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Evaluation of Recycle Grinding Performance in Flour Milling

[1]Siti Mazlina Mustapa Kamal and [2]Colin Webb
[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
[2]School of Chemical Engineering and Analytical Science, The University of Manchester, PO Box 88, Sackville St, Manchester, M60 1QD, UK

Abstract: A typical flour milling process is a very linear operation that is almost entirely void of recycled streams where separate fractions from each operation go ahead as new streams to the next operation. In some cases, there are opportunities for combining some streams, for recycling particles that have been insufficiently broken to go back to the same roller mill. This study introduces this recycle concept in flour milling process at second break system. The recycle grinding assessment was made using a Satake STR-100 test roller mill. The recycle process was started after the second break system and the number of recycle grinding was up to 7 regrinds. The particle size distribution and ash analysis were produced to describe the behaviour of the recycle grinding performance. The material release was sifted on a range of sieves and the ash content was analysed using a laboratory furnace. The performance for each recycle stage was investigated. It was determined that it is possible for some coarse particles that contain only bran to keep being recycled in the recycle circuit. A purging operation was recommended to be included in the recycle system, to separate the unwanted particles.

Key words: Ash content, particle size distribution, recycle grinding, sieving

INTRODUCTION

Flour milling is the process by which wheat is ground into fine particles and through which the wheat grain is separated into its constituent parts: bran, germ and endosperm. The germ and bran are largely discarded while the endosperm is then further reduced into the fine powder that we call flour. Flour is a versatile and valuable food source that contains nutrients including vitamins. The best known use for flour is for making bread, but it also an important ingredient in biscuits, cakes, pies and much more. Majority of flour sold is white (Kent and Evers, 1994), this means it consists almost entirely endosperm. In principle the milling process is established in three stages, which are break system, purification system and reduction system (Posner and Hibbs, 1997). The break system is used to break open the wheat kernel and continue to scrape endosperm from the bran, step by step, by sequential passages. The purification system is to separate the outer bran material from inner white endosperm. The aim of this purification system is to purify the milling material that almost no flour is produced. The reduction system is used to deliberately mill the endosperm of the wheat grain into flour.

In conventional flour milling, the structure of the process and flow of the material streams are arranged in a very linear way (containing only inlet and outlet streams) and have very few combined streams. As a result, the milling process involves many unit operations. This is where improvement can be made in the flour milling process, to reduce the number of operations, as there are likely to be streams that could be combined or recycled.

As options, the break and reduction systems are possible to include the recycle circuit for the milling process. In this paper, the scope of recycle study is emphasized mainly on break system. The objective is to improve the milling process by introducing the recycle system at second break system, which studying the performance of each recycle stage.

METHODOLOGY

Preparation of wheat: Two different sources of raw materials (wheat) were used in this experiment. The first was hard wheat Mallacca type, while the second type was a mixture of hard wheat English (50%) and Canadian (50%) type, which was taken from the Rank Hovis flour mill in Trafford Park, United Kingdom.

Corresponding Author: Siti Mazlina Mustapa Kamal, Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
Tel: +60-3-89466363 Fax: +60-3-86567123

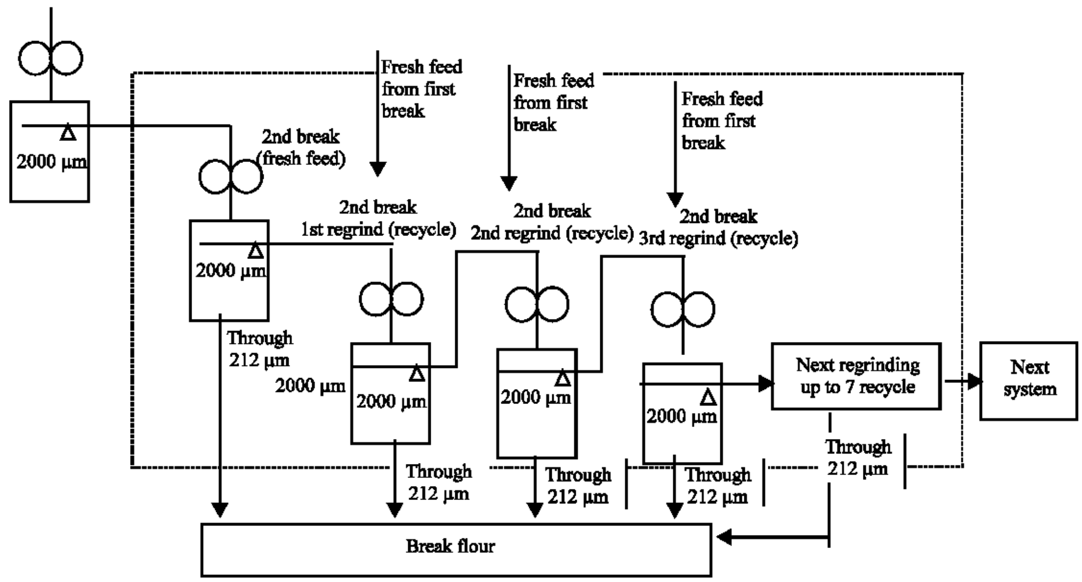

Fig. 1: Schematic of the experimental grinding sequence. The same pair of rolls was employed for second break and each recycle successive stream

Experimental milling: For the hard Mallacca type (stored in SCGPE laboratory), grinding procedure was started from first break rolls. Roll gap was adjustable to 0.5 mm for first break rolls and 0.2 mm for second break rolls. For these studies, a differential of 2.5 was used and fast rolls were set at velocity 550 rpm. Roll for first break was fluted at 4 flutes/cm and second break at 6 flutes/cm and operated in a dull-to-dull disposition. The wheat samples were conditioned overnight to 16% moisture content (wet basis). The wheat used in the experiments was ground on first break rolls and had subsequently overtailed a 2000 µm sieve. Then, the feed for the recycle grinding process was obtained from second break system which overtailed a 2000 µm sieve aperture and repeatedly using it. Batches of 1 kg of this material (particle overtailed 2000 µm) were set as the capacity in the second break and recycle grinding.

The recycle grinding assessment was started after the second break system. The recycle grinding assessment was carried out using the roller mill by simulating a steady state material mixture. The mixture was made up by taking the 2000 µm particle size fraction from each stage of the sequential grinding process and mixing them in their absolute proportions, which for this study the feed to recycle grinding was fixed to a certain amount. This process was repeated until seven regrind (recycle). This series of experiments are illustrated graphically in Fig. 1 and the simplified process is shown by block diagram in Fig. 2. At least two samples were milled at the same condition and sifted.

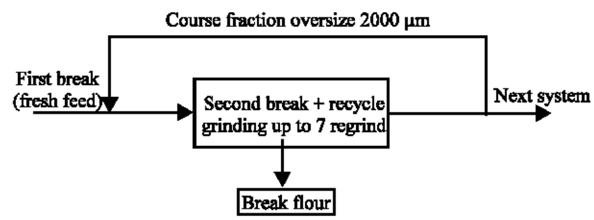

Fig. 2: Block diagram for second break and recycle grinding process

Samples obtained from the Rank Hovis flour mill were of a material produced from the coarsest stream (~ above 2000 µm sieve) of first break system. This material was fed to second break system with the same setting that was used for the Mallacca type and was ready to be used in recycle grinding assessment. Both experiments were carried out on the STR 100 roller mill. The American Association of Cereal Chemistry (AACC, 1995) methods were used for the ash analysis, moisture conditioning and analysis.

RESULTS

Comparison between Mallacca and mixture wheat type: The production of material released for each size distribution separated was measured and shown in Fig. 3 and 4, which show the results in weight percentage for both samples. The material released was sifted on a range of sieves (with 2000-212 micrometer mesh width. Fig. 3 represents results obtained from the hard Mallacca

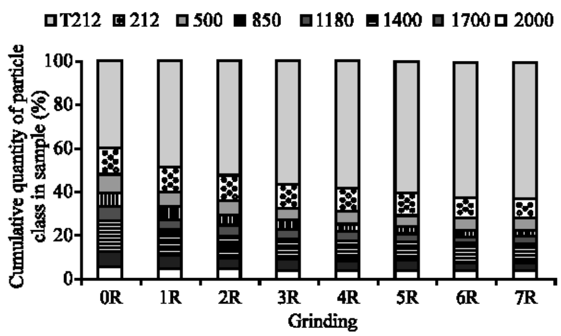

Fig. 3: Particle size distribution produced from second break and recycles for Mallacca wheat type

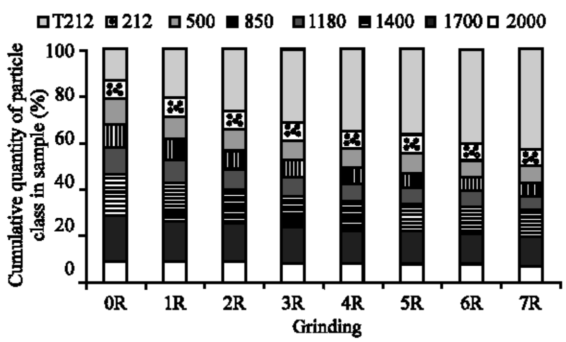

Fig. 4: Particle size distribution produced from second break and recycles for mixture type wheat (English and Canadian)

wheat type, while Fig. 4 shows results for a mixture of hard English and Canadian wheat type.

The particle size overtailing a 2000 μm aperture sieve for both types of wheat (Fig. 3 and 4) was shown to progressively increase with increasing numbers of regrinds. The amount of particle size (>2000 μm) released from Mallacca type was higher than for the mixture type. Mallacca type tends to produce more of the coarsest particle size with fewer finer particle size compared with the mixture type. Weight percentage for particle <212 μm for Mallacca type was less than 5%, while the mixture type produced more than 6%. Grinding the mixture type tended to give a high amount of smaller particles, as the mixture type breaks more to fine particles when passed through the rolls. More fine bran fragments that contaminate the quality of the particles had been produced. This result is supported by ash analysis on particle size >2000 μm and <212 μm shown in Table 1. From ash analysis, the coarsest particle of Mallacca type was higher and for particle size <212 μm was slightly lower than mixture type.

The results demonstrate that both materials can be successfully applied to a recycle grinding process. As the

Table 1: Ash Percentage for size >2000 and 212 μm for Mallacca and mixture type

	Mallacca type		Mixture type	
Regrind	>2000 μm	<212 μm	>2000 μm	<212 μm
SB	1.94	0.39	2.06	0.42
1R	2.06	0.42	2.25	0.43
2R	2.38	0.42	2.34	0.45
3R	2.51	0.55	2.36	0.56
4R	2.65	0.55	2.40	0.57
5R	2.81	0.57	2.45	0.59
6R	2.82	0.58	2.47	0.61
7R	2.84	0.59	2.53	0.62

number of regrinds increased, the coarsest particles tend to increase as well, which indicates that the recycle system successfully separated bran and endosperm. However, the rate of production of coarsest particles was still increasing after 7 regrinds. Looking at ash content, the quality of particles of <212 μm also increased. This suggests that the recycle process has still not achieved constant level after 7 regrinds.

Particle size distribution and ash content for mallacca type: As shown in Fig. 3, the amount of material above 2000 μm that is not comminuted, progressively increases with each successive grind. In contrast the comminution level for other classes of particle slightly decreases with each grind. This means the recycle grinding process does not becomes constant after 7 regrinds and the survival rate of the coarsest particles (>2000 μm) increases with each grinding, instead of them being broken into small particles.

The feed material to the recycle grinding system is a mixture of fresh feed and recycled material; therefore there are some materials that will be ground for the first or second time (Fig. 2). This coarsest material (>2000 μm) tends to be broken into small particles (<2000 μm). This may be because the particle was still in three-dimensional form and was still hard and easily broken. When some of these particles (>2000 μm) have been reground a number of times, they tend to orient themselves to a two-dimensional plane area, whereby these coarsest particles become progressively thinner and slip through the roll gap more easily without being broken into small particles. As the particles become thinner, it will reduce the degree of reduction and so their comminution becomes more difficult. The process of becoming thinner will occur and continue for each grinding. This means that there is some material (>2000 μm) that is likely to keep recycling in the system. This material (>2000 μm) will accumulate and increase the amount for each grinding.

DISCUSSION

The objective of second stage milling is to scrape the remaining endosperm from the bran as cleanly as possible, avoiding any undue cutting up of the bran skin. The objective of a recycle circuit is mainly to recycle the unreacted feed that overtails from the earlier grinding in the process. In this scope, the unreacted feed is the materials that contain bran with attachment of endosperm which has not been scraped efficiently or still survives after the first grinding at second break. These materials might have not been selected to be grinding for the first time entering the second break rolls. The aim of introducing the recycle circuit at second stage has been successfully shown by the results. However, it was found that the recycle grinding process has still not becomes constant and not achieved steady state level after 7 regrinds. There is the possibility that the coarsest particles containing only bran (without endosperm attached) kept being recycled in the system.

Owens (2000) performed preliminary studies on introducing a recycle grinding circuit at second break. The recycle grinding process proposed by him was a normal closed circuit recycle, which this is similar to the recycle circuit that has been applied to other milling processes (Austin and Trass, 1997; Gommeren *et al.*, 1996). Austin *et al.* (1981) also developed model for breakage based on this closed circuit. Figure 5 shows such a normal recycle circuit.

This type of recycle configuration shows that the mill product is passed through a size classifier that gives two exit streams; the coarser stream returned to the mill feed and a finer stream, which is the final product (Austin and Trass, 1997). The similar concept was applied in this study. With applying the normal closed circuit at break system, the result of particle size distribution was found that the recycle grinding did not become constant and not achieved steady state level. There is the possibility that the coarsest particles that contain only bran (without endosperm attached) keep being recycled in this recycle system as inerts. Therefore, these particle need to be released and it can be concluded that the recycle system need to include a purging system. Due to the result found in this study it was suggested that the normal closed circuit was inefficient to be use in flour mill process.

In this study, the coarsest material being recycled was not just changing in terms of physical properties, but changing in term of physical and chemical structure, while in mineral milling it changes in terms of physical properties only (wants to reduce the large size to a smaller size). The physical change means to reduce the endosperm to small particle and the chemical change is to separate the bran and endosperm. This means that the normal closed circuit was not suitable to be used directly in the flour milling process. It would be more efficient,

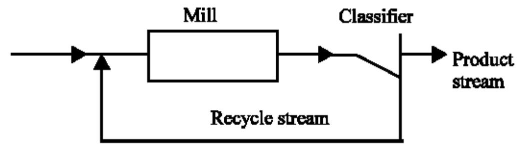

Fig. 5: Normal closed circuit

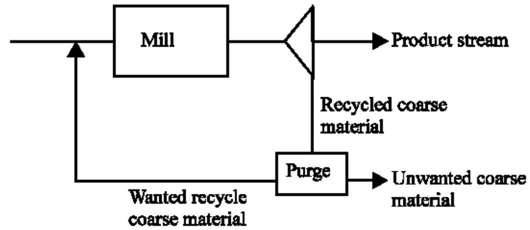

Fig. 6: Closed circuit with purge system

therefore, to use a closed circuit that incorporates a purging stream. Yokohama and Yamaguchi (1984) have shown a simple closed circuit system for a minerals milling process that includes a purge system (Fig. 6).

This type (Fig. 6) of closed circuit is suggested here to be used in the recycle grinding system for the present study. The target is to recycle the coarse material (>2000 μm) that survives on the top sifter and send this to another unit operation (purge unit) to separate this coarse material into two streams; the recycle stream that feed again to the mill is the wanted recycle coarse material, which contains bran and endosperm and the purge stream is the stream for unwanted coarse material that should contain only bran. This concept is more practical to apply in the recycle grinding process of flour mill, since the result in this study has shown that there are materials that contain only bran surviving in the recycle system.

CONCLUSIONS

A normal closed circuit of recycle was applied in this study. The outcomes of the present result shows that it was inefficient to use this concept since the particle size distribution for the recycle grinding process has shown that the recycle did not become constant as the number of grinding increased. To overcome the problem another type of closed circuit was included a purge system. A closed circuit of a recycle grinding is proposed to be included in the design flow sheet of the recycle grinding process in the flour mill. It is also recommended that the suitable equipment that could perform a purging process could be a purifier.

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