Wheat end-use products can be classified into broad categories based on whether a product has strong or weak gluten strength and is high or low in moisture. Pan bread is one example of a strong-gluten, high-moisture product, while a cookie is an example of a low-moisture, weak-gluten product. There are instruments and predictive tests available for evaluating most of these categories of end-products and uses. Dough mixing characteristics are widely used to predict the quality of flours for use in bread production, where gluten performance is of paramount importance. The mixograph, farinograph, extensigraph, and alveograph are examples of instruments used to measure gluten performance. Similarly, the solvent retention series assists in evaluation of the utility of soft wheat flour for use in cookies and crackers.

However, there exists a gap in predictive tests for high-moisture, low-gluten strength products. Within this category are batter-based end-use products, including cakes, pancakes, and batters. These products all discourage gluten development, and low-protein, weak-gluten strength classes of wheat are used to avoid the tough, chewy products that result from gluten formation. This creates a challenge, because leavening gas from chemical leavening agents or incorporated air must somehow be retained by the batter to produce a desirable product. As a result, the viscosity of the batter is closely associated with batter functionality and end-product quality.

Traditionally, the AACC International (AACC) Approved Methods of Analysis (1) has included white layer cake as a method to evaluate flour quality for batter-based products. The white layer cake method has some deficiencies, however, for this application. In a 2008 collaborative test overseen by the AACC Soft Wheat and Flour Products (SWFP) Technical Committee, the method produced little comparable data among laboratories, and therefore, the method provided little utility. Variation among repeated samples was large, and the elevation of the laboratory and use of shortening with trans fat versus shortening with no trans fat played a significant role in the shape of the cake. At sea level, the cake had a dome shape, while at higher elevations the cake shape was concave. Cake volume also was affected. Despite an altitude correction table, the collaborative results demonstrated that the method for predicting flour quality in batters used in this application was inadequate. Use of shortening with no trans fat also reduced discriminatory power between chlorinated and nonchlorinated flours in cake baking.

Clearly, another method to evaluate flour quality for batter-based products was needed. A method that takes advantage of unencumbered, unconstrained viscous flow seems to offer a means of avoiding the issues of altitude and constrained flow yet still provides meaningful, reproducible data on flour quality. Pancakes have the potential to fulfill this requirement.

There is a long history of pancake baking, and most formulations utilize chlorinated flour. Chlorination can reduce the pH of flour used for pancake production from ~6.7 to 5.2. Cake flour is chlorinated to a greater extent, however, reducing flour pH to ~4.5. The chlorination-induced changes affect starch granule surface proteins and lipids as well (4,6,7,8,10). Changes have also been observed as an increase in water-insoluble arabinoxylans (2). The change in starch properties leads to increased starch granule hydrophobicity (9), resulting in pancakes with greater volume and enhanced textural properties in the form of greater springiness. Chlorination essentially adds “insurance” to a flour’s performance in cake and pancake making.

Commercial pancake producers typically use consistency as a predictive measurement of flour quality, using a Bostwick consistometer to measure batter flow over time. Determination of the actual quality of a flour for batter-based products, specifically pancakes, relies on empirical measurement during pancake baking. Each commercial producer of pancake mixes uses its own proprietary formulation and incorporates different ingredients. As a result, there is little agreement on pancake formulations among manufacturers.

Pancakes have been used previously to study the affect of chlorination on batter-based products. In the work by Finnie et al. (5), a full pancake formulation that incorporated biological ingredients other than flour was used. The formulation included soy flour, dried egg yolk, and dried buttermilk. Each additional biological ingredient increased variation in the pancake, beyond the variation due to flour used. For a method to truly measure flour performance, elimination of as many ingredients as possible is beneficial. A very lean pancake formulation accentuates differences among different flour types in batter applications.

The lack of robust methods for evaluating flour quality in batter applications presents cultivar development programs with challenges in breeding wheat varieties that are well-adapted for use in batter systems in general and in pancake baking specifically. Further, research on any batter-based product is hindered by the lack of a consistent, basic pancake method.

To address this challenge, the AACC SWFP Technical Committee undertook a collaborative study on a method for pancake baking that could stand as a method for studying batter-based systems. A lean formulation for pancakes and appropriate testing protocols were developed by SWFP committee members A. D. Bettge, S. M. Finnie, D. Gannon, B. Heidolph, M. Kweon, and Z. Quinde-Axtell.

Preliminary testing and a minicollaborative study were conducted among the University of Idaho Wheat Quality Lab (Aberdeen, ID [K. O’Brien]), USDA-ARS Soft Wheat Quality Lab (Wooster, OH [M. Kweon]), and USDA-ARS Western Wheat Quality Lab (Pullman, WA [A. D. Bettge]) to determine
the optimum chemical leavening system for use with the pancakes. The results were encouraging, and the formulation was the subject of a collaborative trial among 11 participating laboratories in 2012.

Methods
The 11 collaborating laboratories each received 10 flour samples. The flour samples were obtained from the USDA-ARS Soft Wheat Quality Laboratory in Wooster, OH, and the USDA-ARS Western Wheat Quality Laboratory in Pullman, WA. In total, six unique flour samples were used, and the sample set included four embedded, blind duplicate samples. All the flour samples were soft wheat milled on Miag Multimat mills to straight-grade flour. Proximate analysis results for the samples are presented in Table I. The cultivars selected were obtained to represent a range of flour performance in pancake production, as well as reflect

Table I. Proximate analytical data for wheat flour samples tested in the collaborative pancake study

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cultivar</th>
<th>Moisture (%)</th>
<th>Protein (14% mb)</th>
<th>Ash (14% mb)</th>
<th>Solvent Retention Capacity (% Solvent Retained)</th>
<th>Rapid Visco Analysis (cP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td>Carbonate</td>
</tr>
<tr>
<td>1</td>
<td>WA8124</td>
<td>12.9</td>
<td>7.0</td>
<td>0.354</td>
<td>52.2</td>
<td>64.9</td>
</tr>
<tr>
<td>2</td>
<td>Alturas</td>
<td>12.8</td>
<td>9.4</td>
<td>0.471</td>
<td>53.7</td>
<td>68.7</td>
</tr>
<tr>
<td>3</td>
<td>Xerpha</td>
<td>11.7</td>
<td>7.3</td>
<td>0.411</td>
<td>60.2</td>
<td>77.0</td>
</tr>
<tr>
<td>4</td>
<td>Mennel</td>
<td>13.2</td>
<td>8.6</td>
<td>0.492</td>
<td>55.1</td>
<td>73.2</td>
</tr>
<tr>
<td>5</td>
<td>Envoy</td>
<td>13.7</td>
<td>8.2</td>
<td>0.394</td>
<td>53.8</td>
<td>68.0</td>
</tr>
<tr>
<td>6</td>
<td>SS 5205</td>
<td>14.0</td>
<td>7.3</td>
<td>0.353</td>
<td>49.0</td>
<td>64.6</td>
</tr>
</tbody>
</table>

Fig. 1. Pancake parameter values (by cultivar) for 11 collaborating laboratories.
flour that is commonly utilized commercially for pancakes. Samples were not chlorinated for this study. This allowed single-cultivar flours to be used in the study (commercial flours contain mixed cultivars). Previous work by Finnie et al. (5) suggests that a laboratory could use this method for chlorinated flours after performing in-house validation tests that provide good correlation with the reported method performance characteristics.

The flour samples were analyzed according to the protocol developed by the SWFP committee. The parameters measured were Bostwick Consistometer flow, batter specific volume, pancake diameter, pancake height, and pancake weight. Ten samples were sent to each participating collaborator. Four samples were analyzed twice each as blind replicates. The remaining two samples were unique flours analyzed only once. The samples were analyzed for repeatability (S_r) and reproducibility (S_R) per the approved methods guidelines (ISO 5725, 1994) adopted by AACCI. The data were also analyzed for overall S_r and S_R using a regression approach and subsequent calculation (PC-SAS version 9.3, SAS Institute, Inc., Cary, NC) followed by Duncan’s multiple range separation test (DMRT). Using the model output, overall S_r and S_R were calculated using equations 4 and 5 in Delwiche et al. (3).

**Results and Discussion**

The flours tested in the collaborative study were all well within the range of quality observed for soft wheat (Table I). Variation for each parameter was observed, but all the test results indicated that each flour was appropriate for use in pancake applications. Sample flours used in this test were selected to represent a spectrum of good, medium, and poor pancake-making potential. The selections were based on prior work with the flours in pancake applications. Unlike many commercial applications, the flours used in this method were not chlorinated. The goal was to make the method more useful for laboratory-scale use, and chlorinating the flour was determined to be counterproductive. Laboratory-scale chlorinating apparatus is scarce and would have represented a major restriction to the utility of the method. In cultivar development laboratories, ranking the pancake-making ability of a flour is more important than the ability of a flour to produce a pancake in commercial applications. If a flour ranks poorly in the laboratory in an unchlorinated state, it will also present production problems in commercial use.

Collaborators did not indicate any particular issues with making pancakes using the method. However, there does appear to be a learning curve associated with the method. Collaborators who had made lab-scale pancakes in the past grouped consistently in the “middle of the pack” in their results compared with laboratories that had little or no experience (Fig. 1). Further, experienced labs had better repeatability (the ability to obtain the same result from the same flour) than did less experienced labs. With more practice, performance statistics (S_r and S_R) would certainly improve. Mixing the batter appeared to be the most problematic stage of the pancake-making process. The idea that a batter will be lumpy, nonhomogeneous, and mixed in only 20 sec is difficult for laboratory personnel to grasp. Generally, homogeneity and consistency are encouraged in cereal chemistry laboratories. Pancake batter is an exception in that it should be somewhat lumpy and not particularly smooth, and leaving pancake batters in a less-than-perfect slurry is advantageous in pancake making.
Another source of variation was likely the type of griddle used. Griddle types used ranged from free-standing counter models (such as would be found in home kitchens) to cast-iron crepe makers to commercial, floor-mounted griddles. Each type has different heating unit patterns that create various heat zones, different thermostat sensitivities, and different heat recovery times. The differences in griddle types are reflected in the low Sr versus SR values. Repeatability reflects a laboratory’s ability to obtain the same result for the same flour. Reproducibility reflects how closely independent labs can reproduce the same result. Despite the fact that different equipment was used to produce the pancakes, both Sr and SR were reasonably good—Sr more so than SR (Tables II and III).

To test the ability of the method to accomplish its purpose, that of differentiating among flours varying in quality, analysis of variance (ANOVA) was used, with DMRT used as an extension of the overall analysis of repeatability (Sr) and reproducibility (SR) (Table IV). The results indicate that the pancake test did a good job of differentiating flour quality. With the exception of specific volume results, the test consistently segregated the six flours into three categories. As judged by DMRT, Xerpha produced the least acceptable pancakes; SS5205, WA8124, and Mennel consistently produced the best; and Alturas and Envoy varied between. When compared with the results of commercial laboratories using chlorinated flours of the same samples, the rankings were the same.

Altitude was the largest factor contributing to variability in previous collaborative studies on batter-based products. A recent collaborative study on layer cake failed, primarily due to altitude-associated issues with cake shape and volume. In this study, there was no relationship or correlation between any pancake parameter and altitude. Participating laboratories were at altitudes that varied between 50 and 5,000 ft above sea level (15 and 1,500 m, respectively). The fact that altitude played little role in a batter-baking test was judged as a significant positive factor in the pancake test results by the SWFP committee members.

**Conclusions**

The AACCI SWFP Technical Committee has approved the method based on the collaborative results and forwarded the method to the AACCI Approved Methods Committee for final approval.

**Acknowledgments**

The SWFP committee thanks the collaborators who participated in the testing for their work on the study. Collaborative testing takes time and attention and represents a significant commitment to the work of both the AACCI SWFP Technical Committee and the association at large. Thanks to: Bill Besson, Chelsea Milling Company; Art Bettge, USDA-ARS Western Wheat Quality Lab; Tom Donelson, USDA-ARS Soft Wheat Quality Lab; James Jenson, Star of the West Milling; Teresa Johns, Siemer Milling; Grace Lai, Kellogg; Bon Lee, Wheat Marketing Center; Ruben McLean, Pendleton Flour Mills; Toby Moore, AIB International; Dave Reick, Kerry Ingredients; and Jim Schuh, Mennell Milling. We also thank Terry Nelsen, Roy Roberson, and Deb Palmquist for their assistance with the statistics. Without their help the collaborative study would have been difficult to complete.

**References**