Cumulative Attribute Curves

A valuable tool to help analyze the milling process in a variety of useful ways.

When evaluating the flour quality and milling performance of wheat flour milling processes, few analytical tools reveal as much about the flour and mill flow diagram as a cumulative attribute curve.

The cumulative attribute curve, which is referred to perhaps more often as an ash curve, can be used to analyze ash levels but also compare several components of individual flour streams from the milling process including protein, color, and moisture.

Useful Analytical Tool

The objective of the cumulative attribute curve is to describe mathematically and illustrate graphically the distribution of a specific attribute within a mixture.

The curve provides a method of analysis that views the attribute level as a function of the components within the mixture.

Management

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The curve can be used to evaluate mill performance in several key areas.

For example, the most common purpose for creating the cumulative attribute ash curve is to estimate blending ratios and stream selection for flour production.

Straight-grade flour is the flour produced from the mill, when all the flour streams are combined into one end product.

For most mills, the ash content of this straight-run flour is between 0.52% and 0.58% ash on a 14% moisture basis (MB). Of course, the actual ash content will depend a lot on the wheat type and extraction rate or percentage.

For flour customers who prefer lower ash content in their end product, the mill must select streams to cut or remove, in order to form a clear or low-grade flour stream. An ash curve helps to estimate the percentage of the flour produced that can be blended to meet certain customer specifications.

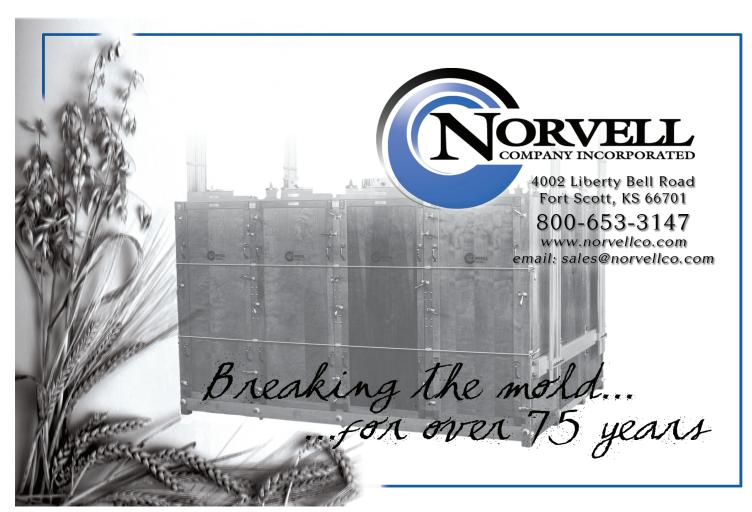This estimate offers several useful aspects in mill manage-

Table 1: Sample Data Collected from Hal Ross Flour Mill | Kansas State University, Manhattan

Col. 1	Col. 2	Col. 3		Col. 4	Col. 5			Col. 8
Flour Streams	Stream Weight (actual lbs./hr.)	Q	Sum of Q	Ash 14% MB	QxA	Sum of QxA		Sum of QxA/Sum of Q
1BK/2BK	63.54	9.17%	9.17%	0.392	0.036	0.036		0.392
1M/2M	184.86	26.67%	35.83%	0.416	0.111	0.147		0.410
GR-1	38.016	5.48%	41.31%	0.438	0.024	0.171		0.414
2BK	72.44	10.45%	51.76%	0.458	0.048	0.219		0.423
1 SIZ	19.329	2.79%	54.55%	0.488	0.014	0.232		0.426
3 BK	20.043	2.89%	57.44%	0.522	0.015	0.248		0.431
2M	47.262	6.82%	64.26%	0.530	0.036	0.284		0.441
2 SIZ	16.054	2.32%	66.58%	0.531	0.012	0.296		0.445
QUAL	44.976	6.49%	73.06%	0.567	0.037	0.333		0.455
3M	40.668	5.87%	78.93%	0.657	0.039	0.371		0.470
4BK	17.568	2.53%	81.46%	0.817	0.021	0.392		0.481
1T	66.075	9.53%	90.99%	0.880	0.084	0.476		0.523
GR-F	40.362	5.82%	96.82%	0.901	0.052	0.528		0.546
5BK	8.32	1.20%	98.02%	1.184	0.014	0.543		0.554
4M	7.641	1.10%	99.12%	1.407	0.016	0.558		0.563
5M	6.11	0.88%	100.00%	1.621	0.014	0.572		0.572

ment from flour production planning to pricing products for customers.

In addition, cumulative attribute curves also are a valuable tool to compare wheat and mill performance, when the type or class of wheat changes.

A cumulative attribute ash curve can be a vital tool to help analyze the changes in mill and flour performance due to annual seasonal changes in wheat or wheat sourced from different geographical regions.

While individual flour streams are analyzed for their chemical and functional properties, an ash curve can estimate only chemical or physical quality characteristics with a linear relationship accurately.

Functional dough characteristics such as falling number, water absorption, stability, and other mixing properties have a nonlinear relationship when blended and therefore cannot be esti-

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A cumulative attribute ash curve can be a vital tool to help analyze the changes in mill and flour performance due to annual seasonal changes in wheat or wheat sourced from different geographical regions.

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mated accurately by using a cumulative attribute curve calculation.

Collecting the Data

Creating an attribute curve is a relatively simple calculation; however, it can be an extremely time-consuming task.

The first step is to weigh off all the flour streams in the mill. For some larger commercial flour mills, this might involve 50 to 60 or more individual streams from individual sifter boxes.

The accuracy of this weighoff is critical, since all the analysis results will be calculated according to the ratios determined from the mill weighoff.

The mill must be balanced and running at its optimal, normal conditions for the attribute curve to be useful.

Milling rate, wheat moisture, break releases, and all roll settings need to be checked and double checked before the weighoff begins.

Filters, set off bins, and any other source that feeds stock into the milling process need to be shut off or confirmed that they are in the normal operating range before streams are weighed off.

Table 1 (see page 35) is an example of the data table used to calculate a cumulative attribute ash curve for the ▶

$$A_M = \frac{\sum\limits_{1}^{N} Q_N \times A_N}{\sum\limits_{1}^{N} Q_N}$$

The actual mathematical equation used for determining a cumulative attribute ash curve. In the equation, exponent M represents the average ash content, and exponent N represents number of samples.

Hal Ross Mill at Kansas State University (KSU), Manhattan.

Starting from the left side of **Table 1**, **Column 1** is the name of the sifter from which the flour samples are taken.

Column 2 (labeled stream weight) is the quantity of the stock weighed off typically reported as a flow rate in kilograms or pounds per hour. In this table, it's pounds per hour.

Column 3 (labeled Q) is the percent-age of each flour stream from the total rate of flour production.

Column 4 (labeled Sum of Q) is the cumulative summation of the flow-rate quantities ($\sum Q$).

Once the stream weighoff is completed, samples then are analyzed for the quality characteristic desired. For this example, the traditional ash content is used.

Column 5 is the measured ash content corrected to 14% MB.

Once all the data is collected, the next step is to complete the calculations. The mathematical process for calculating the cumulative attribute as an ash curve can be represented by the equation seen on this page.

Completing the Calculations

The first step to completing the calculation is to reorganize the data for the streams from the lowest to highest attribute ash level, as shown in **Column 5** in **Table 1** on page 35.

Once the data is in the correct order, the math is relatively straightforward. The ash content (**Column 5**) is multiplied by the proportion of flour (**Column 3**) to determine the quantity of ash each stream represents in the total ash of the straight-grade flour, as listed in **Column 6**).

Example: 1BK/2BK Ash = [0.392 x 9.17%] = 0.036

From this point, the calculations become a blending exercise and more information on creating the table can be obtained by contacting me at: *mfowler@ksu.edu*.

Plotting the Ash Curve

To create the graphical illustration (see **Table 2** on page 38) of the cumulative attribute curve, the data points are plotted as an X-Y pair in a scatter line chart reflecting the increased attribute level, as additional product streams are added to the mixture.

The X data point represents the total percent of flour is plotted along the horizontal axis and is found in the obtained **Column 4** ($\sum Q$).

The Y data point representing the cumulative ash content as the flour streams are blended together is plotted along the vertical axis and is found on page 35 in **Table 1**, **Column 8** ($\sum Q$) x A) / ($\sum Q$).

Whether it is comparing changes in wheat quality due to the crop year and origins or considering adjustments to the milling diagram, the cumulative attribute ash curve is an important tool to illustrate and estimate how any changes will impact flour quality, extraction, and profitability.

Interpreting the Ash Curve

For the graph to be useful, its accuracy must be verified. A few quick checks will allow confirmation of the chart's validity.

First, the chart starts low and increases slowly, as it moves left to right, in a smooth fashion. The end of the curve increases more dramatically than the beginning, since the relative ash content of the tail end mill streams is higher.

The curve must be smooth. If the curve dips down at any point, one or more of the streams are out of order.

The attribute curve can be wheat-based or flour-based. The curve illustrated is a flour-based curve, which extends to 100%.

A wheat-based curve would not look any different but would extend only to the flour extraction percentage. It looks no different in terms of ash; however, the added benefit is that a curve based on wheat milled provides yield information.

An important use for the attribute curve is to estimate the flour extraction of a wheat blend at any quality value.

For example, what is the percent of flour at when it has an ash content of 0.45%?

Using the three plotted lines in the graphic illustration (refer to **Table 2**, page 38), estimating flour extraction can be done by drawing a line perpendicular from the desired quality value to the percentage on the X-axis.

For the three curves in the illustration, the percentage of flour production is approximately 57%, 72%, and 86%, respectively, from top to bottom.
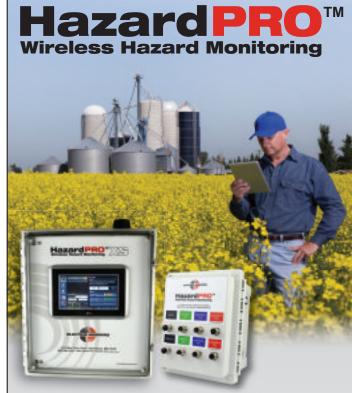
Conclusion

These curves were created by the advanced flow sheets class at KSU, which was led by milling instructor Chris Miller, as an exercise to learn the impact of various adjustments to the Hal Ross Mill on flour quality and extraction.

Creating and using the ash curve is an important part of managing and evaluating the performance of the milling process.

Whether it is comparing changes in wheat quality due to the crop year and origins or considering adjustments to the milling diagram, the cumulative attribute ash curve is an important tool to illustrate and estimate how any changes will impact flour quality, extraction, and profitability.

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