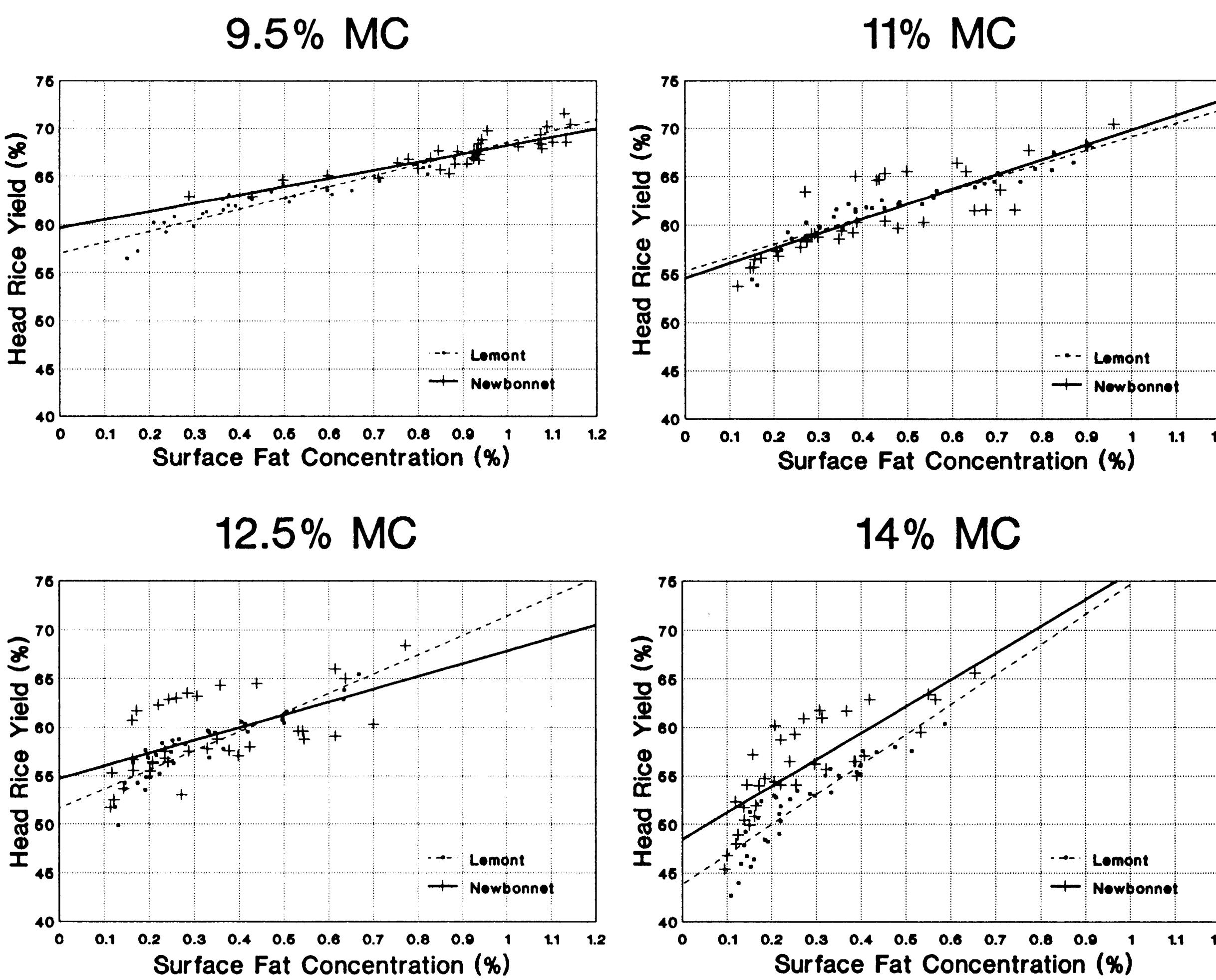


Fig. 5. Relationship between head rice yield and surface fat concentration for Newbonnet and Lemont rice milled at different moisture contents (MC).

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