RESEARCHES REGARDING THE WHEAT GRINDING OPTIMISATION, IN THE FIRST BREAK, FOR SAVING THE MILLING ENERGY

— short presentation PHD thesis —

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Abstract: Wheat is one of the most important cereal crops in the world with various end-uses: food (bread, cakes, cookies, pasta), animal feed, raw material for beer and whisky, biodegradable plastic (from wheat starch). In all these technologies, grinding has great importance and is very energy consuming. So, it is important to evaluate the grinding energy and the factors affecting this parameter. In the industrial milling process of the wheat, 60-75 % from the total specific energy consumption is used in the grinding process. The measurement of the grinding resistance of the wheat kernel can estimate the energy consumption in the grinding process, for diminuate the total energy consumption in the milling process.

Keywords: wheat, grinding resistance, energy consumption

INTRODUCTION

The study of the first break is an ideal starting point to determine the efficiency of the grinding process. (Campbell et. al., 1999) emphasized on the physicochemical properties of the wheat (size distribution, moisture content, kernel hardness) and the settings of the milling equipment which affect wheat breakage during first break roller mill.

For the milling technology, the grinding is the main operation of the processing. This process must be conducted in different ways for each technological step. The milling of the grain consists in the grinding applied to the seed until the flour obtained.

The grinding has distinctive steps, such as: the breaking step, the obtaining of the middlings. Each step has different parameters of the rollers, which means different grinding degrees. Because of the differences between the

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endosperm and the different layers of the wheat kernel, it is possible to sort and sieve these fractions after the grinding process, for the obtaining of the bran.

The national and also international milling technology is using 13-21 grinding consecutive steps.

The well-known companies Buhler, Ocrim and Golfetto, have more or less the same steps in technology:

- breaking : 5-6 consecutive grinding steps
- clear flour : 2-5 consecutive grinding steps
- grinding of the middlings : 6-10 consecutive grinding steps

Each grinding step is different from the next step, through the parameters of the process and also the characteristics of the rollers.

The aim of the research is to study, to measure and register the resistance of the cereals and intermediary products, in the milling process with a new designed micromill. The existent and similar equipments on the market, are not able to provide specific informations, regarding the behaviour of the cereals in the milling process. The existent equipment can offer only a general view, regarding the resistance of the cereals in the grinding process. The design of the roller mill does not offer a specific analysis regarding the resistance of the small fractions resulted in the grinding process. The industrial grinding of the wheat is using two rollers with differential speed. The grains are in the same time under the compression and the shearing efforts. There are no shearing efforts and maximum compression efforts when the rollers have the same speed. The shearing effort appears when the rollers have differential speed. In the grinding process, the speed ratio (k) between the fast speed roller and the low speed roller is from 1:1,5 to 1:2,5. The energy consumption during milling depends on the mill adjustments (Scanlon and Dexter 1986). The new designed micromill determine the grinding resistance of the cereal grain by simultaneously measurements of the compression efforts and the shearing efforts.

The micromill is used in the grinding process of the wheat and of the middling too, for the appreciation of the grain resistance in the milling process, in the same conditions as in the milling industry. The micromill is equipped with rolls measuring 50 mm in length and 90 mm in diameter. The rollers are either smooth or corrugated. The smooth rolls are mainly used in the final reduction and refining steps with soft wheat semolina.The adjustment of the roller characteristics can be done for each type of milling product (grain, semolina, bran). The grinding resistance is represented by one single value for one pair of rollers, instead of two values (one for the slow roller and the other one for the fast roller) obtained by other measurements. This single value is significant for the comparative appreciation regarding the energy consumption in the milling proces, for different wheat cultivars or different batches, but also for different characteristics of the rollers: the size of the gap, roll disposition sharp-to-sharp, sharp-to-dull, dull-to-sharp or dull-to-dull, the corrugations number/cm, the differential speed ratio, profile and inclination. The appreciation of the grinding resistance is made by measurements of the resistant moment of the kernel, between the rollers, in the breaking process.

The cereal particles to be milled are fed in the bunker supply 1 (Figure 1). The clamshell 2 assures the feed rate control over the milling stock. The feed roll 9 is designed to distribute uniformly the milling stock over the rolls. The particles of the cereals are sent by the funnel 3 on the corrugated rolls, the fast speed roll 4 and the slow speed roll 8. After the grinding process, the product is collected by the collection box 7 and then is analysed to make a comparison between the initially and finally granulosity of the particles, for obtaining the grinding degree. The micromill has a metalcase 6 with a transparent window 5.

The resistant moment of the particles grounded between the rollers, is measured by a tensometric cell, conected to a PC computer and managed with a software program.

From the results of the experiments were obtained the curves of the resistance moment variation, using corrugated break rollers with a fast roll speed of 500 rpm, a roll differential speed of 2,5, 5 corrugations/cm, 1 mm roll gap, with a dull-to-dull roll disposition and differential speed (1:2,5).

The wheat grain mechanical resistance is usually assessed on the basis of kernel hardness tests as described by (Pomeranz and Williams,1990). Penetration tests and crush resistance tests are performed using one single wheat kernels but have to be replicated with many kernels to obtain statistically representative results. But the measurements are not very accurate because of the shape and the size of the wheat grain.

In the milling process, a well wheat preparation by conditioning is at least half the battle toward mill balance, which results in the most favorable flour extraction and flour quality and also a lower energy consuming process. The conditioning is influenced by the physical and chemical state of the wheat. An optimum rest time in the wheat conditioning can provide a higher flour yield with 2-5%, a much more satisfactory flour colour and an reduced grinding energy consumption with 10-20%.

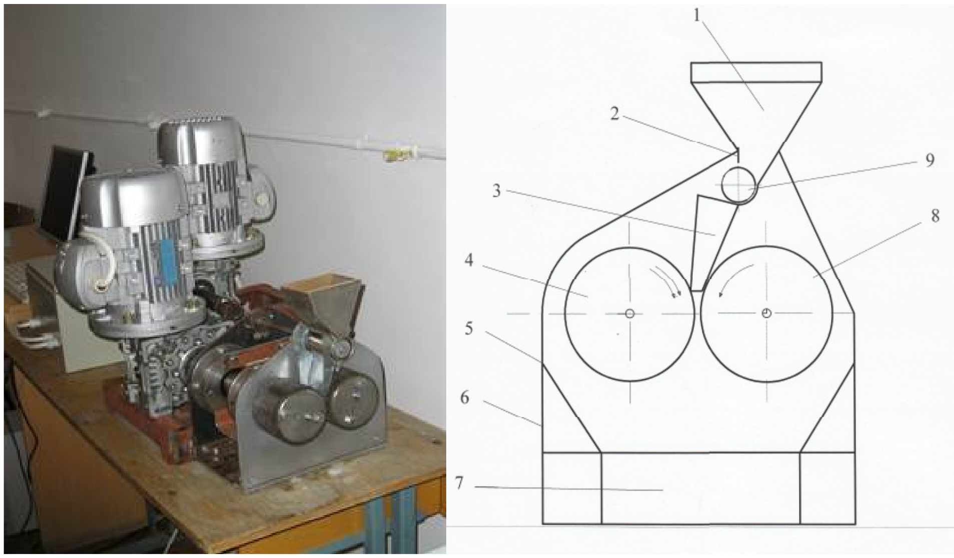

Figure 1. The micromill components

The investigations were carried out on two Romanian winter wheat varieties (*Triticum aestivum, ssp. vulgare*) Dropia and Pegasus, harvested in 2009. The preparation of the samples colected carried out according to the chess-board pattern method, after cleaning with an Sadkiewicz Instruments Scourer. The physicochemical characteristics of the wheat were evaluated as follows: the moisture content using the SR ISO 712 : 2005; the wet gluten content, protein content using the NIR technique (Inframatic, model 8600, Perten Instruments AB); vitreous kernel using the STAS 6283-2/1984 (farinotom apparatus). The quality indices of the studied wheat varieties are presented in Table 1.

Table 1. Quality indices of the wheat varieties

Variety	**Dropia**	**Pegasus**
Protein content [%]	10.8	15
Hectolitric weight [kg/hl]	77,6	77,4
Vitreousness [%]	18	62
Wet gluten content [%]	21	32,4
Moisture content [%]	13	12,3
Falling number [s]	260	333

Wheat preparation by conditioning means removal or, more often, addition of water followed by a rest period. The amount of water added depends on original moisture of the wheat and the relative humidity in the mill processing space. The moistened wheat is then allowed to rest for a period of time, to let the added moisture penetrate evenly throughout the kernel parts.
This tempering process is probably the only stage at which the miller can modify the physical and chemical state of the wheat. The objective is that all kernels reach the same physical condition.
In the Romanian mills, the kernel readiness is achieved without heat by adding cold water to the wheat and allowing the wheat to rest in bins (silos) until it reaches the optimum moisture distribution and kernel suitability for milling.

Usually, the optimum rest time for the moistened wheat is determined from diagrams (nomograms) containing the physical and chemical indicators determined in running laboratory. Another method is using the laboratory mills (Brabender, Buhler, Miag, Chopin) for milling moistened wheat samples, in different period of time (from 0,5 to 1 hour), in few successive breaking steps and then sorting by sieving. Finally, the qualitative and quantitative analysis of these milling products can provide the establishment of the optimum rest time in the wheat conditioning. But all these methods are long lasting proceedings with high working volume. It was state by the authors that there is a correlation between the grinding energy and the technological properties of the wheat (related to the conditioning steps: addition of water and rest time). That is why we propose to asses the optimum rest time in the wheat conditioning, with the micromill designed to determine the grinding resistance of the wheat grain.

CONCLUSIONS

The optimum rest time value for the conditioning of Dropia variety is 5 hours. For this value it was obtained the lowest average resistant moment in the grinding process of this soft wheat variety, which it means also the lowest energy consumption. The lowest average resistant moment was obtained also for the Pegasus variety (hard wheat) for 9 hours rest time in the conditioning process. The resistant moment of the particles grounded between the rollers (measured by a tensometric cell, connected to a PC computer and managed with a software program) has been obtained for each period of rest time for the moistened wheat.

The results are confirming that for the lowest resistant moment value, the optimum rest time is 5 hours for Dropia variety and 9 hours for Pegasus wheat variety. The assessment of the optimum parameters in the conditioning process can be made by the micromill designed to determine the grinding resistance of the cereals.
The method has the same accuracy as the classical one and has the advantage to be quicker and less demanding as work volume.
It is an alternative way to describe the optimum for the conditioning process and can be used in laboratory for the benefice of students as well in the milling industry.
The next objective of the research is to identify the optimum technological parameters (the size of the gap and roll disposition) for obtaining the maximum technological efficiency, with minimum energy consumption on the first breaking step in the wheat milling process.
Samples of Dropia wheat variety (18 % vitreousness) were tempered for 6 hours to 16 % moisture content. The samples of Pegasus variety (62 % vitreousness) were tempered for 14 hours to the same level of moisture, 16 %.The first break was performed by the new designed micromill. The micromill is equipped with rolls measuring 60 mm in length and 90 mm in diameter, 0,6-1 mm roll gap for the first breaking step, 6 corrugations/cm, roll disposition dull- dull (D/D) and then sharp-sharp (S/S), 2,5:1 differential speed ratio, 8% inclination and $30/60^0$ (α/β) profile.To ensure the proper balance and the efficiency of the breaking operation was used the test sifter from Retsch Gmbh with six assortment of sieves (1,25 mm, 630 µm, 400 µm, 315 µm, 250 µm and 160 µm). The best results for the first break, from the point of view of technological efficiency and the energy consumption were obtained for the sharp-to-sharp disposition and a roll gap related to the grinding length of the rollers.
Energy efficiency is an important component of a company‘s environmental strategy. The new mills are designed to reduce labor and machinery to lower capital, lower consuming energy and manufacturing costs. Wheat milling is an energy-intensive industry because it is a wet process that produces dry products. Significant amounts of energy are required to power the large motors for grinding process. Opportunities exist within wheat milling plants to improve energy efficiency while maintaining or enhancing productivity. As food manufacturers face an increasingly competitive global business environment, they seek out opportunities to reduce production costs without negatively affecting product yield or quality. Uncertain energy prices in today‘s marketplace negatively affect predictable earnings, which are a

concern, particularly for the publicly traded companies in the wheat milling industry. Successful, cost-effective investment into energy efficiency technologies and practices meets the challenge of maintaining the output of a high quality product despite reduced production costs. Cross-cutting equipment present well-documented opportunities for improvement. Equally important, the production process can be fine-tuned to produce additional savings.

During wheat flour production only about 1% of grinding energy is transformed into receiving a new surface (Mohsenin, 1986). The main cause of such large energy loss are plastic and elastic strains, (Fang and Campbell, 2002a, 2002b). It is also essential to fully characterize the milling fractions produced when assessing the grindability of wheat in a roller mill. The most common particle size analyses involve sieving analysis (Hareland, 1994).

The grinding energy and how it relates to size reduction has been a subject of considerable interest to researchers.

The motivation to measure energy requirements for size reduction at specified roller mill settings led to the development of instrumented roller mills of various designs (Gehle, 1965) (Kilborn et al., 1982) (Fang, 1995) (Pujol et al., 2000).

The resistant moment of the grains grounded one by one, between the rollers (measured by a tensometric cell, connected to a PC computer and managed with a software program) is represented by the curves from (for Dropia variety) and (for Pegasus variety). The obtained values of the resistant moment are between 0,787 Nm and 1,215 Nm for Dropia variety and between 1,102 and 1,586 Nm for Pegasus variety. The differences of the resistant moment values for each wheat grain are related to the geometrical parameters of the grain and the mechanical properties due the endosperm structure. The energy consumption is represented by the surface aria, below the resistant moment curves. The comparative analysis between the maximum resistant moment curves for Dropia and Pegasus variety, confirm that the values obtained for Pegasus are higher than values of Dropia resistant moment, due the vitreousness . Pegasus is a hard wheat grain (79% vitreousness) and Dropia is a soft wheat variety (31%).

The same results were obtained calculating the maximum resistant moment for both varieties. The grinding of a single wheat grain with the new designed micromill can establish a raw model for the whole process on industrial scale.

One of the main characteristics of the grinding process is the grinding degree, defined by the relationship, between the new created surface (S_f) and the initially surface of the wheat grain (S_i).

$$i = \frac{\Delta S}{S_i} = \frac{S_f - S_i}{S_i}$$

The surface of the particles depends on the following:

1) the average particle size of the material sample
2) the percentage fraction (material collected from each sieve) in the sample;.
3) the material density of the particles γ (g/cm^3).

Was calculated the specific area (S) of material particles at the entrance and exit of the grind zone, with the relationship , knowing the material density of the particles γ (g/cm^3), the average size of this particles *d* (cm) and the weight (*G*) of each fraction from the sifting process.

$$S = \frac{6G_1}{d\gamma} \quad (\text{cm}^2)$$

Knowing the particle surface of each fraction (S_k) , can be calculated the total surface of the sample (S_c):

$$S_c = S_1 + S_2 + S_3 + \ldots\ldots\ldots\ldots S_k = \frac{6G_1}{\gamma_1 d_1} + \frac{6G_2}{\gamma_2 d_2} + \ldots\ldots + \frac{6G_k}{\lambda_k d_k}$$

After the first breaking step in the wheat grinding, were obtained the curves representing the resistant moment of the wheat kernel in the breaking process. The energy consumption is represented by the surface aria, below the resistant moment curves. For both Dropia and Pegasus wheat varieties, the lowest energy consumption is achieved with mill adjustment regarding the dull-to-dull (D/D) disposition, rather then sharp-to-sharp (S/S) disposition. The grinding efficiency is related to the first break intermediate fractions quantity. The aim of the first breaking step is to obtaine a large amount of middlings. The highest yield is obtained for the sharp-to-sharp (S/S) disposition and 0,6 mm size of the roll gap.

One of the fundamental means of classifying wheat is through its endosperm texture. It impacts significantly on the milling process affecting among other things flour particle size and milling yield. The vitreous kernel has a smooth surface and is brittle, translucent, and transparent when cut. Starchy grains are differentiated by a total absence of translucent zones and they exhibit a white and opaque endosperm related to the existence of air pockets that diffract and diffuse the light (Hoseney, 1986). Vitreous durum wheat kernels produce higher semolina yield and lower percent of flour than their soft counterparts. In addition, the semolina protein content from vitreous durum wheat kernels is higher than that from soft wheat grains (Dexter et al., 1988). Wheat grain vitreousness is thus a key factor of the milling performance and the end-use quality of pasta from durum wheat semolina. The genotype, nitrogen fertilization and location are interacting factors affecting vitreousness, with genotype being the most important (Hadjichristodoulou, 1979). Depending on the wheat variety related to vitreousness, it is possible the adjustment of the micromill parameters from the point of view of technological efficiency and the energy consumption. A higher resistant moment was obtained for an increased number of grains (from 1 grain to 8); when the gap between the roll decrease, the resistant moment increase. Also there is a higher resistant moment value for a higher vitreousness of the grain. A higher vitreousness means higher demands in the grinding process regarding the energetic consumption.

PERSPECTIVES

It is very much important to study and define the energy consumption, which directly related to the grinding degree and also the resistance of the cereals and intermediary products, in the milling process. Each grinding step means a certain energy consumption.
The equipment used in this PhD thesis will assure a minimum consumption of energy, related to 1to of cereals. It will be established also the specific resistance to grinding, for each grinding step of the cereals, in the milling process.
In the era of global slowdown and recession, saving energy becomes a ”must have” characteristic of every industrial consumer. The measurement of the grinding resistance of the wheat kernel can estimate the energy consumption in the grinding process and can lead to reduced total energy consumption in the milling process.

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