Collaborative Study on Updated Method 10-52: Baking Quality of Cookie Flour—Micro Method (Sugar-Snap Cookie)[1]

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In order to estimate the potential end-use quality of wheat and wheat flour, a plenitude of methods have been devised over the years. In fact, the American Association of Cereal Chemists was originally organized in 1915 partly to bring order, coherence, and standardization to all of the methods that existed at that time. Since that time, many new methods have been devised. Although these methods addressed the analytical needs of the time very well, it behooves the members of the scientific community to revisit existing methodology now and then to ensure that the methods that once functioned continue to do so.

Many of the methods in the *AACC International Approved Methods of Analysis* analyze various individual physical and biochemical facets and components of cereal grains. Information on each component assists in understanding the nature and potential performance of a particular sample of grain. However, in order to measure the full impact of all the interactions among the array of endogenous components, baking or other end-use tests must be performed.

One such test, which has existed since the 1950s, is AACC Intl. Method 10-52: Baking Quality of Cookie Flour—Micro Method. This method is more commonly referred to as the "micro sugar-snap cookie method."

The method, as it existed for many years, included flour and a base amount of water that also carried chemical leavening agents, plus a small additional amount (11–22%) of water for "protein compensation" (in practical ranges of flour protein content). Although the method dated from the early 1950s (3), it was only approved in 1985 (1,2) and re-approved in 1999. Originally used for cultivar development work, in which protein content varied greatly among undifferentiated, unselected wheat varieties, compensating for protein content seemed to provide better discrimination among early-generation breeding lines. The reason for varying the water based on protein content may have been due more to attempts to compensate for differences in, and the confounding problem of, protein quality versus quantity, but this was poorly understood in the early 1950s (4). As wheat breeders became more discriminating in their crosses and more adept at applying selection pressure for quality at earlier generations through biochemical and molecular biological techniques, assisted by cereal chemists in the quality-testing laboratories, the reasons for varying the water content based on protein content were minimized.

Additionally, in the approval report for the original method, one criterion was to maintain a constant dough-handling consistency, at the time assumed to depend on the water-holding capacity of a particular flour. However, water-holding capacity is related to several factors, such as endogenous flour components like damaged starch, arabinoxylans, and glutenins, plus the effect of flour treatments, such as chlorination, and milling procedures. But total flour protein content itself had little to no effect on flour functionality, with respect to cookie-baking performance or product quality. Moreover, dough consistency isn't related to cookie-baking performance or product quality. Consequently, the additional adjustment of the water level in the formula, based on total flour protein content, results in experimental variation that is not related to flour functionality. As a result, diagnostic evaluation of the baking quality of cookie flours is impaired if the original method is used.

This method, especially when used on western U.S. wheat flours, produces dough that is so dry as to be unmanageable crumbles and cookies that are irregularly shaped and small, with large crevasses and cracks. Uniformly round, and thus easily measured cookies, are seldom seen in early-generation testing where wider phenotypic variation is observed. Therefore, cultivar development labs began to "tweak" the formulation to produce more uniform cookies by increasing the amount of water added. Furthermore, the modified methods used exactly the same ingredients and hydration levels for all cookies without adjusting hydration for protein content, as recommended by the approved method. Unfortunately, the various laboratories all came up with different versions of the basic method, as revealed by an informal survey by the AACC Intl. Soft Wheat and Flour Products Technical Committee (SWFP) of laboratories routinely using the method.

One modified method used a constant total of 166% added water beyond that specified in the original method. This method produced doughs that tended to be sticky. The resulting cookies, however, were uniform in geometry (no oval cookies; no large edge cracks) and exhibited a range of differences in diameter. Another laboratory's modification was to boost the water content to a constant total of 133% added water beyond that of the original method. This modification produced reasonable doughs and a good range of diameters. Other modifications included using somewhat less flour than that specified in the original method, and holding the hydration level constant among flours. Examples of the results of some of the modifications in use by various laboratories are shown in Figure 1. Three flours were used for this example; good, adequate, and poor baking quality flours were used at four hydration levels: the base hydration from addition of leavening solutions; the hydration level of the AACC Intl. method as it previously existed; the hydration level used in the current collaborative; and the hydration level used by the laboratory with the greatest amount of added water. Presented also are the cookie diameters for each of the treatments.

A further problem with the various water and flour contents was that the sugar syrup concentration and total amount varied,

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adding an additional, uncontrolled variable to the test. Varying the flour content changed the amount of sugar syrup available. Increasing the added water or varying the water to “adjust for protein” changed both the sugar syrup amount and concentration (5).

Briefly, cookie geometry is dependent on the interaction among endogenous compounds within the flour and formulation ingredients. The sugar-snap cookie formulation establishes a competition for water primarily among arabinoxylans (both water extractable and unextractable), damaged starch, and protein fractions (6). The formulation should be balanced so that differences in flour composition are revealed by the test and the suitability of a particular wheat variety or flour lot for cookie baking becomes manifest. Research has demonstrated that cookie geometry (diameter and height, as well as surface cracking) is dependent on both the syrup concentration and the total amount of syrup in the formulation. Varying the water content among cookies leads to differences in the critical concentration and content of the sugar syrup and hence affects the outcome of the competition for water among the various endogenous components and ingredients. To reliably compare different flours, a constant formulation is critical.

At the 2007 San Antonio, TX, U.S.A., meeting of the SWFP, some time was devoted to discussing a potential modification, through reformulation, of Method 10-52: Baking Quality of Cookie Flour—Micro Method. The committee decided that the University of Idaho Quality Lab, Aberdeen, ID, U.S.A., and the USDA-ARS Wheat Quality Labs in Wooster, OH, U.S.A. (SWQL), and in Pullman, WA, U.S.A. (WWQL), would conduct a minicollaborative of several iterations of the current method 10-52. This minicollab was conducted and the results reviewed at the AACC Intl. Pacific Northwest Section meeting in Portland, OR, U.S.A., January 2008. Several flours, representing a known range of cookie-baking quality, were used to evaluate five different formulations for cookie baking, including the current method 10-52.

After considering the results of the minicollab at that meeting, it was determined that a formulation using a constant amount of water greater than the existing approved method recommended produced the best results in terms of producing a range of cookie diameters, as well as producing doughs that were easily handled. The range of diameters and the magnitude of average diameter were the greatest at 8.7-mL total water, as opposed to the current method, or using more (166%) water or decreasing flour weight.

Additionally, the resulting sugar syrup concentration, created by using a constant amount of total water (when the flour is at 14% moisture) that is 145% that of the original method, brings the micro sugar-snap cookie method into agreement with the sugar syrup concentration of the macro version cookie-baking method 10-50D. Furthermore, the use of a greater volume of water minimized differences among labs, in that the cookies’ ranking was essentially the same across the participating labs (which varied in altitude from 1,100 to 4,500 ft [335 to 1,375 m] of altitude). The absolute diameters among labs were statistically significantly different, but in “real” terms were not meaningfully different and the cookies were ranked in the same order as measured by diameter.

Having multiple versions of an approved method being used for both routine and research use contributes to confusion and difficulty in interpreting and comparing results among labs. This situation clearly represented a need, as established at the inception of the American Association of Cereal Chemists, to develop common methodology and to revisit existing methods as time passed and needs changed. The committee therefore voted to engage in a collaborative test. The collaborative involved 12 participating laboratories, each of which baked a total of 18 cookies using the new method. The data collected were the average diameter and stack height of the paired cookies that resulted from each bake test and the weight loss from dough to cookie during baking. The 18 flours baked into cookies represented about a half day of baking in most labs.

Materials and Methods

Flour samples (Table I) were obtained from the USDA-ARS SWQL and WWQL. All were milled on Miag Multimat pilot mills. Samples were selected from current eastern U.S. and Pacific Northwest cultivars, as opposed to varieties under development. Hence, all of the flour used in this study is within a range

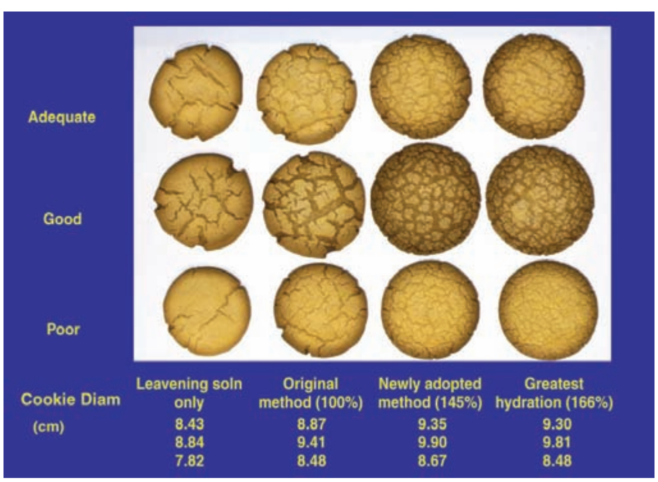

Fig 1. Cookies made with three flours representing good, adequate, and poor baking quality at four hydration levels: base hydration level from addition of leavening solutions; hydration level as indicated in the previous AACC International method; hydration level used in collaborative studies of the current method; and the highest hydration level used. Cookie diameters (in centimeters) are given below each column for each of the treatments.

Table I. Cultivars tested and proximate analysis

Sample #	Source[a]	Cultivar	BlindDup[b]	Protein[c]	Moisture (%)
1	WWQL	Louise	no	8.0	11.5
2	WWQL	Alturas	no	8.6	11.2
3	WWQL	ORCF102	no	8.7	10.9
4	WWQL	ID93-64901A	no	8.5	10.6
5	WWQL	Eltan	no	8.6	10.3
6	WWQL	Cataldo	no	10.4	9.9
7	SWQL	AGS2000	no	10.5	13.7
8	SWQL	USG3209	no	7.4	14.2
9	SWQL	Jamestown	no	8.5	14.7
10	SWQL	MPV57	no	7.9	13.8
11	SWQL	D8006	no	7.5	14.6
12	SWQL	Jewel	no	7.8	13.7
13	WWQL	ORCF102	yes	8.7	10.8
14	WWQL	ID93-64901A	yes	8.5	10.6
15	WWQL	Eltan	yes	8.6	10.3
16	SWQL	USG3209	yes	7.4	14.2
17	SWQL	Jamestown	yes	8.5	14.7
18	SWQL	D8006	yes	7.5	14.5

[a] Flour source: USDA-ARS Western Wheat Quality Laboratory (WWQL) and USDA-ARS Soft Wheat Quality Laboratory (SWQL).
[b] Flour an internal, blind duplicate for calculation of repeatability.
[c] 14% moisture basis.

of quality that might be expected to be encountered in commercial marketing channels. Much greater variation in cookie quality is seen in early-generation varieties; since the proposed method illuminates differences among flours derived from cultivars, it would certainly be expected to expose quality deficiencies in wheat undergoing cultivar development testing.

Blind duplicates, necessary to the analysis of the results of the collaborative, were provided by incorporating six duplicate flour samples (samples 13–18; Table I). Samples were sent to 12 laboratories for baking as part of the collaborative testing.

The modified formulation and procedure can be obtained through the *AACC International Approved Methods of Analysis* online version. Since flour is weighed on a 14% moisture basis to ensure that the dry matter content is the same in each cookie bake, the amount weighed necessarily varies depending on the moisture of the flour. However, the differences in moisture content must be adjusted in order to maintain a constant sugar syrup concentration and amount. When flour's moisture content is less than 14%, and most soft wheat flour is, an upward adjustment in the amount of water added must be made so that the total amount of sugar syrup and the concentration of the syrup remain the same for all samples.

A major impediment to recruiting more participants to the collaborative was the need to use a 35-g cookie-dough mixer. This is apparently a relatively uncommon instrument, used primarily in cultivar development labs where large numbers of samples, of limited amounts of available flour, are processed. Substitutions of other mixers that do not use a planetary motion of pins will not provide the same mixing energy or degree of mixing.

Laboratories were asked to report baking weight loss, cookie diameter, and cookie height. Each cookie formulation was used to bake two cookies; therefore, each reported value is the average of repeated measures of the two cookies created in each bake, divided by two. Summary data for each cookie are shown in Table II.

Outlier detection for each reported value was calculated from *z*-scores (the number of standard deviations each laboratory was from the overall mean for each value). The *z*-score is calculated as $z = (x - \mu)/\sigma$, where x = laboratory mean, μ = mean of all laboratories, and σ = standard deviation of all data. If the *z*-score of a particular lab exceeded 2, that laboratory's data for that variable were deleted and the repeatability and reproducibility calculations were then calculated.

Analysis of the results was conducted using PC-SAS v.9.1.3 in conjunction with the AACC Intl. Technical Committee statistician. An ANOVA model (Table III) was used to generate the repeatability and reproducibility statistics required for collaboratives. Repeatability, the ability of one lab to obtain the same measure on the same sample (i.e., blind duplicates), is the mean square error for the model (Table III). Reproducibility, the ability to obtain the same measure among collaborating labs, is (mean square error + mean square error for collaborator)/2. The SAS code used to generate the a) analysis; b) statistical models and results for moisture loss; c) cookie diameter; and d) cookie height are shown in Table III.

Table II. Summary statistics; mean values

Sample	N[a]	Weight Loss (%)	Cookie Diameter (cm)	Cookie Height (cm)
1	11	14.34	9.01	0.69
2	11	14.68	8.88	0.75
3	22	13.34	8.46	0.84
4	22	13.69	8.84	0.71
5	22	13.69	8.68	0.74
6	11	13.09	8.43	0.83
7	11	13.17	8.42	0.82
8	22	13.83	8.43	0.80
9	22	13.59	8.51	0.77
10	11	13.84	9.05	0.65
11	22	13.87	9.02	0.65
12	11	14.06	8.68	0.74
Mean		13.73	8.68	0.75

[a]N = number of samples baked.

Results and Discussion

Twelve laboratories reported results from the baking. Cookie diameter, cookie height, and weight loss during baking were the data reported. Historically, cookie diameter has been the most frequently reported parameter from sugar-snap cookie baking. Cookie height is closely related to diameter and generally seen as a redundant variable. The correlation between cookie diameter and cookie height was $r = 0.94$. Weight loss has been regarded as an optional measurement.

For various reasons, some of the collaborators were unable to furnish complete sets of results. All participants provided complete data for the variable cookie diameter. However, one lab was judged to be an outlier for cookie diameter and height. Those data were excluded from the calculations. Otherwise, all data were within the 2-*z*-score range of acceptability. The number of labs included in the analyses were greater than the number needed to be acceptable for purposes of collaboratives, according to the AACC Intl. guidelines.

The critical parameters of repeatability and reproducibility were calculated and are quite good. Repeatability refers to the ability of a single lab to produce the same value on the same sample twice. The repeatability for weight loss was 1.44; for cookie diameter was 0.04; and for cookie height was 0.002.

The reproducibility index describes the ability of different laboratories to obtain the same value for the same sample. Given the variables among laboratories (altitude, differing ovens, and slightly different lab technique and ingredients), the reproducibility index incorporates a great many variables that are apt to be encountered in common use of the method. The reproducibility index is expected to be greater than the repeatability index. In the case of this modified baking method, the reproducibility index for weight loss was 27.5; for cookie diameter was 0.61; and for cookie height was 0.05.

Weight loss was most problematic in terms of repeatability and reproducibility. In a reel oven, even one additional turn of the reel was sufficient to impact the amount of water lost. Given that the shelf with a particular cookie on it could be anywhere in a revolution at the end of the baking time, moisture loss could depend somewhat on the random factor of how much oven time the cookie actually experienced. Unless bake time can be strictly controlled, weight loss will be a factor with too much variation for routine use.

As an additional measure of the quality of the method, the level of significance of the interaction term between sample and collaborator was obtained (Table III). There was no significant interaction between sample and collaborator for any of the three variables measured. In other words, no systematic interaction was a significant part of the method.

Qualitatively, the new formulation allows for better-handling dough and, judging from the results of the collaborative and the preceding minicollab, provides for cookie diameters that are larger than the current method. Additionally, methods that include more water led to smaller cookies, likely because the increased amount of water allowed some gluten formation that otherwise would not occur in such a high-fat, high-sugar formulation.

Table III. Results of modified AACC International Method 10-52

a. SAS Code for Analysis

```
Proc glm;
Class sample collaborator;
Model weight loss diameter height = sample | collaborator;
Random sample;
    Test h = sample e = sample*collaborator;
    Test h = collaborator e = sample*collaborator;
Run;
```

b. Results for Weight Loss (after outlier removal)

Whole model: Source	df[a]	SS[b]	MS[c]	F[d]	p[e]
Model	131	835	6.38	4.43	<0.0001
Error	66	95	1.44		
Total	197	930			
R^2 = 0.90	CV = 8.74				

Model parameters: Source	df	TypeIII SS	MS	F	p
Sample	11	28	2.5	1.6	0.096
Collaborator	10	536	53.6	35.0	<0.0001
Sample*collaborator	110	2	1.5	1.1	0.395

c. Results for Cookie Diameter (after outlier removal)

Whole model: Source	df	SS	MS	F	p
Model	131	27.8	0.21	5.31	<0.0001
Error	66	2.6	0.04		
Total	197	30.5			
R^2 = 0.91	CV = 2.30				

Model parameters: Source	df	TypeIII SS	MS	F	p
Sample	11	11	0.98	29.7	<0.0001
Collaborator	10	12	1.18	35.9	<0.0001
Sample*collaborator	110	4	0.33	0.8	0.818

d. Results for Cookie Height (after outlier removal)

Whole model: Source	df	SS	MS	F	p
Model	119	1.76	0.01	8.62	<0.0001
Error	60	0.10	0.002		
Total	179	1.86			
R^2 = 0.94	CV = 5.50				

Model parameters: Source	df	TypeIII SS	MS	F	p
Sample	11	0.66	0.06	42.4	<0.0001
Collaborator	9	0.89	0.10	69.5	<0.0001
Sample*collaborator	99	0.14	0.00	0.8	0.796

[a] df = degrees of freedom.
[b] SS = sums of squares.
[c] MS = mean squares.
[d] F = calculated *f*-value.
[e] p = calculated *p*-value.

Conclusion

The results of the collaborative indicate that cookie diameter and height are reliably measured with the modified method. Weight loss during baking is less reliably measured, especially among laboratories (reproducibility). This parameter appears to be more variable and more difficult to measure than cookie geometry. It is recommended that the diameter of one cookie, averaged from four measurements on two cookies (a cookie pair), be the parameter reported. Cookie height was well related to diameter and essentially redundant for sugar-snap cookies and weight loss was too dependent on other variables. The revised method, approved by the AACC Intl. Approved Methods Committee, represents an advance in both the utility of the method and in returning standardization of methodology to laboratories using this method.

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