The cumulative ash curve: a best tool to evaluate complete mill performance

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Revised: 18 September 2011 / Accepted: 30 September 2011 / Published online: 14 October 2011

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Abstract Slick test is carried out by a flour miller to qualitatively segregate the flour from different streams in a roller flour mill. This test is done manually by pressing flour samples on tray using thin bladed paddle (the slick) and inspecting color or dress of the sample. However, the test is subjective and totally depends on human judgment. Cumulative ash curve relates to cumulative flour ash content and cumulative flour yield, which could help a flour miller to be more precise while selecting flour streams for different needs. In this study, cleaning and conditioning of wheat was carried out in the pilot plant of International School of Milling Technology (ISMT). Further, roller flour milling of wheat was done. Flour from different streams (four breaks, five reductions) was collected. Each flour stream was analyzed for ash content using standard AACC methods. The analytical values of ash content were used to plot the cumulative ash curve. It was found that ash content increased in the break passages from first to last break, with exception of first break (ash content 0.71%). An increase in percentage of ash was observed in the reduction passages (C1 to C5), however, C3 ash (0.76%) was slightly higher than that of C4 (0.65%). Higher yield of flour with minimum ash content was obtained from the front reduction passages C1 and C2; whereas, the break passages and the tail end reduction passages produce less flour with higher ash content.

Keywords Wheat flour milling • Cumulative ash curve • Millstream

Introduction

Wheat milling technology gradually evolved from the mortar & pestle used by primitive cultures 10000 years ago, to the invention of millstone in roman times. Millstone remained in vogue until late in the 19th century, when the invention of purifier, plan sifter & horizontal roller mill revolutionized the milling process (Dexter and Wood 1996). The objective of the wheat flour milling is to separate endosperm from bran and germ as clean as possible and reduce the endosperm into flour. The wheat flour milling process involves breaking open the grain, scraping the endosperm from bran & germ, and then gradually reducing the chunk of the endosperm into flour by a series of grindings, with intermediate separation of products by sifters & purifiers. Wheat starchy endosperm constitutes over 80% of the wheat kernel (Ziegler and Greer 1971). Complete separation of starchy endosperm from other layers of wheat is difficult mainly because of the oval shape and crease of the wheat kernel, and by the absence of natural line of cleavage between the aleurone layer and the starchy endosperm. The projections of the aleurone cells into the starchy endosperm, the stepwise borderline, and the absence of structural differences make the separation difficult (Pomeranz 1961). However, even under the best conventional roller milling conditions, complete separation of the starchy endosperm from other kernel constituents cannot be achieved. The flour ash & flour brightness begins to deteriorate when the extraction reaches 65%. Beyond 75% extraction, the rate of loss of flour refinement accelerates (Ziegler and Greer 1971). The purity of the wheat flour traditionally has been expressed as ash content. Ash is the mineral residue remaining after a sample has been completely oxidized in a manner such that all organic volatile material is driven off, while preventing any mineral

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material from being lost (Posner 1991). The gradient of ash increases from center to the outer layers of wheat kernel (Hinton 1959). Low ash content in the flour indicates less contamination with the bran and germ. About 60% of the total mineral content of the wheat kernel is concentrated in aleurone layer (Hinton 1959). The aleurone layer is botanically apart of endosperm, but during the roller milling process it causes technical difficulties in separating from the bran layers. The high yield of flour, results from the efficient separation by scratching of aleurone layer from the bran with increased ash. As flour extraction from the wheat kernel increases, a higher percentage of bran ends up in the flour. Ash content alone is misleading as a flour-grading factor; low ash at low extraction percentage can be deceptive in evaluating mill results. One of the best applications of ash content is in evaluating mill performance by constructing cumulative ash curves. Shellenberger (1965) referred to the ash curve as one of the major advances in the control of flour milling process. The objective of the present study was to assess the ash content of different flour mill streams to construct the cumulative ash curve and evaluate cumulative ash curve for ISMT pilot plant (20 t/day).

Materials and methods

Raw material

A commercial available wheat variety PBW 175 procured from local Mysore market was used for the present study.

Physicochemical analysis

Analysis of wheat was carried out for physical and chemical properties. The moisture, ash, sodium dodecyl sulphate (SDS) sedimentation value and protein content were determined by the AACC methods (AACC 2000). Hectoliter weight and the thousand-kernel weight were determined by standard procedures (Pomeranz 1998)

Preparation of wheat

Thorough cleaning of wheat was done at the flow rate of one ton per hour by using cleaning machineries, namely, magnetic separator; size separator; aspirator; destoner and indented cylinder. Wheat was then conditioned by adding water using automatic moisture unit (MYFC, MOZF, Buhler, Switzerland) and mixing wheat and water in intensive dampener to increase moisture up to 15.5%. Wheat was then rested for 24 h in conditioning bins. Before wheat was sent to milling it was passed through scourer and magnetic separator.

Milling of wheat

After cleaning and conditioning, the wheat was milled in an ISMT pilot plant (20 tons/day; Buhler, Switzerland). The pilot plant consists of four break (B1 to B4), five reduction (C1 to C5) passages, two purifier passages (S1 and S2) and bran duster. The mill was set to yield 76% straight run flour and 24% bran. The technical aspects and break releases of the roll passages are shown in the Table 1. Break rolls were adjusted to produce the standard break releases of 31, 57 and 63% from the B1, B2 and B3 respectively. The break release was calculated using following equation:

$$\text{Break Release(\%)} = \frac{(W1 - W2)}{W1} \times 100$$

Where,

W1 Total weight of sample collected for the test

W2 Total weight of over tails of the 20 wire mesh from the sieving of the sample

The break release values are actually the percentage of stock passing through 20 wire mesh. 250 gm of stock for each break was sieved for the 3 min in the lab sifter (MLU 300, Buhler, Switzerland).

B4 rolls were adjusted to deeply scrap the remaining endosperm from the bran flakes with minimum cutting of bran. After B1 roll the ground material is sifted in the plansifter (MPAD 814, Buhler, Switzerland) for size grading. The first scalping was further processed to remove the endosperm by break passages and sifter.

The objective of the break system was to remove the endosperm from the bran without breaking the bran into smaller particles; some cutting of the bran occurs and results in a mixture of endosperm and bran in released middlings. This mixture of middlings and bran is purified in purifier S1 and S2 (MQRE-4, Buhler, Switzerland) to separate the pure endosperm and the bran particles. The purifier also grades the endosperm into particle size ranges, which can more efficiently ground separately in the reduction system. The clean separation from the purifier is sent to the head reduction system. Reduction passages (C1 to C5) were utilized to

Table 1 Technical features and break releases of rolls

Passages	Corrugation (C/inch)	Differential	Action	Break release (%)
1 BK	10	2.5:1	D/D	31
2 BK	14	2.5:1	D/S	57
3 BK	20	2.5:1	D/D	63
4 BK	26	2.5:1	D/D	–
C1 To C5	–	1.25:1	–	–

BK Break, C Reduction, D/D Dull/Dull, D/S Dull/Sharp

Sieves W	Opening Micron
18W	1220
20W	1110
22W	990
34W	635
40W	525
50W	410
60W	310
70W	290

Sieves GG	Opening Micron
18GG	1180
24GG	850
26GG	800
28GG	710
32GG	600
34GG	560
36GG	530
38GG	500
42GG	450

Sieves XXX	Opening Micron
9XXX	150
10XXX	132
11XXX	118

BK = Break, C = Reduction, S = Purifier, BD = Bran Duster, FL = Flour, W = Wire, GG = Grit Gauze, XXX = Flour Sieve.

Fig. 1 Milling flow sheet of ISMT pilot plant. BK = Break, C = Reduction, S = Purifier, BD = Bran Duster, FL = Flour, W = Wire, GG = Grit Gauze, XXX = Flour Sieve

Table 2 Flour mill streams data for the calculation of cumulative ash curve

Flour streams	Moisture%	Ash% (DB) (A)	Stream weight Kgs/hr	Stream% (Q)	Cumulative Extraction $y=\sum Q$	Q x A	Cumulative $z=\sum Q \times A$	Cumulative Ash z/y
C1 (FL1)	13.6±0.32 ^c	0.42±0.02 ^a	165.10±3.85 ^h	19.73	19.73	8.29	8.29	0.42
C1 (FL2)	13.3±0.14 ^c	0.47±0.03 ^a	35.85±2.63 ^c	4.28	24.01	2.01	10.30	0.43
C2 (FL2)	12.5±0.23 ^b	0.52±0.02 ^b	28.52±2.57 ^b	3.41	27.42	1.77	12.07	0.44
C2 (FL1)	13.0±0.18 ^c	0.56±0.02 ^b	115.65±3.02 ^g	13.82	41.24	7.74	19.81	0.48
B2	13.0±0.30 ^c	0.57±0.01 ^b	45.18±2.23 ^d	5.40	46.64	3.08	22.89	0.49
C4	11.2±0.24 ^a	0.65±0.01 ^c	63.52±1.87 ^f	7.59	54.23	4.93	27.82	0.51
B3	13.6±0.15 ^c	0.67±0.02 ^c	53.28±2.06 ^e	6.37	60.60	4.27	32.09	0.53
B1	13.9±0.23 ^d	0.71±0.02 ^d	33.32±2.70 ^c	3.98	64.58	2.82	34.91	0.54
C3	12.3±0.14 ^b	0.76±0.03 ^d	23.14±1.80 ^a	2.76	67.34	2.10	37.01	0.55
B4	13.6±0.28 ^c	1.26±0.01 ^e	42.42±2.30 ^d	5.07	72.41	6.39	43.40	0.60
C5	11.5±0.19 ^a	1.43±0.03 ^e	25.11±1.56 ^a	3.00	75.41	4.29	47.69	0.63

B Break streams, C Reduction streams, FL1-Flour 1, FL2- Flour 2

Values of the column with the same letter in the superscript are not significantly different from each other at $p \leq 0.05$

produce maximum flour. Pollard was collected as an over-tail of flour sieve from last reduction passage. ISMT pilot plant milling flow sheet is represented in the Fig. 1.

Collection of the stream

Rubber caps of the spouts below the plansifter were kept open to prevent excessive negative pressure within the plansifter (pneumatic mill). The mill was perfectly balanced and maintained steadily throughout the sampling time. The collection of the sample from each stream was done accurately over a fixed duration of time. The collection was done stream wise in the reverse order, i.e. from last reduction passage (C5) towards the first break (B1). The weight of the samples collected was converted into Kg/hr.

Chemical characteristics of streams

Moisture and ash content of the stream were determined as per the standard methods (AACC 2000).

Statistical analysis

Data was statistically analysed using Duncan's new multiple range tests (DMRT) with different experimental groups appropriate to the completely randomized design with four replicates each as described by Steel and Torrie (1960). The significant level was established at $P \leq 0.05$.

Results and discussion

Physico - chemical characteristics of raw material

Wheat selected for the study had the following physico-chemical characteristics: Moisture content 9.6%, thousand kernel weight –40 gm, hectoliter weight –80.2 Kg/hectoliter, sodium dodecyl sulphate (SDS) sedimentation value –45 ml, ash–1.6%, protein–10.3%. The above results indicate that the wheat used for the study is of medium hard quality.

Fig. 2 Cumulative ash curve of ISMT mill. B - Break streams, C – Reduction streams, FL1-Flour 1, FL2- Flour 2

The cumulative ash curve

The cumulative ash curve shows the relation between cumulative flour ash content and cumulative flour yield. Cumulative ash curve can be constructed from the rate of flow, percentage of ash and moisture level of all the intermediate flour streams of the mill. The individual flour streams were arranged according to ash content in the increasing order, with lowest-ash flour first. Starting with the two lowest ash streams, series of calculation were made to determine ash content from blending of two streams. Then the ash of new blend, consisting of first two flours plus the third flour higher in ash content was calculated (Farrell and Ward 1965). Table 2 shows the set of calculation for the cumulative ash curve for ISMT mill. The flours were arranged in an increasing order starting with the C1 (FL1) flour with 0.42-ash percentage and C5 (1.43%) at the end. The cumulative flour extraction (Y) and the cumulative ash content (Z/Y) were calculated. Plotting a graph with Y and Y/Z develops the cumulative ash curve as shown in Fig. 2. The ash curve increases gradually below 60% extraction and shows sharp increase above 60% extraction. Since break rolls open the wheat kernel and remove the endosperm and germ from the bran coat with least amount of bran contamination, the front break passages releases relatively pure particles of endosperm and while the tail break passages cleans up the bran and releases smaller pieces of endosperm along with the more fine pieces of bran and germ. The break releases adjustments of first three breaks have an effect on cumulative ash of resulting flours and intermediate stock distribution in mill (Peterson 1949). As the roll gap goes on decreases from the B1 to B4, the ash content goes on increases from the B2 to B4. The ash of B1 passage is more than the B2 passage, which could be due to the release of surface dusts from the wheat and over sieving of the material on flour sieves as only little quantity of flour is produced there. The lower ash percentage streams are the front reduction passages in the mill, namely, C1 and C2. These passages get the clean endosperm from the purifier and the bran free endosperm middlings from the front break rolls (B1, B2 and B3). The front reduction rolls recover more pure flour from the endosperm by leaving the branny stock to the tail reduction rolls. However, the ash percentage increases from C1 to C5, the ash content of C3 flour is more than C4 as it is collecting passage and receives the branny scalplings from C1 and C2.

Maximum flour yield of 24.01%, is produced from the C1 passage followed by C2 (17.23%), C4 (7.59%), B3 (6.37%), B2 (5.40%), B4 (5.07%), B1 (3.98%), C5 (3.0%) and C3 (2.76%). The cumulative ash curve gives the important information of percentages of the different yields of the patent, first clear, second clear flours and their ash cutoff point (Kim and Flores 1999). Any change in the corrugation of break rolls or variation in adjustments of

rolls, sieving or purification can be detected by irregularities in the ash values of milled flour streams and their quantities expressed by cumulative ash curve (Posner 1991).

As shown in the curve, the minimum ash with more yield of flour comes from the front reduction passages C1 and C2, whereas the break passages and last tail reduction passages comparatively contributes less quantity of flour with more ash.

Conclusion

The study has shown an increase in ash content from B2 to B4 flour mill streams as the roll gap decreases from B1 to B4. As the material passed from front to the tail end reduction rolls, an increasing in ash content was observed from C1 to C5, which was due to recovery of pure endosperm from front reduction passages and scalping of larger branny into the tail end reduction passages.

The minimum ash with more yield of flour has come from the front reduction passages C1 and C2, whereas the break passages and last tail reduction passages comparatively contributed less quantity of flour with more ash content. The cumulative ash curve also gives the information about the yield of different grades of flour and their cut off ash content. Based on this information, miller selects and blends several flour streams for maximum amount of flour at specified ash content.

References

- AACC (2000) American association of cereal chemists. Approved methods. AACC, St. Paul
- Dexter JE, Wood PJ (1996) Recent application of debranning before milling. *Trends Food Sci Technol* 7:35–41
- Farrell EP, Ward AB (1965) Flow rates and analysis for ash and protein of all streams in the Kansas State University pilot flour mill. *Assoc Oper Millers Tech Bull*, Mar., pp 2842–2847
- Hinton JJC (1959) The distribution of the ash in wheat kernel. *Cereal Chem* 36:19–31
- Kim YS, Flores RA (1999) Determination of bran contamination in wheat flours using ash content, color, and bran specks counts. *Cereal Chem* 76(6):957–961
- Peterson WL (1949) Controlled break extraction. *Assoc Oper Millers Tech Bull*, Jan., pp 1722–1723
- Pomeranz Y (1961) The problem involved in peeling of the wheat kernels. *Cereal Science Today* 6:76–79
- Pomeranz (1998) In: *Wheat chemistry and technology* Vol. 1. St. Paul, MN, USA: American Association of Cereal Chemists, pp 17–21
- Posner ES (1991) Wheat and flour ash as a measure of malleability. *Cereal Food World* 36:626–629
- Shellenberger JA (1965) Fifty years of milling advances. *Cereal Sci Today* 9:260–262
- Steel RGD, Torrie JH (1960) *Principles and procedures of statistics*. McGraw-Hill, New York
- Ziegler E, Greer EN (1971) *Principle of flour milling*. In: Pomeranz Y (ed) *Wheat: chemistry and technology*, 2nd edn. American Association of Cereal Chemists, St. Paul, pp 115–199