

Prediction of Sugar-Snap Cookie Diameter Using Sucrose Solvent Retention Capacity, Milling Softness, and Flour Protein Content

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ABSTRACT

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During testing of wheats at the early generation developmental stage, often there is not enough seed to mill for bake testing products such as sugar-snap cookie diameter. This study reports a prediction equation for sugar-snap cookie diameter that uses sucrose solvent retention capacity (SRC), wheat milling softness, and flour protein content. A total of 507 wheats were milled using three laboratory milling systems (short, medium,

and long mill flow). Prediction equations were similar for all three mills. Standard errors of prediction were <2% of the mean estimate of cookie diameter. Additional observations eliminated lactic acid SRC (an indication of glutenin strength), alkaline water retention capacity (a traditional predictor of pastry quality), and flour yield (the main milling quality characteristic) from the prediction model.

In the eastern half of the United States, sugar-snap cookie diameter has been used for 65 years to predict the potential performance of breeders' soft wheats for pastry-type end-use applications such as cookies, crackers, cakes, pies, and Danish pastries. Softer wheats that are lower in protein content tend to make larger cookies and have been highly suited for the pastry market (Finney et al 1987; Finney 1989). However, during testing of wheats at the early generation developmental stage, often there is not enough seed to mill into flour for bake testing of cookie diameter.

A solvent retention capacity (SRC) test method using four solvents (water, sucrose, lactic acid, and sodium carbonate) was published by Approved Method 56-11 (AACC 2000) after Slade and Levine (1994). The percentage of weight increase after centrifugation is the SRC value for each solvent. Generally, lactic acid SRC is associated with glutenin characteristics, sodium carbonate SRC is associated with levels of damaged starch, sucrose SRC is associated with gliadin, and pentosan characteristics, and water SRC is influenced by all of those flour constituents (Slade and Levine 1994; Gaines 2000). All four SRC values differentiate among wheat cultivars across environmental effects with limited genotype × environment interaction (Guttieri et al 2001, 2002). The methods were recently micronized and successfully applied to the evaluation of whole meals by Bettge et al (2002) and used as early-generation screening tools. The four SRC values are particularly effective when evaluated as a pattern of four values and correlated with product end-use parameters (Slade and Levine 1994; Gaines 2000).

Three test mills were used because mills produce characteristic evaluations of kernel softness and because kernel softness was expected to be a potentially important component of the prediction. The shortest flow system was a single Brabender Jr. mill, which makes three automatic passes, which does not produce flour in quantity sufficient to bake cookies. The intermediate length flow mill was a dual Brabender Jr. milling system (six passes) which does produce sufficient flour for baking cookies because more wheat is milled. The longest flow mill is an Allis-Chalmers four-stand milling system (15–20 passes), which also produces sufficient flour for baking cookies. Each milling system produces

a small but consistent effect on most measurable characteristics of flour quality, although each mill ranks the heritable milling qualities of wheats similarly. Specifically, each mill produces a unique combination of flour particle size, ash content, and damaged starch that collectively influence sugar-snap cookie diameter (Gaines 1985).

Sugar-snap cookie diameter is an excellent indicator of general soft wheat pastry baking quality (Finney and Andrews 1986). Yet among modern soft wheats, a method has not been available that predicts sugar-snap cookie diameter among early-generation soft wheat test lines, a developmental stage at which flour quantity is insufficient to bake cookies. The objective of this study was to develop a multiple linear regression equation to apply during micro-testing to predict sugar-snap cookie diameter as a screening tool for breeders' micro samples.

MATERIALS AND METHODS

Wheats and Milling Procedures

Three milling procedures were used to evaluate a total of 443 soft red and soft winter wheats variously grown in six states (Kentucky, Michigan, Missouri, New York, Ohio, or Virginia) from six crop years (1994, 1996, 1997, 1998, 1999, and 2001). The Allis-Chalmers milling system (Approved Method 26-32 AACC 2000; Yamazaki and Andrews 1982) was utilized to mill 128 wheats from 118 soft wheat cultivars. A dual Quadrumat Jr. (Brabender Instruments, South Hackensack, NJ) milling system (Finney and Andrews 1986) was utilized to mill 315 wheats from 287 soft wheats and test lines. A single Quadrumat Jr. mill (Approved Method 26-50 AACC 2000) as modified by Finney and Andrews (1986) and described by Gaines et al (2000) and was used to mill 64 of the wheats milled by the Allis-Chalmers milling system. The Allis-Chalmers milling system (15–20 passes) will be referred to as the long flow mill system, the dual Quadrumat Jr. milling system (six passes) will be referred to as the intermediate flow milling system, and the single Quadrumat Jr. milling system (three pass) will be referred to as the short flow milling system. Softness equivalent (SE) was calculated from both Quadrumat Jr. milling systems according to Finney and Andrews (1986) and Gaines et al (2000). SE is highly correlated with break flour yield from a larger mill.

Three additional validation wheat sets were evaluated by milling them using the short flow milling system and predicting baking quality scores and by using the intermediate flow milling system and producing enough flour to bake sugar-snap cookies. The three nurseries contained 36, 37, and 41 soft wheat developmental lines or released cultivars.

Analytical Tests

Wheat test weight was determined using Approved Method 55-10 (AACC 2000). Sucrose and lactic acid SRC values were deter-

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mined using Approved Method 56-11. Alkaline water retention capacity (AWRC) was determined using Approved Method 56-10. Flour protein content was determined using Approved Method 46-12. Sugar-snap cookie diameter was determined using Approved Method 10-52. Cookie diameter was expressed as the mean diameter of two cookies.

Statistical Analysis

Analytical tests were duplicated per sample and were analyzed using Statistica 6.1 for Windows PC (StatSoft, Inc., Tulsa, OK). Multiple linear regression modeling of the mean sample data was accomplished using a simple least squares model. Best-fit linear regression models were determined using backward variable elimination and *t*-tests on independent variables selected for inclusion in the models. Models were evaluated for predicted value residual errors and linearity. Simple linear correlation coefficients and intercepts for selected models were determined when appropriate.

RESULTS AND DISCUSSION

Each of the three milling systems studied mills different amount of grain depending on the different development stage of the soft wheat test lines and the amount of grain available. Flours from each mill were evaluated separately. Mean and range values for all analytical evaluations for each mill are shown in Table I. Milling system influenced mean sucrose SRC and lactic acid SRC values.

Long Flow Milling System Flours

Using the long flow milling system, sugar-snap cookie diameter was significantly correlated with sucrose SRC, protein content, break flour yield, lactic acid SRC, and flour yield (−0.66, −0.55, 0.54, −0.42, and 0.28, respectively) (Table II). The best-fit regression model for predicting sugar-snap cookie diameter using long flow milling system flours was

$$CD = 22.78 - 0.065(SSRC) - 0.123(P) + 0.051(BFY) \quad (1)$$

where CD is sugar-snap cookie diameter, SSRC is sucrose solvent retention capacity, P is flour protein content, and BFY is break flour yield. The multiple linear regression model had an adjusted R^2 of 0.66 ($P < 0.0001$) and a standard error of estimate of 0.26 cm (1.5% of the mean diameter of two cookies).

Intermediate Flow Milling System Flours

Using the intermediate flow milling system, sugar-snap cookie diameter significantly correlated with sucrose SRC, protein content, lactic acid SRC, flour yield, and softness equivalent (−0.56, −0.52, −0.45, 0.28, and 0.18, respectively) (Table II). The best-fit multiple linear regression model for predicting sugar-snap cookie diameter from the intermediate flow milling system flours was

$$CD = 22.8 - 0.055(SSRC) - 0.28(P) + 0.045(SE) \quad (2)$$

where CD is sugar-snap cookie diameter, SSRC is sucrose solvent retention capacity, P is flour protein content, and SE is softness equivalent. The multiple linear regression model had an adjusted R^2 of 0.59 ($P < 0.0001$) and a standard error of estimate of 0.35 cm (1.9% of the mean diameter of two cookies).

Short Flow Milling System Flours

The sucrose SRC correlation coefficient between flours milled on the short flow milling system and flours milled on the long flow milling system was 0.81 ($P < 0.01$). The short flow milling system does not produce sufficient flour for cookie baking, however sugar-snap cookie diameters produced from a subset of the long flow milling system flours were significantly correlated with several short flow milling system flour values (i.e., flour yield, softness equivalent, and sucrose SRC [0.58, 0.53, and −0.46, respectively]) (Table II). The best-fit multiple linear regression model for predicting the sugar-snap cookie diameter of long flow milling system flours was

$$CD_{LF} = 21.9 - 0.070(SSRC_{SF}) - 0.145(P_{SF}) + 0.049(SE_{SF}) \quad (3)$$

TABLE I
Mean (14% mb), Standard Deviation, Range, and Quartile Range of Wheat and Flour Quality Characteristics from Three Milling Systems

Mill	Mean	Standard Deviation	Range	Quartile Range
Allis-Chalmers (<i>n</i> = 128)				
Test weight (lb/bu)	62.2	1.3	6.9	1.9
Protein (%)	9.6	1.0	5.0	1.3
Flour yield (%)	77.2	1.1	5.5	1.3
Break flour yield (%)	30.5	3.0	18.6	3.7
AWRC (%) ^a	55.5	2.1	9.7	3.3
Cookie diameter (cm)	17.6	0.5	1.9	0.6
Lactic acid SRC (%) ^b	93.2	12.7	55.1	17.2
Sucrose SRC (%)	85.5	3.6	16.8	5.7
Dual Quadrumat Jr. (<i>n</i> = 315)				
Test weight (lb/bu)	64.1	1.2	6.3	1.8
Protein (%)	8.3	0.9	4.3	1.3
Flour yield (%)	71.9	1.2	7.4	1.5
Softness equivalent (%)	55.2	3.3	19.1	4.3
AWRC (%)	58.0	2.8	21.7	3.3
Cookie diameter (cm)	18.0	0.5	2.7	0.8
Lactic acid SRC (%)	105.4	15.8	83.3	21.0
Sucrose SRC (%)	90.0	5.3	33.0	6.3
Single Quadrumat Jr. (<i>n</i> = 64)				
Test weight (lb/bu)	62.4	1.2	6.2	1.8
Protein (%)	9.4	0.9	5.0	1.3
Flour yield (%)	71.2	1.3	5.2	1.9
Softness equivalent (%)	52.8	3.7	19.3	4.5
AWRC (%)	55.8	1.9	7.5	2.6
Cookie diameter (cm)	17.6	0.4	1.5	0.6
Lactic acid SRC (%)	87.0	10.1	48.1	14.0
Sucrose SRC (%)	77.8	3.2	12.8	5.0

^a Alkaline water retention capacity (AWRC).

^b Solvent retention capacity (SRC).

where CD_{LF} is sugar-snap cookie diameter from long flow milling system flours, $SSRC_{SF}$ is the sucrose solvent retention capacity from short flow milling system flours, P_{SF} is protein content from short flow milling system flours, and SE_{SF} is softness equivalent from the short flow milling system. The multiple linear regression model had an adjusted R^2 of 0.58 ($P < 0.0001$) and a standard error of estimate of 0.27 cm (1.5% of the mean diameter of two cookies). Sucrose SRC values of the short and long flow milling systems were significantly correlated at 0.82 ($P < 0.0001$).

Validation Sets

The baking scores from milling three additional nurseries using the short flow milling system were validated against sugar-snap cookie diameters produced by milling the same wheats using the intermediate flow milling system. Baking scores were produced using the short flow milling system equation. Within each nursery, ranges in baking score were 35, 41, and 52, and ranges in cookie diameter were 2.0, 2.5, and 2.7 cm. R^2 values for the correlations were 0.40, 0.51, and 0.58, the later of which was the same as that produced by the original regression equation sample set.

Lactic Acid SRC and AWRC

AWRC has been used to assist selection of soft wheat test lines by distinguishing between wheats with hard or soft wheat characteristics. Between those classes, it is correlated with sugar-snap cookie diameter (Finney and Andrews 1986). However, among the genuinely soft wheats, it is not well correlated with cookie diameter as demonstrated by the three wheat sets studied. In contrast to AWRC, sucrose SRC was correlated with sugar-snap cookie diameter. An additional observation was that the mean sucrose SRC values for the same wheats milled on both the long and the short flow milling systems was 77.8 and 84.8%, respectively. That indicates that a direct comparison of sucrose SRC values should be made within a particular milling system.

Lactic acid SRC indicates relative strength of gluten proteins, but it was not selected to be included in multiple linear regression

best-fit modeling of sugar-snap cookie diameter. However, it was negatively correlated with cookie diameter. That suggests that some stronger gluten soft wheats have diminished pastry baking potential, even though they have increased potential for products that require stronger gluten, such as crackers, flat breads, baguettes, etc.

CONCLUSIONS

Sugar-snap cookie diameter, which predicts general pastry baking quality, can be predicted by a simple regression equation with independent variables sucrose SRC, flour protein content, and a milling estimate of kernel softness. The prediction improves the estimation pastry baking potential of soft wheats when wheat and flour quantities are insufficient for a baking evaluation test.

The short flow milling system produced flour yield and softness equivalent values that were significantly correlated with long flow milling system flour yield and break flour values (0.81 and 0.93, respectively, $P < 0.0001$). It was only with the intermediate flow milling system that there was a very low significant correlation between flour yield and kernel texture (softness equivalent) and no significant correlation for the long and the short flow milling systems. It is both naturally and commercially correct that there should be no correlation between kernel texture and flour yield. That is because milling characteristics such as flour yield are highly genetically controlled (Campbell et al 2001; Collaku et al 2002), and environmental factors must first be removed from the milling process (Gaines et al 2000) to reveal cultivar milling qualities. We suggest that milling systems and methods that have a statistical correlation of kernel texture on flour yield are not balanced and report erroneous flour yield values.

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TABLE II
Significant ($P = 0.05$) Correlation Coefficients Among Milling and Flour Analytical Values for Short, Intermediate, and Long Flow Milling

System	Test Weight	Protein	Flour Yield	Break Flour Yield or SE	AWRC	Cookie Diameter	Lactic Acid SRC	Sucrose SRC
Long flow milling ($n = 128$)								
Test weight	1.00							
Protein	0.23	1.00						
Flour yield			1.00					
Break flour yield	-0.30	-0.35		1.00				
AWRC ^a	0.43				1.00			
Cookie diameter		-0.55	0.28	0.54		1.00		
Lactic acid SRC ^b		0.43	-0.27			-0.42	1.00	
Sucrose SRC		0.31	-0.55	-0.19	0.26	-0.66	0.59	1.00
Intermediate flow milling ($n = 315$)								
Test weight	1.00							
Protein	-0.18	1.00						
Flour yield			1.00					
Softness equivalent	-0.18		0.19	1.00				
AWRC		-0.28	-0.35	-0.22	1.00			
Cookie diameter		-0.52	0.28	0.18	-0.14	1.00		
Lactic acid SRC		0.59		0.23	-0.17	-0.45	1.00	
Sucrose SRC		0.13	-0.36		0.25	-0.56	0.40	1.00
Short flow milling ($n = 64$)								
Test weight	1.00							
Protein	0.39	1.00						
Flour yield			1.00					
Softness equivalent	-0.30	-0.39		1.00				
AWRC	0.47	0.36			1.00			
Cookie diameter		-0.46	0.58	0.53		1.00		
Lactic acid SRC		0.55	-0.36			-0.43	1.00	
Sucrose SRC			-0.64			-0.46	0.44	1.00

^a Alkaline water retention capacity (AWRC).

^b Solvent retention capacity (SRC).

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