Operational control of grain grinding efficiency

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Abstract. The authors of the article consider the properties of grain as an expensive and very complex raw material. With varietal milling of wheat in the cost of flour, the main share falls on the purchase of grain - up to 80 ... 85%. Therefore, when organizing and maintaining varietal grinding, it is required to optimize the modes of the main processes of the technology both in the preparatory and grinding sections of the mill, moreover, based on the choice of objective criteria for the efficiency of processes. The authors found out that the values obtained are significantly behind modern ones, which indicates the progress made in the organization and management of flour technology, in particular, characterizes the success in equipping our technology with highly efficient equipment.

1 Introduction

Grain is an expensive and very complex raw material. For example, when varietal milling of wheat in the cost of flour, the main share falls on the purchase of grain - up to 80...85%. Therefore, when organizing and maintaining varietal grinding, it is required to optimize the modes of the main processes of the technology both in the preparatory and grinding sections of the mill, moreover, based on the choice of objective criteria for the efficiency of processes [1].

It should be noted that millers constantly paid close attention to this issue. In the 19th and in the first half of the 20th century, efficiency was evaluated by flour yield, some technologists also took into account the ratio of flour varieties obtained. At the same time, up to the mid-30s of the last century, many mills produced up to 10 varieties of flour, and 5...7 varieties were common. But after the introduction of the standard of three types of flour, this situation changed, grinding began to be organized according to the recommended technological schemes, and the determination of the ash content of flour was added to the account of the grinding efficiency. On this basis, in 1936, P.P. Tarutin proposed to use in the practice of flour milling the technological indicator K, which is the ratio of the yield of flour to its ash content. This indicator was actively used in assessing the operation of mills on a national scale [2].

However, this indicator was focused only on the final result of grinding, regardless of the initial characteristics of the grain, so its use for a comparative assessment of the efficiency of grain processing in mills operating under significantly different conditions did not provide an objective description of the process. With the same results in terms of yield and ash content of flour, the K indicator received the same value, but to achieve this, when grinding grain of

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high and low ash content, it is necessary to expend significantly different efforts and often apply a special, more complex technology. Therefore, this indicator K is not a real criterion, because does not have the necessary objectivity in evaluating the results. On its basis, it is impossible to carry out a comparative analysis of the efficiency of processing a batch of grain with different initial characteristics, first of all, its different ash content.

Therefore, at different times, attempts were made to introduce more objective criteria into practice. The German engineer Moos proposed to evaluate the efficiency (in a comparative version) by the form of the so-called cumulative flour ash content curve, which is obtained by removing and processing the balance of flour. This requires in a direct test to determine the percentage yield of flour from each of the technological grinding systems and the ash content of each of these flour streams. Based on the obtained primary data, the weighted average ash content of the combined flour flows is calculated, as its output increases, and then a graph is plotted in the axes "ash content - output". According to the shape of this curve, it was proposed to evaluate the grinding efficiency, for which it was compared with a certain reference curve proposed by the author of this method. At different times in the future, various options for analyzing and processing this curve were proposed in order to obtain some quantitative comparative criterion values. However, the duration of the experiment excludes the possibility of using it for operational control and management of the process of flour technology, so it is used only in research practice, when the time factor does not play a decisive role.

Scientists and practitioners searched for criterion values, also based on the structural features of the grain and the chemical composition of its anatomical parts. At the same time, it was based on the fact that the ash content of the starchy part of the endosperm, from which it is supposed to form varietal flour, is an order of magnitude lower than the ash content of its shells, the aleurone layer and the germ, which are released as by-products during grinding. It was also used that starch and gluten-forming proteins are concentrated only in the starchy part of the endosperm. Therefore, based on the determination of the degree of extraction into flour during grinding of these substances, it is possible to assess the completeness of the use of grain, i.e. varietal grinding efficiency.

Recently, other criteria have been proposed based on taking into account the initial characteristics of the grain and the results of grinding [2].

The provisions of the theory of informatics require that, when forming efficiency criteria, they must include both quantitative and qualitative indicators of the process. Only such criteria have the ability to carry out a comparative analysis of the same type of processes, but performed under significantly different conditions [3].

2 Research methods

The criteria for grinding efficiency noted above do not fully meet this requirement.

Their main disadvantages include the following:

- Methods based on flour balance analysis (based on the analysis of cumulative flour ash content curves) require a significant amount of time to obtain initial data and process them, as a result of which they are unsuitable for operational control and process management.
- Methods that include the value of the ash content of the endosperm in the calculation formulas do not differ in reliability, because it is practically impossible to obtain reliable values of the ash content of the endosperm in a simple experiment.
- The method based on determining the amount of starch and dry gluten content in grain and flour is characterized by sufficient reliability, but even in this case, the costs of this analysis are high, i.e. and this method is not efficient.

– The technological indicator K proposed in the 30s of the last century does not differ in the necessary objectivity, and therefore is not a criterion.

In the 90s of the last century to use for the operational evaluation of the results of grinding the complex criterion E %, which was successfully used by specialists to control the effectiveness of the functioning of sieve systems. This criterion meets the requirements of computer science, is objective and operational, and its use is possible in any conditions of modern flour milling. The calculation of the criterion value is carried out according to the following formula (3):

$$E = U\frac{Z_0 - Z_1}{Z_0} \quad (1)$$

where - Z0, and Z1 are the ash content of grain and flour. U - the output of flour.

In our work, we proposed a different type of efficiency criterion for testing, namely:

$$D = U\frac{Z_0}{Z_1} \quad (2)$$

This criterion, like the previous one, also has the necessary objectivity, since takes into account the initial characteristics of the grain.

Both of these criteria can be used not only to assess the final results of grinding, but also for operational control of the effectiveness of individual technological systems or stages of technology (torn, sieve, grinding, grinding processes). In this case, it is necessary to use data on the recovery on this system (or in this process), as well as the weighted average ash content of the incoming and extracted products [4].

An analysis of the calculation formulas shows that the value of the criteria D and E is affected by the ash content of the grain, the ash content of the flour (extracted product), and the size of the extraction. Table 1 provides an analysis of the effect of flour ash content on these criteria. The calculation was carried out under the condition that the ash content of the grain is 1.85%, as is accepted by the Rules for the organization and conduct of the technological process at mills as a base value when calculating product yields during varietal milling of wheat. The ash content of flour of the highest-grade baking, according to GOST R 52189 -2003 is 0.55%, and the 1st grade - 0.75%.

Table 1. Influence of flour ash content on grinding efficiency.

Flour output, %		Weighted average ash content of flour, %	Criteria	
B.c.	1 c.		D %	E %
10	65	0.72	192.7	45.8
20	55	0.70	198.2	46.6
30	45	0.67	207.1	47.8
40	35	0.64	216.8	49.1
50	25	0.62	223.8	49.9
60	15	0.59	235.2	51.1
70	5	0.56	247.8	52.3
75	—	0.55	252.5	52.7

We see that the values of the criteria naturally increase with the ash content of flour, which meets the requirements of practice. However, these changes occur according to a complex law, which is clearly shown by the graph presented in Figure 1, built for a wider range of ash content changes.

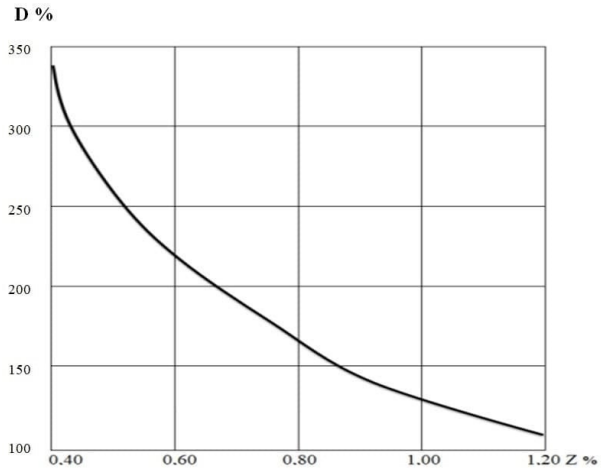

Fig. 1. Dependence of criterion D on the ash content of flour.

This graph covers the ash content of flour at various grindings of soft wheat into bread flour, as well as when grinding durum wheat into flour for pasta. In addition, in its construction, the results of the analysis of the effectiveness of individual systems of tattered, sieve and grinding milling processes were used. The graph shows that the lower the ash content of the flour (or the extracted product), the more significant the effect of its change on the value of criterion D. However, the criterion E changes almost according to the law of a straight line, so that for every 0.01% of the ash content of flour, its value changes by 0, 41. Rectilinear is the dependence of the criterion D also on the value of the yield of flour and % and the ash content of the grain %.

The dependence of criterion D on the ash content of flour in the range of its values from 0.70% to 1.20%, i.e., can be considered practically rectilinear. for those values that are typical for pasta grinding of Durum wheat.

These dependencies are approximated by the following straight-line equations:

- for the influence of the initial ash content of the grain (with the value of the correlation coefficient r = 0.912 +- 0.044):

$$D = 0.30 + 1.36\, Z_0 \qquad (3)$$

for total flour output
(r = 0,719+-0,114):

$$D = -17.5 + 3.6\, U \qquad (4)$$

- for the influence of the ash content of flour (in the range of its value 0.70 ... 1.20% with a correlation coefficient r = 0.978 +- 0.098):

$$D = 266.3 - 125.0\, Z_1 \qquad (5)$$

These equations can be used for engineering technological calculations related to the choice of rational (pseudo-optimal) parameters of the modes of grinding systems, as well as for operational control and management of the grinding process. At the same time, 252.5% can be taken as the reference value of criterion D for grinding (this value is obtained with a grain ash content of 1.85%, the output of premium flour is 75% with an ash content of 0.55%). Under these conditions, the criterion E = 52.7%. These values of the criteria should be strived for when organizing control and management of the process of grinding wheat into baking flour [5].

3 Results and discussions

When grinding a batch of wheat with an ash content of 1.92%, a flour yield of 76.4% with an ash content of 0.64% was obtained. In this case, the criterion D = 223.8%, i.e. lower than the standard by 28.7. In the range of 0.65 ... 0.55% of the ash content of flour, the criterion D changes at a rate of 3.88 for every 0.01% of the ash content of flour. Therefore, in order to ensure the optimal value of the criterion, it is required to reduce the ash content of flour by 28.7:3.88 - 0.07% with the same flour yield. If we turn to regulation by increasing the flour yield, then it will be necessary to increase it by 28.7: 3.6 = 8%. Obviously, in this case, it is required to simultaneously change the flour yield (for example, bring it to 76%) and reduce the ash content of flour (for example, by 0.03%). Under these conditions, the value of the D indicator will increase to 239.2%, i.e. by 15.4, compared with its original value. The same should be done in other cases.

To analyze the applicability of the criteria under consideration for the control and regulation of individual technological systems and stages of technology, we processed the data on the quantitative and qualitative balance of wheat grinding at the mill of v. Ramenskoye (Russia), equipped with Buhler technological equipment. The results are shown in Table 2.

Table 2. Efficiency of grinding and its individual stages.

Processes (stages)	Z_0%	И %	Z_1%	D %	E%
First two tattered systems	1.75	67.0	1.00	117.3	28.7
First three tattered systems	1.75	79.5	1.09	127.6	30.0
torn process	1.75	85.3	1.10	135.7	31.7
Sieve process	1.22	61.8	0.81	93.1	20.8
Grinding process	1.31	54.7	0.67	107.0	26.7
First three grinding systems	0.73	81.3	0.40	148.4	36.8
grinding process	1.19	86.7	0.66	156.3	38.6
Grinding in general	1.75	77.9	0.59	231.1	51.6

These values of the criteria can also be taken as a reference and used in technological calculations for control and management in the technology of varietal milling of wheat into baking flour.

For comparison, we processed the quantitative and qualitative balance of wheat grinding at one of the varietal grinding mills in 1940, published in the monograph by S.I. Sherbakova [6]. This balance is interesting in that a batch of wheat of almost the same ash content, 1.77%, was used in grinding. As at the mill in Ramenskoye. The flour yield during this grinding was 76.25% with an ash content of 0.77%. For criterion D, the following values were obtained: grinding in general 175.3%, torn process 58.0%, sieve process 49.0%, grinding process 138.5%. When calculating the criterion E, the following values were obtained: for grinding 43.1%, for the tattered process 16.6%, sieve 14.8%, grinding 32.7%. All these values are significantly behind modern ones, which indicates the progress made in the organization and management of flour technology, in particular, characterizes the success in equipping our technology with highly efficient equipment [7].

4 Conclusions

Thus, the use of the proposed grinding efficiency criteria, which have the ability to objectively display the results of the operation of the mill or individual elements of the

grinding technology, allows for a comparative analysis of the activities of technologists at any modern enterprise and when grinding grains with different initial characteristics. The use of these criteria in technological practice gives specialists a tool for making decisions on improving the technology at any of its stages, in the implementation of measures to control and manage the efficiency of grain processing in mills for high-quality grinding of wheat.

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