YIELD IN MILLING

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Motto: "A good miller is an artisan. Flour milling is to be considered an art."

Content:

1. **Introduction**.

Milling is to be considered an art. Unlike other industries where the influence of various factors determining the dynamics of the process is well known, as the process is well described by equations and formulas that enable efficient sizing and operation of this equipment, the number of factors affecting milling quality and equally the quantity of finished products is extremely high and often, after the analysis of raw materials, the miller must adjust the entire plant according to his own intuition and ability, in order to obtain the best results in terms required by the expected quality of the finished product.

All with minimum cost.

That being said, we will next try to take a look of what technological efficiency of grinding equipment is.

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The theme of this presentation is Milling extraction.

The purpose of the grinding is transforming a raw material, which comes in the form of grains, into the final product.

We do not specify the type of finished products for that I will try to make a qualitative rather than a quantitative approach of the problem.

Before proceeding with the exposure, I would like to mention that the theme of the presentation is extremely wide and treats all milling technology. However I will try to make the presentation briefer and I will expose for debate only those matters that I consider relevant.

2. Definitions and used terms.

Raw material	Processed cereal type, be it soft wheat, durum wheat, corn, rye, etc., briefly the processed cereal product
Processing	All operations by which grain is converted into finished products
Obtained products	Total products resulting from processing operations
Finished products	Main valuable products obtained after processing, usually for human consumption
By-products	Lower value-added products, secondary products resulting from processing operations, namely the bran
Specific consumption of raw material	Amount of raw materials consumed from which we get a unit mass of finished product
Processing capacity	Quantity of raw materials introduced for processing in the first technological passage in the unit time
Technological loss	Quantitative difference between processing capacity and total quantity of products resulting from the mill
Extraction	Percentage of finished products of the total resulting products

Please note:

- The total amount of resulting products will always be less than the quantity processed, of which it came
- The difference between them is the technological loss
- One must make a clear distinction between the fact that the milling capacity defines the amount of product in the first technological passage while percentages of resulting products are calculated from all products resulted.

3. Factors influencing the extraction.

As I said above, the purpose of a milling activity is the transformation of a mass of milling grain in finished products. The process itself is a collection of operations that involves several steps, including:

- Preparing for milling raw material
- Grinding itself

In our analysis we start from the consideration that the raw material meets the quality parameters as defined by industry standards.

Under these conditions, the technological efficiency of the steps defined above is essential for extractions. The extraction is the parameter that firstly defines the plant efficiency, the production cost of products being directly influenced by the specific consumption of raw material

We know that the cleaning and conditioning operations of raw materials is of major importance to achieve a high extraction rate. There is a true saying in milling: 'Well cleaned wheat is half grinded!'. Irremovable foreign bodies lead to distortion of finished product quality and reduce extractions. Among all operations of cleaning and conditioning department, the one that is very important is the moistening. Wheat with constant humidity will create conditions for stable milling, a loading at relatively constant flows of products, cleaner intermediate products, finished products with lower and constant ash content, products of a granulation corresponding to the final goal and not ultimately minimal specific power consumption. Cereals being grinded by current technologies through rollermills and plansifters and the fact that the bran is being separated from the endosperm are due to the different behavior of the various parts of the grain under the mechanic action of the rolls. By adding water, this difference is accentuated; the husk becomes more elastic and less brittle, while the endosperm is softer and more plastic. The problem is obvious in the high extraction mills where the milling is made in the boundary layer between the endosperm and husk bran, namely aleuronic layer. How this process is controlled defines the extraction performed by the plant.

In the milling section, there are mainly grinding and sifting operations. By ensuring proper working conditions of the plant in this area, there are ensured the premises of a controlled and stable milling, to generate finished products in accordance with market requirements. The balance of factors seriously influencing the final outcome is ruled by three parameters: the processing capacity, the extraction and the type of finished product. In the triangle described by these 3 factors, changing one of them influences the other two parameters (Fig. 1). Thus, a capacity beyond the physical limit of the system will result in lower extractions while lower grained products will require lower working capacity.

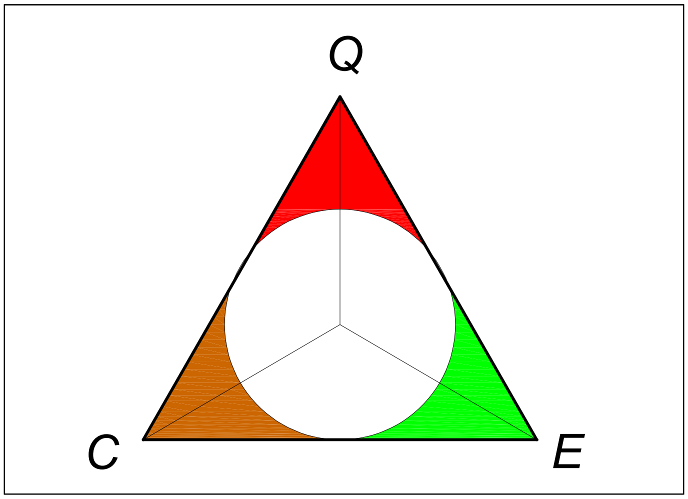


Fig. 1: Capacity-Extraction-Quality Triangle

From the triangle we can easily see that:

- Increasing the capacity is at the expense of extraction. This is obvious on overloading the mill.
- Increasing capacity alters the granulation of flours, meaning it lowers the average diameter of flour fractions
- Operation of the mill on under capacity conditions increases the extraction and alters the flour color, increasing their ash content. Oversifting occurs.

Considering that the mill is correctly working in loading the equipment, we can classify the factors that influence the extractions performed in 4 groups:

3.1. Factors related to raw materials
3.2. Factors related to cleaning / conditioning-grinding operation
3.3. Factors related to the miller operator
3.4. Factors related to market conditions

In the following lines, I will do a brief review of these factors.

3.1. Quality parameters of raw material that influence extractions are the type of cereal and the growing conditions, moisture, hectoliter weight, foreign matter content, grain size, the ratio of the amount of husk and amount of endosperm, the protein content and harvest, transport and storage conditions.

Each of these factors has a major influence on extractions performed.

3.2. Cleaning / conditioning means the sum of all the cereal preparation operations for milling, operations preceding the grinding operation. Unlike grinding, cleaning operations refer to cereal and grain kernels without harming, if possible, its integrity. Each of the operations taking place in the cleaning department has a well defined purpose. Through the reduction of specific consumption of electric power, in the modern cleaning sections were removed the redundant operations. This means that each machine must work continuously at a high efficiency, without a repetition of that operation.

For example, an insufficient aspiration will lead to:

- A significantly higher presence of mineral dust particles in the mass of the cereal and on the surface of cereal kernels. This dust presents a high risk of moving to flour mass, generating color problems, ash, etc.
- Unseparated foreign bodies in the cleaning section, because of higher friability than endosperm's, may generate particles that give the same problems of color, i.e. ash, and also affects extraction by inflating the bran percentage.

A question that very few millers ask themselves is: 'How is it possible to grind wheat with rollermills (and plansifters) and separate the floury core of the shell?'

The influence of moistening operation on the extraction level is a known fact among millers. What is not very well known is the influence of the moistening operation before 1-st Break (B1) . As I said above, that especially milling is done by mechanical action of grinding rolls, combined with sifting separation, is based on different behavior of the various anatomical parts of the grain under the mechanical action of the grinding rollers. I refer to the floury core and bran husk. If these two anatomical parts had the same behavior, the milling as we know it today would not be possible. By adding water, this difference is accentuated, the core becomes more plastic and gives less resistance to grinding, and the husk become more elastic, which allows its processing with rollermills, finishers, etc. Due to their different structure which generates absorption and capillarity phenomena, the core and the shell have different behaviors on water hydration. Due to the rest time needed for water penetration into the core and to the fact that the core is more hydrophilic than the husk, the husk loses part of the water percentage.

By virtue of the foregoing, it becomes obvious the importance of moistening operation before the B1 for the levels of flour extractions under Grinding Section.

By grinding destruction of grain integrity occurs. This is achieved by a controlled manner, the ultimate goal being to have products of maximum purity:

- Flour with minimum husk content
- Bran with minimum core content

Bran and flour together represent the quantity of products of the milling department, and the percentage of what they are found in the total of final products measure the technological efficiency of the plant. Considering the grinding section a 'black-box' in which the Wheat enters and of which results the finished Products, the Sankey diagram of the process can be seen in Fig. 2:

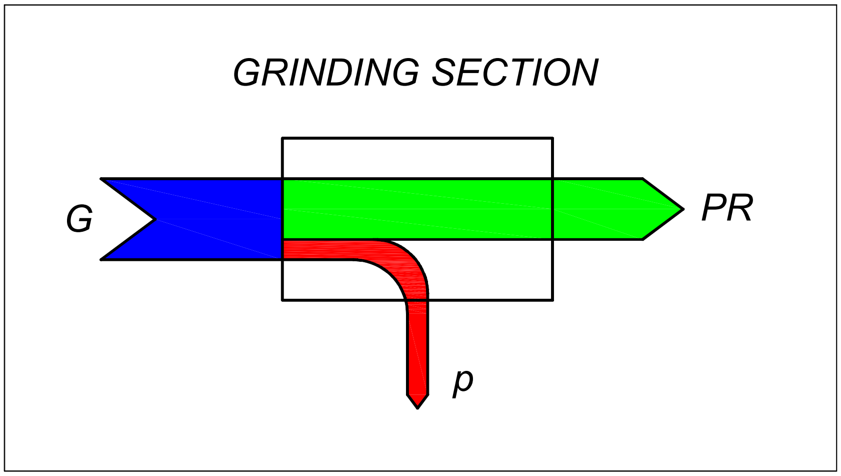


Fig. 2: Sankey diagram of a grinding section

We can write:

$$G = PR + p \qquad (1)$$

where:

G – amount of wheat entering the First Break passage, [kg/s]

PR – total products resulting from the grinding section, [kg/s]

p – mechanical loss of the plant, [kg/s]

I specified as units of measurement the weight flows, since such a facility does not function in charges, but in continuous flow .

As one can see, the mechanical loss of the facility can be assessed only as the difference between the total amount of finished products PF and the wheat G prepared for grinding. Or as a percentage of the total amount of processed grain.

By its nature, this loss may be due to:

- Water evaporation
- Low efficiency of air filtration equipment
- We do not take into account the accidental loss of product within the plant, but only the continuous losses.

The mechanical loss depends on:

- The type of the grinding, intensive or classic
- The quality of the finished products that are intended to be obtained (see Fig. 1)

- Climatic conditions, air relative humidity, which is widely used both for technological purposes (semolina purifier) and for ancillary purposes (hygiene, pneumatic transport)

- The efficiency of air purification equipment (filters)

The miller does not receive its money back for this loss, and all he can sell are only the finished products PF. For this reason, a proper reporting of extraction, meaning the quantity (the percentage) of finished products resulting from the grinding section, can only be made by reporting the amount of flour in total of finished products PF.

In the amount of finished products PR we have flour and bran, so we can write:

$$PR = F + T \qquad (2)$$

where:

F – quantity of flour obtained, [kg/s]

T – quantity of bran obtained, [kg/s]

It is obvious that we can write the extraction as:

$$E = F / PR \times 100 \qquad (3)$$

where:

E – extraction of resulted flour, %

Equipment within the grinding section has different technological features. Relating to this equipment, we classify the factors influencing the extraction in two major groups, namely:

a. Factors related to the technological features of the equipment
b. Factors related to the plant concept, the grinding diagram

a. Each machine within the grinding section has certain technological features. They are not chosen at random, but are a whole. Thus, the characteristics of the first-pass grinding at B1 are chosen according to the balance of the elements in Capacity-Extraction-Quality triangle. An incorrect corrugation at B1 will immediately affect the plant performance. This is valid also for sifting, semolina purifiers, etc.
b. If at the first item it is required 'tree' visualization, at the diagram elaboration one must see the 'forest' as a whole. The products are directed by qualities and granulations and this determines the level of the extractions.

In the grinding section, they become very important for the extraction level basic things in equipment operation, which superficially treated prevents achieving high extractions, such as:

- Feeding of the grinding rolls in layers of uniform thickness
- Cleaning the smooth rollers
- Cleaning the meshes of plansifters and purifiers, etc.

3.3. Factors related to the miller operator. Skipping the basics that a trained miller should know (such as: adjusting the equipment, estimating the origin of a product, organoleptic characteristics of a product at a particular passage, etc.), what is often missing from a miller operator is how he perceives his grinding diagram. A problem arising somewhere in the milling section is solved only by identifying the cause that generated it and which often must be sought in the technological upstream of that point. Otherwise, there are at least extraction issues.

3.4. Factors related to the market. Each market has its characteristics and by designing a grinding plant, from the beginning must be clarified things related to the type/sort of grinded cereal, the production capacity and the type of finished products which are intended to be obtained. All these things will ultimately determine the extractions that can be achieved with that plant. For a market where flours are high in gluten and are obtained by mixing several varieties of wheat, some with high vitrescence, will require lower specific loading on the machines, larger milling lengths and higher specific consumption. All this must be combined with finished products granulation, which often conditions the ash content of the flour. For a market where flours are acceptable with higher ash content, then this will allow the plant to operate at higher loads.

4. **Extraction predictability, estimation criteria**.

The accurate estimate of extractions that can be done in a particular raw material is a worrying issue for all millers. This conditions directly the production cost of flour by the specific consumption of raw material. From equations (1), (2) and (3), we can write:

$$CS = G / F \qquad (4)$$

where:

CS – specific consumption of raw material, [kg of raw material/(kg of finished product)]

By specific analyzes, the miller manages to a large extent to appreciate the extraction to be performed from a raw material of whose quality indices knows. Under these conditions, the estimation criteria of the extraction generally take into account:

- The hectoliter mass
- The raw material humidity
- The content of foreign bodies

These indicators somehow appreciate the raw material as ‘building materials’.
It is made an estimation of the extractions achieved by using artificial references, based on correlations noticed by millers between these indicators and extractions that can be performed. It is known the direct correlation between the Hectoliter mass and the extraction that can be achieved or between the mass of one thousand grains and the extraction .

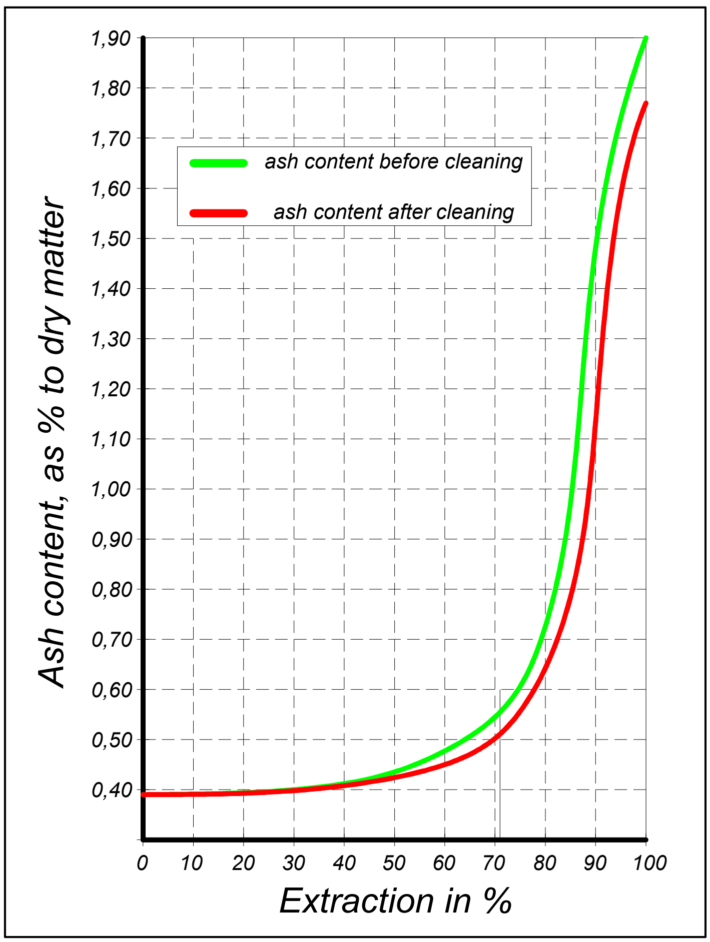


Fig. 3: Mohs curve of variation of ash content depending on the extraction percentage

But we should consider that there are situations when estimating the extraction based on these quality indicators may give errors. We simply have to remember that a sort of wheat that has small round grains will have a higher hectoliter weight than a large long grain type of wheat. However the results regarding the extractions performed with the two varieties of wheat, for the same flour quality, are higher for the larger grains

wheat. If we add the influence of foreign bodies, we can be quite misleading estimates on extraction.

An important aspect for the level of the extractions achieved and which is not very often evaluated by the millers is the ash content of the grain and especially the ash content of the endosperm. Often, though overall parameters of wheat are good, extractions are lower due to color and ash content of flours.

In this respect, it is used the Mohs curve, cumulative curve of ash content of the grain, as it is represented in Fig. 3. The curve profile depends on the cereal variety, the growing conditions and it is also influenced by how the cleaning – conditioning process is run and implicitly by the equipment in the cleaning section.

The red curve shows a shift to the right, which can be interpreted as an increase of extraction at the same ash content, with lower ash content, if the rate of extraction is kept as reference.

Given the quality indicators of grain weight and of the grain itself, there were suggested various formulas to calculate a so-called 'Grinding quality' of the wheat.

The best way to assess the grinding quality of a batch of wheat still remains a small scale grinding or a laboratory milling for that batch of wheat.

5. **Key issues in flour extraction**.

5.1. The influence of rollermills working regime on the extraction.

By their technological features and by the way is lead the grinding regime, the grinding rollers directly influence the granulometric composition of the grinded product and especially the ash content of these fractions. Next I will present several aspects of this issue.

I considered a rollermill passage B1, to which is inserted for grinding a soft wheat, properly cleaned and conditioned, with a humidity between 16.5 and 17 %. Fig. 4 shows the variation of the screened product percentage (extraction) according to the opening between the rollers, by sifting on different meshes sizes. The problem is to properly balance this operation, in the sense that the resulting products present in small percentages micronic fractions of bran particles.

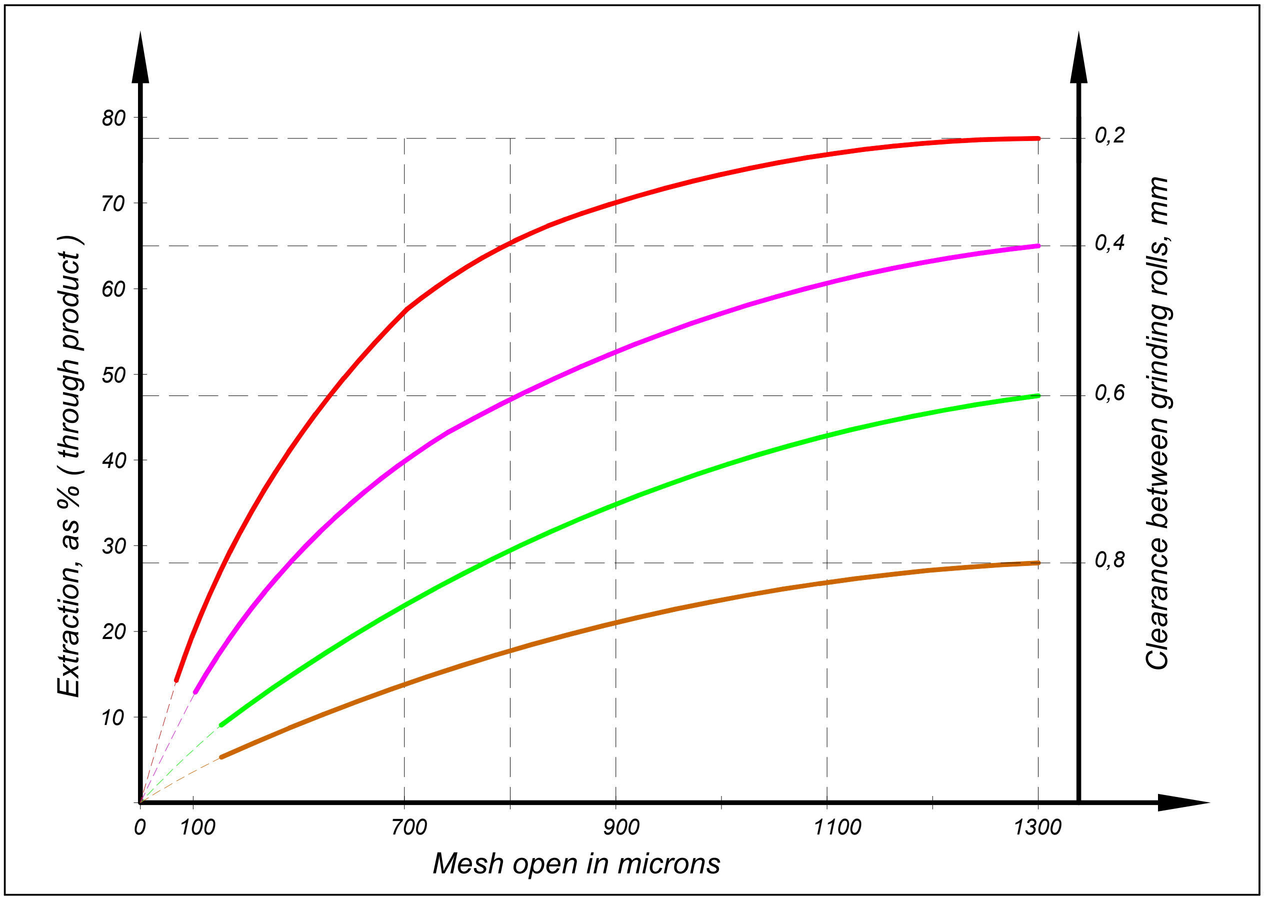


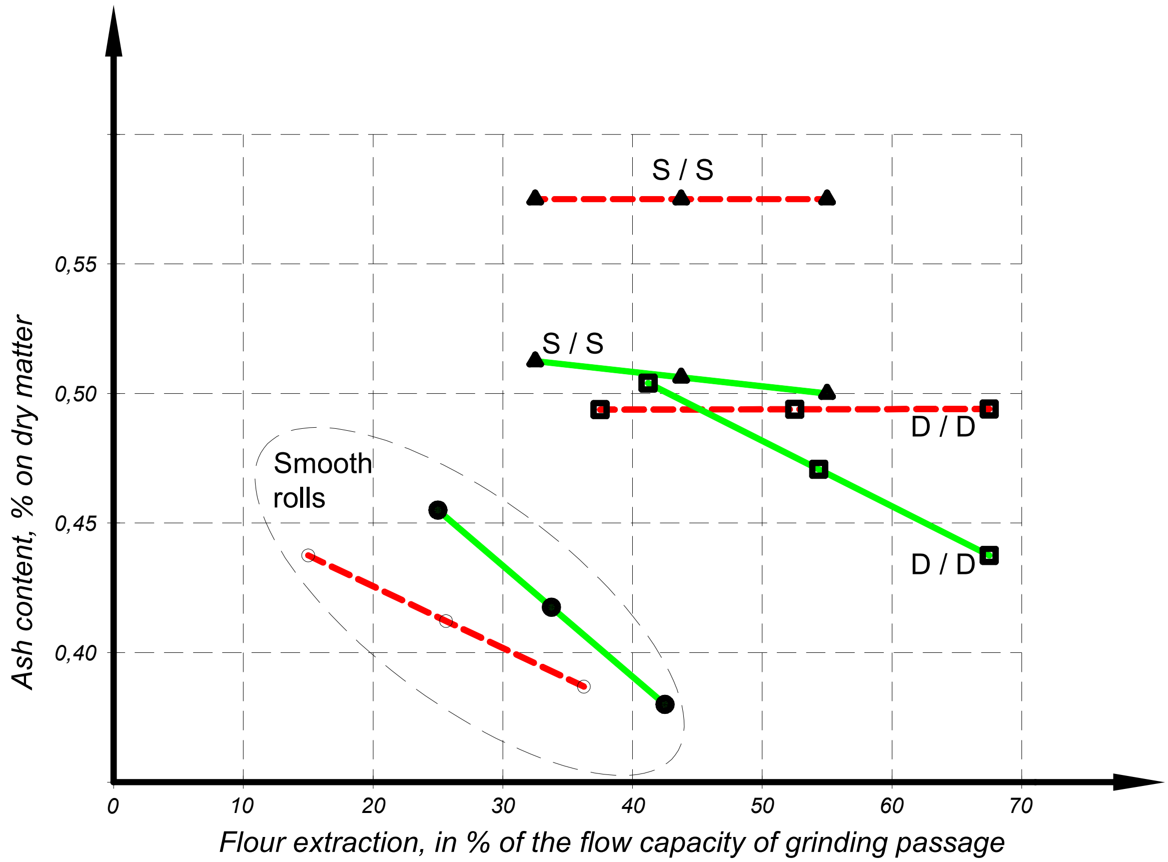
Fig. 4: Variation of the extraction depending on the grinding roller setting and screen meshes open

In the idea that flours obtained at each passage are essentially the result of the technological effect of the crushing operation on grinding mills, Fig. 5 shows the influence of the rollers surface on the grinding effect. The product tested was a product of the passage C1.b, in a soft wheat flour mill, with granulation between 900 micr. (screen 23) and 500 micr. (screen 38). It can be easily seen that smooth rollers performs extractions up to about 40 %, while corrugated rollers make extractions of over 50 % in Sharp/Sharp position and over 60 % in Dull/Dull position.

The smooth rollers were followed by a cylindrical detacher while corrugated rollers had the following characteristics: speed ratio 1:2,5; 10 corrugations/cm; angles 45/65 and working position Dull/Dull or Sharp/Sharp.

It is also obvious the influence of semolina purifiers on ash content of resulted flour.

In conclusion, we recommend the use of corrugated rollers to increase the technological effect of the rollermills, but only by using semolina purifiers .



Legend:

Smooth Rolls :	red dashed line, open circle	semolina from a flour mill without semolina purifier
	green line, filled circle	semolina from a flour mill with semolina purifier
Corrugated Rolls :	red dashed line, triangle	semolina from a flour mill without semolina purifier
	green line, square	semolina from a flour mill with semolina purifier
Working position:	▲	relative position S / S (Sharp to Sharp)
	◘	relative position D / D (dull to dull)

Fig. 5: Variation of extraction and ash content, depending on rolls surface condition, at the passage of rollermill C1.a

5.2. The influence of sifting regime on the extraction: correlation between the sifting time and the sifting efficiency and the correlation between the specific load of the screen and the sifting efficiency.

The correlation between the number of mesh and the ash content of the screened product is well known. The flour sieves numbers are generally consistent with the technological passage and the type of flour to be obtained.

Given that the mill is not working at full capacity and it can be above or below capacity, the sifting operation is affected.

The same thing happens in the case of the mismatch of the sifting surface size with the flow and type of product to be sieved. In Fig. 6 we can see the influence of product flow on the effectiveness of the sieving operation or otherwise of the sifting time on the sifting efficiency. We assimilate the insufficient capacity with sifting with an overpassing necessary time and the overcapacity with sifting in a shorter time than the required one (or the size of the sieving surface with the product flow).

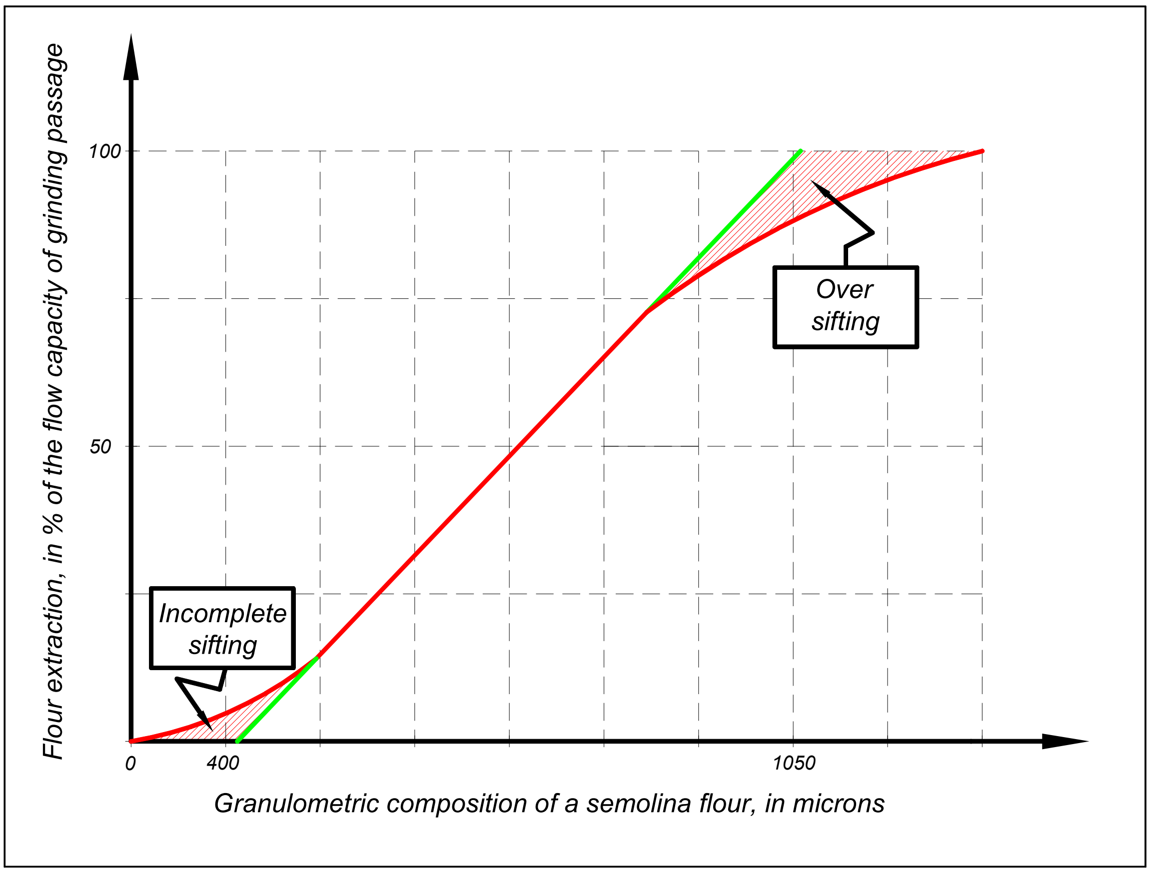


Fig. 6: The influence of sifting time on the sifting efficiency

From the point of view of sifting efficiency, the best results are obtained at the upper limit of the incomplete sifting area. It is better to have a lower sifting efficiency, meaning that in the refusal there is a small fraction of product that would have to be sieved, than reaching the oversifting area.

Another factor affecting the sifting efficiency is the load operation of the sieve. This directly influences the effective operation of sifting through the phenomenon called auto stratification. A better understanding of this phenomenon contributes to obtain flours with low ash content. In Fig. 7 we graphically represented the influence of specific loading of the screen on the sifting efficiency.

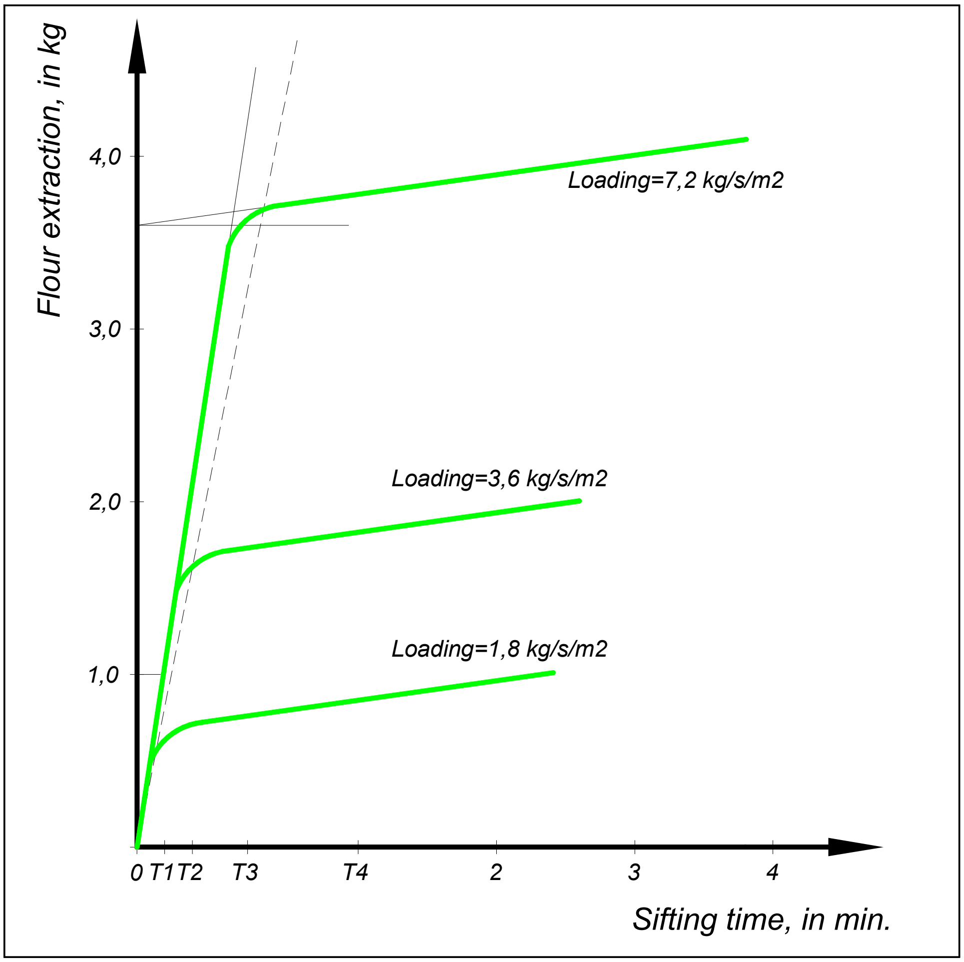


Fig. 7: The influence of the specific loading of the screen on the sifting efficiency

5.3. Formation of flour types.

By the expression 'Formation of flour types' we understand the composition of types of flours which should be reflected in the silo or in the mill warehouse, as they are denominated in the mill delivery program. It is an important issue because it directly affects the economic efficiency of a grinding section.

As I said above, every technological passage of grinding-sifting produces a flow of flour. Intermediate products processed in the technological diagram differs from passage to passage, therefore intermediates are sorted based on granulation characteristics, product type and ash content. Depending on these characteristics there are imposed the features of the grinding rollers and fabrics from the sifting passages. The resulting flours vary from passage to passage and there are no two identical flours. The miller has to conduct these flour flows on the flour screws, so that in the end to result finished products to fit in the specifications of the type of flour.

But what often happens is that the miller under appreciates the quality of the floor, many times for fear of risking not having a product worse than it is provided by the specification. Thus, if one has to make a flour type 500, which means an ash content of 0.5 % (in dry matter), most times it has the ash content way below this value. This means impoverishment of a flour flow over another. If we note the flour flow by 'q', resulting from any technological passage noted by 'i', then we can write:

$$A = \sum_{i=1}^{n} (q_i \text{x } a_i)/Q \tag{5}$$

where:

A – ash content of the fraction of final flour, [%]

q_i – the flour flow collected from passage 'i', [kg/s]

a_i – the ash content of the flour fraction resulting from the passage 'i', [%]

Q – the flow of flow fraction consists of all fractions from 1 to 'i', [kg/s]

Going back to Sankey diagram of the grinding section (see Fig. 2), writing the material balance equation based on the ash content of the fractions that occur in the process, with equations (1) and (2), we have:

$$G\text{x}A_g = F_1\text{x}A_{f1}+F_2\text{x}A_{f2} + F_3\text{x}A_{f3}+T\text{x}A_t \tag{6}$$

where:

A_g – ash content of the wheat, [%]

A_f – ash content of the flour, [%]

A_t – ash content of the bran, [%]

We noted the equation for simultaneous extraction of 3 fractions of flour. Be noticed that any 'loan' of product with lower ash content from one flour to higher ash content flour, it enlarges the ash content of the flour fraction, from which that fraction was taken. The final result is that the miller will have to lower the extraction of one higher ash content flour, affecting the total realized extraction.

5.4. Products control board.

The tracking of the work mode of the grinding plant is realized by the miller operator by checking how the grinding machines are working (rollermills) and especially the sifting equipment (sifters). The checking operation of the working mode of the plansifters is a time-consuming operation that requires attention. Analyzing a product while the mill is working can be difficult because of issues related to time of the day that

the product is analyzed, and even how the workspace is illuminated in the area.

To perform a quick analysis, on the plansifters floor it should be a special place where the miller operator place samples taken earlier, until the arrival of the master miller or the person responsible for production. On this table should be placed all products resulting from plansifters operation. Moreover, the same thing must exist in the collecting screws of the finished products. On a specially designed table, they are placed all the flour fractions derived from the grinding process.

Drawings and figures:

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