

THE EFFECT OF USING THE DRUM DETACHERS IN THE INDUSTRIAL WHEAT FLOUR MILLS

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The work is concerned with the effects of applying the drum detachers as flake disrupters in industrial wheat flour mills. The stocks entering and leaving the drum detachers applied on the different reduction passages in two industrial mills were intercepted and employed in the experiments. The changes in the flour release and flour ash content were followed. The results show that the drum detachers are effective in disrupting the flakes formed in the smooth roller mills grinding zone. However, the contribution of the drum detachers to the overall milling efficiency is in close correlation with the nature of the formed flakes. If the flakes are primarily composed of endosperm particles, the employment of drum detacher results in a statistically significant increase of the flour yields without deterioration of flour quality. If flakes, formed on the end passages of the reduction system, contain large portion of branny particles, the increase of the flour ash content following the drum detacher is statistically significant.

KEY WORDS: wheat flour milling, reduction system, drum detachers

INTRODUCTION

Wheat flour milling is a gradual reduction process consisting of sequential and consecutive size reduction and separation (1). Particle size reduction is achieved by passing cleaned and conditioned wheat through a series of break (fluted) and reduction (smooth) rolls (2). Segregation between the kernel parts occurs in plan sifters, where the sieves separate particles of different size, and in purifiers, where the sieves and air-flow separate particles of different size, specific gravity and shape (3). Breaking the wheat kernel is affected by corrugated cast steel rolls that gradually separate the endosperm, bran and germ. The objective is to obtain a maximum yield of large middlings (endosperm particles with various degrees of attached bran) with a minimum yield of flour and fine middlings that cannot be purified before reduction to flour (2). Reduction of relatively pure endosperm to flour is achieved by using smooth rolls.

In order to rationalize their production facilities, today mills are forced to reduce the equipment, operating and maintenance costs (4, 5). The trend in recent years has been to shorter mill flows, necessitating harsher grinding on both break passages and reduction

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passages, which could have significant consequences to milling results (6). Although the roller mills and plan sifters still remain the primary machines, the process has been supported by the machines such as bran finishers, vibro-sifters, impact detachers and drum detachers.

Detachers are designed for the gentle detaching of the stock flakes during the reduction passages. Particles passing through the grinding zone of the reduction (smooth) rolls are subjected to shear forces from the contact between points on the particles and the roll surfaces, and compressive forces on the particles as a whole. The reduction in size resulting from particle fracture occurs after a given amount of deformation (7). The roll parameters (roll gap, feed rate of stock to rolls, roll velocities and differential) influence the magnitude of the stress and the relative contributions of compressive and shearing forces (8). The magnitude and the nature of the forces acting on endosperm particles will determine the degree of particle size reduction, energy required for grinding and bran contamination of the flour (9). Considering the grinding conditions on reduction passages (smooth rolls and 1.25 differential), as the roll gap decreases, greater compressive stresses are imposed, thereby increasing the number of endosperm fractures. This creates more flour particles while flattening the tougher branny particles, which would not pass into the flour. On the other hand, at tight roll gaps the compressive forces could be so intense that fractured endosperm particles create flakes. Flakes would reduce the flour yield and commercial flake disrupters are commonly used before sieving to overcome this. They are positioned between the roller mills and plan sifter, immediately after the roller mills or just before plan sifter inlet (after the air locks of the pneumatic conveying system). Drum detachers are used for the gentle disruption of endosperm flakes without disintegrating any bran and germ particles. The material to be detached is fed through the inlet directly to the rotor and is caught by the inner surface of the jacket, which is installed with a number of impact bars. The pitch of beaters directs the material from the feeding point to the discharge point of the machine. The use of these machines should increase flour yields without causing any significant increase in ash or color. In order to do that, the rotary speed is limited to a maximum 14-16 m/s (10). They allow the sifter passage to perform more effectively and prevent losing good stock to by-products.

The purpose of this work was to examine the effect that drum detachers have on the milling results on the different passages of the reduction system in industrial wheat flour mills. The changes in the flour release and flour ash content were followed.

EXPERIMENTAL

The streams entering and leaving the drum detachers applied on the different reduction passages in two industrial mills (A and B) were intercepted and employed in the experiments. In the industrial mill A, the drum detachers are employed from the third reduction passage (3M) up to the end of the reduction system, having a total of eight passages. In the wheat flour milling process, the characteristics of the stocks are constantly changing from the beginning of the process (the first breakage passages) to the end (the last reduction passages). Considering these differences, the samples were taken from different reduction passages covering the head (3M), middle (5M) and end (8M) reduction passages. Also, the roll gap setting is constantly decreasing from the beginning to the end

of the milling process. Usually the drum detachers are not employed on the first passages of the reduction system. The materials milled on these passages mainly consisted of large middlings composed primarily of endosperm, while the gap setting is not as tight as it is on the later reduction passages. This is the reason why the formation of flakes is not apparent as it is later in the reduction system. On these passages, impact detachers are sometimes applied to support the grinding of clean middlings. In the industrial mill B, the drum detachers are used only on the end passages of the reduction system (5M and 6M), which consists of a total of six milling passages. In this mill, on the head passages of the reduction system, the impact detachers are employed. The working principle as well as the role of the impact detachers in flour milling process is completely different compared to the role of the drum detachers.

Before sampling, the mills were checked for any kind of disturbances in the process, and sampling was carried out with balanced load to machines. Since the detachers are used diagrammatically between the roller mill and the plan sifter the samples were taken after the air locks of the pneumatic conveying system before entering the appropriate section of the sifter. The mass of each sample was around 2 kg. Three sets of batches of 100 g of each sample (stocks entering and leaving the drum detachers applied on the mentioned passages) were sieved for 3 min on a Bühler laboratory sifter (gyratory in a horizontal plane), model MLU-300 (Uzwil, Switzerland). The sieve opening was 150 μm , and a bottom collecting pan was fitted.

Moisture and ash contents of the samples were determined according to ICC standard methods No. 110/1 and 104/1, respectively (11, 12).

The results are expressed as mean \pm standard deviation. The significance of the differences in flour yield and flour ash content between the stocks that enter and leave the detachers has been tested by Student's *t*-test.

RESULTS AND DISCUSSION

The moisture content of the stock decreases towards the end of the reduction system in both industrial mills (Table 1). This is expected considering the pneumatic conveying of intermediate stocks. With every grinding passage, the stock is more exposed to a drying effect of the air from the pneumatic system. Also, in the industrial mills the heating of the rolls occur especially in the cases of tight roll gaps and increased feed rate to the rolls (increased friction between particles and between the roll surface and particles). The stock from the last reduction passages, that has been transported by more pneumatic lifts and exposed to more grinding action by the rolls, has a lower moisture content compared to the stocks from the previous passages.

Ash content of the stock increases towards the end of the reduction system in both investigated mills (Table 1). This is expected considering that the aim of the milling process is to obtain the best possible dissociation of the starchy endosperm from the other parts of the grain (13). During the process, the endosperm is gradually removed from the bran coat. Ash is concentrated in the bran and the ash content increases from the inner to the outer part of the wheat kernel (14), with over one half of the total in the pericarp, testa and aleurone (15). This is the reason why the purity of the stocks in flour milling (either intermediate or final) is traditionally expressed as ash content (16). A higher ash content

of the samples taken from the last reduction passage indicates that they are relatively enriched in bran and germ compared to the samples from the previous milling passages.

Table 1. Moisture and ash content of the stock following the reduction passages in two industrial mills (A and B)

Milling passage	Moisture content (%)	Ash content (%) _{dm}
3M (A)	12.1±0.06	1.25±0.029
5M (A)	11.6±0.17	1.78±0.032
8M (A)	11.3±0.15	2.50±0.036
5M (B)	12.0±0.15	4.77±0.039
6M (B)	11.6±0.26	5.01±0.043

Values are mean ± standard deviation of three independent determinations.

It is interesting to note that there are significant differences in the ash content of the stocks between investigated mills. These differences can be attributed to different flow diagrams and roll gap settings in these mills, as well as to the fact that the impact detachers are used on the front passages of the reduction system in mill B. As it was mentioned earlier in the text, the working principle and the role of the impact detachers in flour milling process is completely different compared to the role of the drum detachers. Drum detachers are used as flake disrupters while the impact detachers use impact as the principal size reducing force. The material is reduced when the particle is struck by a high-velocity impeller with a rotary speed up to 100 m/s (10). They are supplementing the roller mills by supporting the grinding of clean middlings ahead of the plan sifter (17). The use of these machines increases flour yields and therefore reduces the amount of endosperm that reaches the end passages of the reduction system. This explains the considerably higher ash content of the stocks in mill B compared to corresponding stocks in mill A (without impact detachers).

Drum detachers are used for the gentle disruption of endosperm flakes without disintegrating any bran and germ particles. In order to evaluate their performance, the changes in both flour yield and flour ash content must be observed. Presuming that the rotary speed is within the usual range, there are three possible outcomes following the use of drum detacher:

- increase in flour yield without increase of the flour ash content,
- no changes in flour yield and flour ash content,
- increase in both flour yield and flour ash content.

The outcome mainly depends on the characteristic of the stock that has been sent to the drum detachers. In the investigated mills, all three mentioned outcomes have been registered (Figure 1; Table 2).

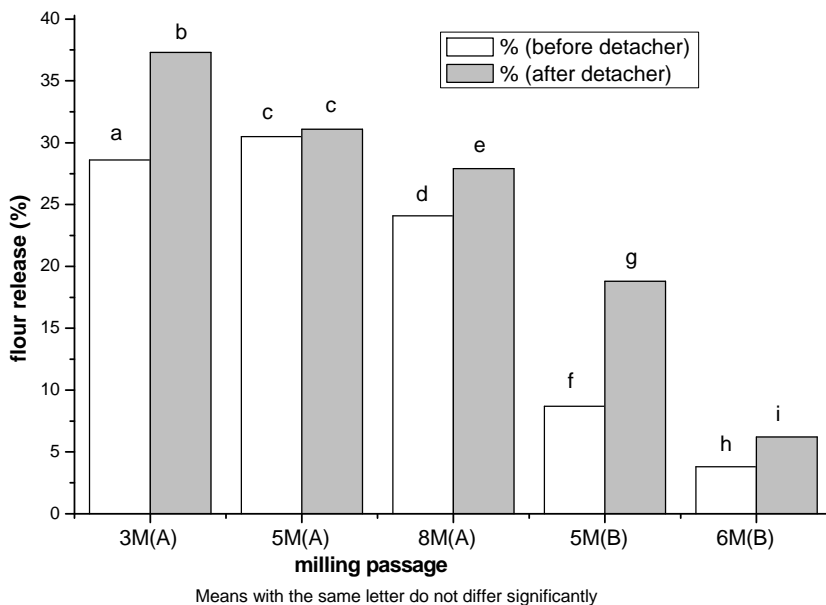


Figure 1. Flour release before and after the drum detachers employed on the reduction passages in two industrial mills (A and B)

The first two outcomes are acceptable, meaning that the drum detachers are working properly. The first outcome is registered on the following passages: 3M(A), 8M(A) and 5M(B). On these milling passages the use of the drum detacher has been followed by the statistically significant increase in flour yield ($p < 0.01$), while at the same time, there is no statistically significant change in flour quality as determined by ash content ($p > 0.01$). Practically, the results show that the flour flakes are formed in the roller mills grinding zone, but they are disrupted by the detacher without disintegration of the outer layers of the kernel. The results show that the use of the drum detachers on these milling passages contributes to the efficiency of the milling process.

The second outcome is registered on 5M(A) milling passage. The changes in both flour release and flour ash content are not statistically significant ($p > 0.01$). The practical meaning of the results is that there is no formation of the flour flakes in smooth rolls grinding zone. Otherwise, the flour release would increase following the drum detacher. The fact that the flour ash content remains the same suggests that the outer kernel layers are not disintegrated by the action of the drum detacher. In this case, the use of the drum detacher does not increase the efficiency of the process, but at the same time, there are no negative side effects. Also, this does not exclude the possibility that in the future flour flakes would be present in the stock (especially when the roll gap setting is tight). If that is the case, considering that there is no increase of the flour ash content, it is reasonable to assume that the drum detacher would disrupt the flour flakes and thus contribute to the process efficiency.

Table 2. Moisture and ash content in the flour before and after the drum detachers employed on the reduction passages in two industrial mills (A and B)

Milling Passage	Moisture content (%)		Ash content (%) _{dm}	
	before detacher	after detacher	before detacher	after detacher
3M (A)	11.3±0.29	11.9±0.10	0.56±0.015 ^a	0.56±0.023 ^a
5M (A)	10.8±0.11	10.7±0.29	0.85±0.021 ^b	0.85±0.030 ^b
8M (A)	10.6±0.11	10.4±0.17	1.11±0.026 ^c	1.12±0.030 ^c
5M (B)	11.4±0.23	11.5±0.23	1.98±0.030 ^d	2.01±0.035 ^d
6M (B)	10.9±0.21	10.9±0.06	2.99±0.038 ^e	3.14±0.036 ^f

Values are mean ± standard deviation of three independent determinations

Means with the same letter do not differ significantly

The third outcome is registered on 6M(B) milling passage. The changes in both flour release and flour ash content are statistically significant ($p < 0.01$). The ash content of the stock that enters the detacher is high (Table 1). Also, the flour release on this passage is small, especially compared to flour release on the other investigated milling passages. The previously mentioned facts are not unusual considering that this is the last milling passage in the reduction system and the endosperm is almost completely removed from the stock. Under the present grinding conditions: smooth rolls, small differential (1.25) and tight roll gap, the compressive forces in the grinding zone are intense. Compressive stresses are more effective in causing the disintegration of the brittle endosperm material while flattening the tougher branny particles. Bran, being tough and fibrous, is more prone to fracture imparted by shear forces. The absence of endosperm particles and the predominant branny character of the stock result in a small flour yield. At the same time, the increase of the flour ash content is significant. Similarly to the endosperm particles the small branny particles also agglomerate and form flakes. Practically, in this case the drum detacher disrupts the branny flakes formed in the grinding zone, therefore increasing the number of branny particles in the flour.

CONCLUSION

The roles of the supporting machines, such as the drum detachers, are very important in the modern flour milling process. The results presented in this study show that the drum detachers are effective in disrupting the flakes formed in the roller mills grinding zone. The trend to shorter mill flows causes harsher grinding on both break and especially reduction passages. The use of drum detacher is especially recommended in the process with relatively tight roll gap setting when the formation of the flour flakes is apparent. The disruption of the flour flakes increase the flour yield and prevents losing the good quality stock to by-products. However, the efficiency of the drum detachers is in close correlation with the characteristics of treated material, i.e. relative contribution of endosperm and branny particles in the stock. The increase of the flour ash content following the drum detacher could be expected in the cases of high ash content of treated stock.

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АНАЛИЗА ЕФЕКТА РАДА ДЕТАШЕРА У МЛИНОВИМА ЗА ПШЕНИЦУ

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У раду су испитивани ефекти примене деташера у индустријским млиновима за пшеницу. Као материјал за испитивање коришћени су узорци млива на пролазиштима у фази мљења гриза и осевака на којима су укључени деташери. Узорци млива узимани су непосредно испред и иза деташера. Ефекти рада деташера праћени су одређивањем приноса брашна и садржаја пепела у брашну. Резултати показују да се деташери могу ефикасно користити за разбијање пахуља насталих у млевном простору глатких ваљака. Међутим, допринос деташера ефикасности технолошког поступка мљења је у блиској корелацији са карактером формираних пахуља. Уколико су формиране пахуље претежно састоје од честица ендосперма, примена деташера доприноси статистички значајном повећању приноса брашна без погоршања његовог квалитета. Уколико пахуље, које настају на задњим пролазишћима у фази мљења гриза и осевака, имају повећан садржај мекињастих честица примена деташера доводи до статистички значајног повећања садржаја пепела у брашну.

Кључне речи: производња брашна, фаза мљења гриза и осевака, ротациони деташери

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