Introduction

Experimental milling is an important function in the operation of a flour mill. Sourcing of wheat suitable for the type of flour desired is essential for producing flour with consistent quality. Experimental milling is one of the most important steps in wheat and flour quality evaluation. Wheat varieties used to mill flour differ in size, shape, and hardness, making it necessary to prepare the wheat appropriately for milling. The hardness of the wheat and the roll pressures used to mill the wheat influence flour particle size and starch damage, which in turn affect the flour absorption and rheological behavior of dough. It is important to use standardized experimental milling procedures when operating laboratory mills to eliminate disagreements concerning flour quality evaluations made by millers and their customers. The flour obtained can also be used in further tests, including test baking.

In preparation for milling, the wheat is first cleaned and then brought to a specified moisture content and held for a set time. This process is called tempering.

The CHOPIN CD1 laboratory mill (Fig. 1) is equipped with heavy-duty rolls that can last for a long time under normal milling conditions (clean and tempered wheat). It requires no roll adjustment, thus eliminating operator variations. Although this concept seems contradictory to the normal milling process in which millers adjust roll gaps to obtain the best results, the objective of the CD1 mill is to ensure a uniform milling process regardless of where the mill is located and who operates the mill.

The CD1 mill is widely used, and an experimental milling method using this mill has been published as part of an AFNOR/CEN/ISO standard (ISO 27971:2015) (5). Because the CD1 mill is used by millers in many regions around the world, the AACC International (AACCI) Experimental Milling Committee decided to evaluate the performance of the CD1 mill and determine whether this method should be considered for approval as an AACCI Approved Method.

Note, the CD1 mill is not designed for milling durum. For milling durum a completely different laboratory mill, the CD2, is available.

Principle of Operation

The principle of operation of the CD1 laboratory mill is based on progressive milling of a wheat sample by passing it through break and reduction rolls. For the break stage, wheat is passed through three corrugated rolls arranged in a series (Fig. 2). The gaps between the rolls are fixed: 0.10 mm between rolls 1 and 2 and 0.010 mm between rolls 2 and 3. Roll speeds are also fixed: rolls 1 (upper) and 3 (lower) at 200 rpm and roll 2 (middle) at 450 rpm. The meal from the break pass is sifted on a centrifugal sifter equipped with a stainless-steel flour sieve (71 µm wire diameter; 160 µm opening; 48% effective area) and a galvanized-steel sieve (315 µm wire diameter; 800 µm opening; 51% effective area) to yield bran, middlings, and flour.

Note, various terms are used around the world to describe different wheat fractions. In this report middlings will be used to describe the coarse particles of endosperm created by the breaking process of the corrugated rolls. This term varies by country and region and also by wheat variety. In the United States, the term farina is also used for these particles from soft and hard wheat, and the term semolina is used for the same particles from durum wheat.

After sifting, middlings are weighed and placed in the reduction side feed hopper. The reduction side is equipped with two smooth rolls. These rolls are cleaned by two adjustable scrapers fitted with bob weights and a spring. Roll speed is fixed at 325 rpm for the upper roll and 445 rpm for the lower roll. The roll gap is fixed at 0.010 mm. The reduced middlings are sifted on another centrifugal stainless-steel flour sieve (71 µm wire diameter; 160 µm opening; 48% effective area) to yield shorts and flour.

When there are differences in the results from multiple laboratory mills at multiple locations, the reasons for such differences include

- Inappropriate wheat preparation or tempering
- Variations in settings used with the same type of laboratory mill
Device. Supplementary equipment includes

- Cleaning device: A dockage tester, if available, or any mechanical cleaner specifically equipped for cleaning wheat kernels
- Tempering device: A rotating drum mixer, such as the CHOPIN MR2L or MR10L, is recommended to ensure uniform application of tempering water
- Moisture determination: Use an air oven to determine wheat kernel moisture according to AACC Approved Method 44-15.02 (1)
- Sample divider: A Boerner or similar sample divider
- Miscellaneous: Balance, airtight sample containers, scoops, trays, brushes, and water-measuring devices

Procedure. The experimental milling procedure includes cleaning and tempering the wheat sample, milling the sample to separate the endosperm from the bran, and reducing the endosperm to flour. A schematic of the milling process is shown in Figure 2.

Preparation of Wheat for Test Milling. Wheat preparation prior to milling should ensure that all extraneous materials and impurities are removed, using a CHOPIN Quatuor mechanical cleaner, Carter dockage tester, or other similar equipment to avoid any damage to the rolls during wheat kernel reduction and to make sure only grain kernels are milled. A magnetic device is placed on the hopper to remove any metallic contaminants. Use of a divider, such as a Boerner divider, ensures that the test sample is representative of the wheat lot. A minimum of 1,600 g of sample wheat is required for the determination of moisture content and milling on the laboratory mill; 100 g of sample wheat is required to determine the moisture level of the wheat prior to tempering; 1,500 g of sample wheat is tempered; 1,000 g of tempered wheat is required for the milling test; and the remainder is used to warm up and flush out the mill prior to the actual test.

Determine the moisture content of the wheat according to the procedure described in AACC Approved Method 44-15.02 (1) or using a moisture meter that has a measurement that does not differ from the reference value by more than 0.4 g of water/100 g of sample. The wheat must be tempered before milling to facilitate better separation of bran and endosperm by toughening the bran and softening the endosperm. The wheat tempering moisture target is set at 16%. Although it is recognized that 16% may not be used for all varieties of wheat and in all applications, it is used to standardize the process. A specific method is provided to ensure that the 16% target is achieved uniformly.

Milling with the CD1 Mill. The milling process is covered in two major steps, which are described in detail in the AACC Approved Method. Tempered wheat is first passed through a set of break rolls. Bran, middlings, and break flour are produced and separated using a rotary sieve, and these portions are collected separately. The bran and break flours are not processed further. The middlings are processed further through a set of reduction rolls and split into shorts and reduction flour. Reduction flour is collected with the break flour to determine the extraction rate.

Data Obtained. Milling results are calculated as follows:

- Bran (%) – The weight of bran separated from the break centrifugal sifter divided by the weight of the wheat sample
- Middlings (%) – The weight of middlings from the break centrifugal sifter divided by the weight of the wheat sample
- Shorts (%) – The weight of shorts from the reduction centrifugal sifter divided by the weight of the wheat sample
- Extraction (%) – Total weight of break and reduction flours divided by the weight of the wheat sample

![Fig. 2. CHOPIN CD1 experimental mill flow diagram.](image-url)
Collaborative Study

Set Up of Collaborative Study. Fourteen wheat samples were selected from Europe, Australia, the United States, Canada, and South America, with different wheat types included to represent a wide range of milling quality. Each sample was cleaned and divided into 10 test samples—one for each collaborator. Sufficient material was provided for each test sample to permit triplicate milling analyses; triplicate values were averaged to produce a single value per property for each sample from each collaborator. Using the previously discussed methodology, the samples were cleaned and divided into 14 subsamples. The subsamples were sent to 10 laboratories that were equipped with a CD1 mill (Table I). Each laboratory milled the 14 subsamples in triplicate using the CD1 mill and following the same, previously described, procedure.

The wheat samples were selected from around the world to represent a wide range of milling qualities, from soft wheat to hard wheat varieties (Table II). Flour characterization was not the aim of this collaborative trial, and as a result, protein and ash were not reported. However, other publications report ash contents between 0.50 and 0.60 (% dm) for a wide range of wheat varieties (2,6).

The milling results were collated and statistically analyzed by AACC International Statistical Advisory Committee members in accordance with ISO 5725:1994 recommendations (3,4). Cochran and Grubbs tests were used to identify outliers in the data sets. A glossary of terms used is provided in the sidebar below.

Results. In Table III, flour extraction rate and repeatability and reproducibility statistics for each of the wheat samples for all collaborators are presented. The average extraction rate ranged from 61.7 to 71.9%. With the exception of samples 5 and 6, the standard deviation of repeatability (SDr) was <1%, implying the extraction rate was repeatable within the sample set and CD1 mills. Wheat varieties with lower extraction rates tended to have higher standard deviations of repeatability.

Repeatability (r) limit is defined as the value above which the difference between two results is detected at a 95% confidence interval. It is calculated by multiplying SDr by 2.77. Observed r limit values ranged from 0.9 to 6.4.

Reproducibility (R) limit is defined as the value above which the difference between two results is detected at a 95% confidence level. It is measured by multiplying standard deviation of reproducibility (SDR) by 2.77. Observed R limit values ranged from 5.8 to 23.0.

The extraction rate for middlings in this study varied from 38.8 to 59.4% (Table IV). The extraction rates and corresponding repeatability and reproducibility statistics for bran and shorts in this collaborative study are provided in Tables V and VI, respectively.

Uncertainty is a parameter that characterizes the scattering of values that could reasonably be attributed to the results. It is calculated from the SDR and a constant of 2.
The r limits are obtained using the following equations:

For extraction rate: \( r = 0.83 \times 2.77 = 2.33 \)
For middlings extraction: \( r = 0.63 \times 2.77 = 1.77 \)
For bran extraction: \( r = 0.44 \times 2.77 = 1.23 \)
For shorts extraction: \( r = 0.63 \times 2.77 = 1.76 \)

The R limits are obtained using the following equations:

For extraction rate: \( R = 3.60 \times 2.77 = 10.07 \)
For middlings extraction: \( R = 1.88 \times 2.77 = 5.25 \)
For bran extraction: \( R = 2.36 \times 2.77 = 6.62 \)
For shorts extraction: \( R = 2.79 \times 2.77 = 7.81 \)

Comments on Reproducibility. The collaborative trial was conducted with actual milling units in use around the world and represents actual data from real users. Before they are released, all new mills are thoroughly inspected prior to shipping. The measured performance of the most recent 11 units shipped is outlined in Table VII.

### Conclusions

The experimental wheat milling method using the CHOPIN CD1 mill was evaluated in a collaborative trial with 10 laboratories representing 5 countries and analyzing 14 wheat samples. Statistical analyses of the results showed the method is able to differentiate the milling quality of wheat samples with reasonable repeatability and reproducibility (RSDr ≈ 1–6% over the various milling fractions; RSDR ranging from 2 to 44%, depending on fraction and sample).

Taking into account the fact that every lab was required to run the samples in triplicate, the observed relative standard devia-

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**Table IV. Mean middlings extraction rate and repeatability and reproducibility statistics for all collaborators for each sample**

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<th>Wheat Sample</th>
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<td>0.65</td>
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<td>1.74</td>
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**Table V. Mean bran extraction rate and repeatability and reproducibility statistics for all collaborators for each sample**

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<tr>
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<td>0.54</td>
<td>0.37</td>
<td>0.46</td>
<td>0.23</td>
<td>0.27</td>
<td>0.42</td>
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tion of repeatability ($RSD_r$) values for most of the samples were <1, which indicates the mill results are very repeatable. The relative standard deviation of reproducibility ($RSD_R$) values were 3–4 times higher than the $RSD_r$ values. Reproducibility was influenced by different equipment conditions at the laboratories. (For example, some of the laboratories used CD1 mills that are decades old, including some that were manufactured as early as 1970.) The results of this collaborative trial represent a true image of the current situation. They also show that improved results (reproducibility results closer to repeatability) could be obtained with consistently well-maintained mills, as shown by the results for new CD1 mills at the time of initial production (Table VII). The introduction of AACCI Approved Method 26-70.01 also will assist operators by providing a consistent procedure.

Acknowledgments

We would like to express our warmest thanks to the all of the participating laboratories for their time spent and dedication to this project, to the members of the AACCI Experimental Milling Committee for their advice, and to the members of the AACCI Statistical Advisory Committee for their support in interpreting the data.

References