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DESIGNING THE IMPACT OF OPERATIONAL PROCESSES OF DOUGH DIVIDING MACHINES

ПРОЄКТУВАННЯ ВПЛИВУ ЕКСПЛУАТАЦІЙНИХ ПРОЦЕСІВ ТІСТОПОДІЛЬНИХ МАШИН

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Abstract. *The article investigates the process of wheat dough separation, which is a critical stage in bakery production. The influence of physical and mechanical properties of the dough, in particular moisture and consistency, on the accuracy of the weight of dough pieces, the level of dough sticking to the equipment, and the integrity of the structure after separation is analyzed. The work of dough dividers of various types (piston, rotary, vacuum) was experimentally evaluated and the optimal conditions for ensuring high-quality division were determined. The results obtained allow us to propose technical and technological solutions to improve the efficiency and stability of the process, which is relevant for improving industrial bakery production lines. Studies have shown that during intensive mechanical processing of the dough before separation, the separation accuracy is achieved at relatively low pressure due to the preliminary removal of carbonic acid from the dough. To identify the rational parameters of the dough separator workflow, we conducted studies in which samples of factory-made dough were compressed in an experimental chamber and then rounded manually.*

The purpose of the article is to evaluate the process of dividing dough into pieces before forming and to propose ways to optimize the process, taking into account current trends in the baking industry.

Key words: *wheat dough, dough separation, dough structure, dough dividing machine, visco-plastic properties, bread making.*

Introduction.

The process of dividing dough is one of the key stages of bakery production. The shape, weight, and quality of the finished product depend on the accuracy and uniformity of the division. Modern production uses both manual and mechanized methods of division, which necessitates a deeper study of this process to improve its efficiency.

Dough is a product that, in accordance with the requirements of the technology, has previously been subjected to prolonged fermentation with yeast and other microorganisms. As a result, a capillary-porous structure was formed, which is held together by an elastic elastic-plastic skeleton, the pores of which are filled with a gas consisting of carbon dioxide, water vapor, alcohol and other volatile fermentation products. Under the influence of the gas produced during fermentation, the dough increases in volume, decreases in density, and changes in structure and properties. During fermentation, microbiological and enzymatic processes actively take place in the dough, changing its physical properties.

During the working cycle, the following operations are performed in the chamber of the dough cutting machine and determine its workflow: filling the working chamber with dough, compressing it to working pressure, moving it through the working chamber, filling the measuring chamber, stabilizing the pressure, dispensing the measured workpiece, returning the remaining dough to the receiving funnel, are performed in the chamber of the dough cutting machine [1,2].

Research methodology.

The aim of the study is to investigate the physical and mechanical properties of wheat dough that affect the process of its separation, as well as to analyze the operation of dough-separating mechanisms in order to optimize the technological process.

During the separation of degenerate dough, processes occur that are caused by a specific property of fermented dough, which has a capillary-porous structure with a sufficient amount of gaseous fermentation products in the pores. During separation, such dough loses a significant portion of its gases, decreases in volume, and becomes denser, as bread dough is compressed to 0,5 MPa or more during separation.

The processes that take place in the working chambers of dough dividers are carried out cyclically in a relatively short time, measured in seconds or their parts. Therefore, in the analysis, we take into account only those processes that significantly affect the dough properties or the process itself during the working cycle of the divider. Dough fermentation is very slow and therefore these operations are not taken into account. The short-term effects of pressure and mechanical mixing that occur in the working chamber of the dough divider have a significant impact on the structure, physical and mechanical properties of the dough and the nature of its subsequent fermentation. They are the determining factors when choosing the parameters of a dough divider.

Until recently, when considering the working process of a dough dividing machine, attention was paid mainly to one aspect of the process: the effect of pressure in the working chamber on the accuracy of separating dough pieces.

For example, when pressure is applied to the fermented dough, the volume of the gas phase decreases and part of the gas is absorbed by the dough, and with simultaneous intense mechanical mixing, gas bubbles are divided into smaller ones, which contributes to the formation of a uniform microporous structure and the removal of large gas bubbles. Such a structure is able to better retain the gas medium at subsequent stages of the process [3,4].

Fermented dough after any mechanical treatment has an approximately constant volume weight, which is significantly lower than that of freshly mixed dough. The purpose of leavening the dough before dividing it is not to increase the volume of the dough, but to accumulate flavor and aroma substances. A well-fluffed end product, bread, is mainly influenced by the accumulation of the gas environment after the mechanical impact on the dough, i.e., distribution and shaping, is completed. After any mechanical processing, the loosened dough easily loses some of the gas medium and retains the other part of it quite firmly.

This is because the gases that fill the macrocapillaries are easily removed from the dough during kneading, and the gases in the microcapillaries and intermolecular spaces of micelles are retained by denser adsorption bonds and the microcapillary structure of the dough [5-8].

Research results.

It was found that the separation of dough with a moisture content of more than 46% is accompanied by a higher viscosity, which complicates the operation of the mechanisms and reduces the accuracy of the weight of the workpieces. Piston machines provide the best separation accuracy, but require frequent cleaning. The least dough damage was observed when using vacuum separation.

For the study, wheat dough of different moisture content (from 42% to 48%) and protein content (from 10% to 13%) was used. The study was carried out using dough dividers of different types: piston, rotary and vacuum. The following parameters were determined: uniformity of the weight of the workpieces; degree of dough sticking to the mechanisms; changes in the structure of the dough after separation [9-12].

To calculate the process of dough compression in the working chamber of the dough divider, it is necessary to have an equation of state of the fermented dough, which reflects the functional relationship between the specific volume and the pressure applied to the dough, which is in a closed space at a constant temperature.

The dough that enters the dough dividing machine has not a single-phase but a multiphase composition consisting of solid structured flour particles, acidified moisture, and a gas environment that includes carbon dioxide, ethyl alcohol, air, volatile acids, etc. The diagram of the real dependence of $P = f \cdot (\rho)$ is shown in Fig. 1.

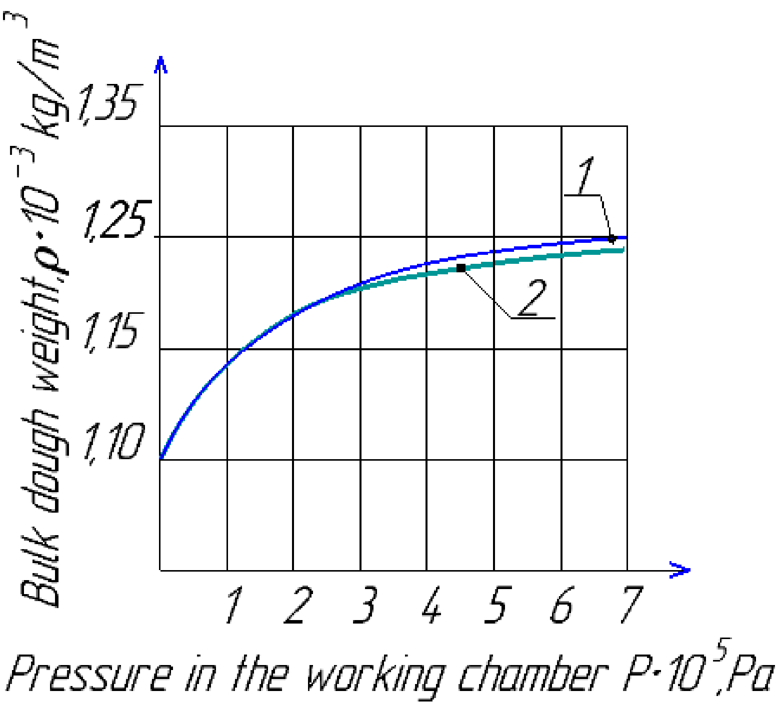

Figure 1 - Dependence of dough density ρ on pressure P:

1 – *dough that was not processed in the dough divider*;

2 – *dough that has passed the dough divider*

The bulk density of bread dough after kneading is ρ_n = 1100-1180 kg/m^3, at the end of fermentation before separation ρ_δ = 820-900 kg/m^3, and after the divider ρ_d = 1040-1090 kg/m^3.

When the dough is compressed in a closed volume, it exhibits the properties of an elastic body, mainly due to the gas phase and partially due to the elastic protein skeleton. As the compression pressure increases, partial absorption and dissolution of gas inclusions occurs, i.e., a decrease in the gas phase, which mainly determines the compressibility of the dough with increasing pressure. Therefore, when the pressure increases above 0,5 MPa, the compressibility of the dough decreases sharply, and then it behaves like a solid (Fig. 1).

Technological methods and equipment have changed significantly over the past decade. Nowadays, dough is prepared using intensive kneading and a shortened fermentation period, as well as the addition of enzymatic, surface-active preparations.

When studying the effect of mechanical dough processing on its elastic and viscous properties, we noted that mechanical dough processing affects the elastic and viscous properties of the dough and, at a certain stage, improves the porosity structure and affects the color of the crumb. Enhanced mechanical processing of the dough helps to increase the gas-forming and gas-retaining capacity of the dough, and thus improve the quality of the final product, bread [13-16].

Our experiments have shown that with intensive mechanical processing of the dough before separation, the separation accuracy is achieved at a relatively low pressure of about 0,05 MPa due to the preliminary removal of carbonic acid from the dough.

To identify the rational parameters of the dough divider's working process, we conducted studies in which samples of factory-made dough were compressed in an experimental chamber and then rounded manually [17-21].

The experiments carried out at the enterprise “Pekarsky Dom” of FOP Blazhkun V.P. in Khmelnytsky during the production of a 0,4 kg road baguette using the KEMPER dough divider allowed us to establish the fact of a positive effect of pressure on strengthening the dough structure and the zone of rational pressure values.

Since dough is a multiphase system that can be described as a quasi-elastic medium with gas inclusions, we used a generalized type equation:

$$P = K \cdot \left(\frac{\rho}{\rho_0}\right)^n \quad (1)$$

where: P – pressure, Pa; ρ – dough density after separation, kg/m³; ρ_0 – initial dough density before compression, kg/m³; K, n – experimental coefficients (for dough, they may depend on moisture content, structure, temperature)

$$P = 50000 \cdot \left(\frac{1060}{850}\right)^2 = 77757 \text{ Па}$$

This corresponds to the zone of rational pressure according to experimental data.

Define the compression ratio of the dough as:

$$k_C = \frac{V_0}{V} \quad \text{or} \quad k_C = \frac{\rho}{\rho_0} \quad (2)$$

This means that the dough was compressed to 80% of its original volume.

To estimate the energy consumption, you can use the formula:

$$W = \int_{V_0}^{V} P(V)\, dV \quad (3)$$

If we assume isothermal compression of the gas part (similar to the ideal gas model for microinclusions), then:

$$W = P \cdot V_0 \cdot \ln\left(\frac{V_0}{V}\right) \quad (4)$$

Or in terms of density:

$$W = \frac{P}{\rho} \cdot m \cdot \ln\left(\frac{\rho}{\rho_0}\right) \quad (5)$$

Thus, each workpiece requires about 10,2 J of energy for compression under vacuum or piston separation conditions.

Dependence of mass accuracy on humidity (statistical analysis). The coefficient of variation was determined:

$$V = \frac{\sigma}{m} \cdot 100\% \quad (6)$$

For a humidity of 42%: $V = \frac{2,8}{440} \cdot 100\% \approx 0,64\%$

For a humidity of 48%: $V = \frac{6,2}{448} \cdot 100\% \approx 1,38\%$

Consequently, when the humidity doubles, the coefficient of variation also increases, which means that the accuracy of the weight of the workpieces decreases.

The research and calculation made it possible to establish a zone of rational pressure in the working chamber of the dough divider within 0,1-0,2 MPa.

However, when choosing a rational value of the working pressure of the dough divider, it is necessary to take into account the fact that when the working pressure is reduced from 0,2 to 0,1 MPa, a better combination of dough quality indicators is achieved, the power of the drive motor and energy consumption are reduced by about 30 %, the volume of maximum loads on all moving elements of the machine is almost halved, and the durability and reliability of the dough divider are significantly increased [22-26].

In this regard, it is necessary to pay attention to the latest foreign developments in the field of dough dividers, in which the working pressure is within 0,05-0,12 MPa. Reducing the working pressure in these machines does not lead to a decrease in separation accuracy, but significantly reduces metal consumption and energy consumption for the machine drive, and also helps to simplify the design and improve the reliability of the machine.

In addition to the working pressure, the intensity of dough working in dividers is also characterized by the dough compression ratio in the working chamber, which depends on the design of the blower and the perfection of the workflow.

With an increase in the dough compression ratio to 5 MPa, energy consumption increases, while dough homogeneity and plasticity do not deteriorate. The approximate value of K_4'=5,6 (for the KEMPER dough divider) with an intensive blower (paddle, screw) corresponds to 5-6, and with a non-intensive blower (slow-moving roller, paddle) it is close to 10. For new models of machines, the value of K_4' should be adjusted taking into account the adopted design of the supercharger and the divider scheme [27-30].

Conclusions.

The results obtained suggest that the optimal dough moisture content for effective separation is in the range of 43-45%. It is also proposed to change the configuration of the piston chambers to reduce dough sticking and improve the lubrication system.

The process of dough separation largely depends on its physical and mechanical properties. The choice of the type of dough dividing machine should take into account the moisture content and structure of the dough. Optimization of the separation process improves the quality of the finished product and reduces production costs.

Thus, a rational pressure in the working chamber should be considered a pressure in the range of 0,05-0,12 MPa, which achieves the best combination of all the performance indicators of dough dividers.

References:

1. Piddubnyi, V., Stadnyik, I., Chahaida, A., Petrychenko, Y. Justification of mixer parameters for flour components. Technical Engineering.(1(89).–2022.–P.3-10.

2. Piddubnyi V., Sabadosh A., Mushtruk M., Chahaida A., Fedorov V., Kravcheniuk K., Krasnozhon S., Radchenko I. Innovative thermodynamic modeling for enhanced yeast dough mixing: energy perspectives and applications. Potravinarstvo Slovak Journal of Food Sciences.– 2024. – Vol. 18. – P. 251–267.

3. Piddubnyy V., Kahanets-Havrylko L., Fedoriv V., Senchishin V., Stadnyk I. Peculiarities of heat exchange in dough under rotary rollers action. Scientific Journal of TNTU (Tern.). –Vol 109, № 1.).–2023– P. 43-53.

4. Stadnyk I., Piddubnyy V., Chagaida A., Fedoriv V. Dynamics of interaction of components during mixing. Scientific Journal of TNTU. — Tern.: TNTU, –2022.

– Vol 107. № 3. – P. 86-98.

5. Stadnyk, I., Piddubnyi, V., Kolomiiets, O., Chahaida, A., Kravets, O., Fedoriv, V., Ieremeieva, O., Mihailik, V., Kravcheniuk, R., Radchenko, I. (2025). Determining the influence of drum mixer parameters on the change in dough components concentration at the initial mixing stage. Eastern-European Journal of Enterprise Technologies, 2 (11 (134)), 6–15.

6. Stadnyk I., Piddubnyi V., Mykhailyshyn R., Petrychenko I., Fedoriv V., Kaspruk V. The Influence of Rheology and Design of Modeling Rolls On the Flow and Specific Gravity During Dough Rolling and Injection. Journal of Advanced Manufacturing Systems.– 2023. –Vol. 22(02). – P.403–421.

7. Stechyshyn M.S., Martynyuk A.V., Oleksandrenko V.P., Bilyk Yu.M. Cavitation-Erosion Wear Resistance of Fluoroplasticics in Model Food Production Media. J. Frict. .–2019. –Vol. 40. P.468-474.

8. M. S. Stechyshyn, A. V. Martynyuk, Y. M. Bilyk, V. P. Oleksandrenko, N. M. Stechyshyna. Influence of the ionic nitriding of steels in glow discharge on the structure and properties of the coatings. Mater. Sci.,53, No. 3, 343–349 (2017).

9. Fedoriv V.M., Liukhovets V.V., Mankov V.I., Stepanets O.V. Обгрунтування конструкцій хлібопекарських печей з рециркуляцією продуктів згоряння. Modern Engineering and Innovative Technologies. – Issue №35, Part 1,– Karlsruhe.–2024.– P.30-36.

10. Fedoriv V.M., Stechyshyn M.S., Martynyuk A.V., Kurskoi V.S., Pereima A.R. Обгрунтування конструктивних параметрів віброзмішувачів для борошняних компонентів. Modern Engineering and Innovative Technologies. – Issue №32, Part 1,– Karlsruhe.–2024.–P.11-19.

11. Fedoriv V.M., Stechyshyn M.S., Martynyuk A.V., Liukhovets V.V., Honcharuk V., Matsiuk I. Проєктування впливу експлуатаційних параметрів на деформацію тіста при нагнітанні. Modern Engineering and Innovative Technologies. Issue №37, Part 1,– Karlsruhe.–2025.–P.36-46.

12. Fedoriv, V., Stechyshyn, M., Martynyuk, A., Liukhovets, V., Lysenko, I., Trofymchuk, M. Design and construction of operational performance of modern flour mixers. SWorld-Ger Conference Proceedings.The current stage of development of scientific and technological progress '2025 . –No. gec37-00(2025). – C. 7–11.

13. Fedoriv V.M., Liukhovets V.V., Lisevych D.V., Manita I.M. Substantiation of structural and mechanical characteristics of baking bakery products. SWorld-Ger Conference Proceedings. Technique and technology of the future '2024. –No. gec35-00(2024). – C. 9–13.

14. Dmytrenko O.V. Formation of students' communicative competence in English classes by intensifying the educational process / Zbiór artykulów naukowych. Z40 Zbiór artykulów naukowych Konferencji Miedzynarodowej Naukowo-Praktycznej organizowanej dla pracowników naukowych uczelni, jednostek naukowo-

badawczych «Obiecujace osiagniecia naukowe Pedagogika » (30.09.2017) – Warszawa. –2017. – P.34-35.

15. Fedoriv V.M., Stechyshyn M.S., Martynyuk A.V., Kurskoi V.S., Pereima A.R. Determination of the relative speed for screening bulk materials. SWorld-Ger Conference Proceedings. Scientific and technological revolution of the XXI century '2024. –No. gec32-00(2024). – С. 5–9.

16. Визначення розрахункових навантажень виробничих механізмів і машин та технологічні розрахунки виробництва борошняних виробів / П. Гаврилко та ін.; за ред. І.Я. Стадник. Ужгород. 2023. 464 с.

17. Доломакин Ю.Ю., Ковалёв А.В., Глуздань А.А., Федоров В.М. Теплопоглощение тестовой заготовкой в процессе выпечки в конвективных хлебопекарных печах // Ukrainian Food Journal. – 2012. – № 2. – С. 84-87.

18. Каплун П. В. Енергозберігаючі технології підвищення довговічності та надійності деталей машин. / П. В. Каплун, В. А. Гончар, В. В. Люховець. // Підвищення надійності машин і обладнання. 1-а Міжнародна науково-практична конференція. – Кропивницький. 2019. – С. 113-114.

19. Ковальов О.В., Бабко Є.М., Місечко М.О., Федорів В.М. Zeovac вакуумне охолодження – технологія майбутнього //Хлебопекарное и кондитерское дело. – 2010. –№2. – С.28-30.

20. Ковальов О.В., Федорів В.М. Просіювання сипких матеріалів. Харчова і переробна промисловість. –2004. –№ 5. – С. 24-25.

21. Ковалёв А.В., Бурлака Е.Н., Мисечко Н.О., Федоров В.М. Теплопоглощение тестовой заготовкой в процессе выпечки // Хлібопекарська і кондитерська промисловість України. –№ 5, – 2008. – С. 36-37.

22. Ковалёв А.В., Бурлака Е.Н., Леметар С.Ю., Федоров В.М. Теплопоглощение тестовой заготовкой в конвективних хлебопекарных печах // Хлебопекарское и кондитерское дело. –№ 3. – 2008. – С. 48 - 49.

23. Логвінський Р.В., Доломакін Ю.Ю., Ковальов О.В., Федорів В.М. Теоретичні розрахунки і практичні вимірювання параметрів теплообміну в конвективних хлібопекарських печах // Ukrainian Food Journal. – 2012. – № 1. –

С. 86-90.

24. Приліпко Т.М., Федорів В.М. Методи сучасних видів експертизи якості, ідентифікації фальсифікації продовольчої сировини тваринного походження Вісник Львівського торговельно-економічного університету Технічні науки. Харчові технології. 2023. № 35. С. 43–48.

25. Стечишин М. С. Технологія азотування в тліючому розряді сталей різального комплекту м’ясоподрібнювальних машин / М. С. Стечишин, В. П. Олександренко, М. В. Лук’янюк, В. В. Люховець, М. М. Лук’янюк // Проблеми трибології. – Хмельницький: ХНУ. 2017. – № 2. – С.50-55.

26. Технологічні комплекси харчових виробництв: Навчальний посібник / В.І. Теличкун, О.М. Гавва, Ю.С. Теличкун, О.О. Губеня, М.Г. Десик, О.М. Чепелюк. – Київ: Видавництво «Сталь», 2017. -456 с.

27. Федорів В.М., Олександренко В.П., Мартинюк А.В. Експлуатація та обслуговування обладнання: навч.посіб. Хмельницький: ХНУ, 2024. 335 с.

28. Федорів В.М., Ковальов О.В., Аністратенко В.О. Універсальний тістоподільник: високоточний, економічний і водночас спрощений // Зерно і хліб. – 2002. – № 4. – С. 46-47.

29. Федорів В.М., Ковальов О.В., Миколів І.М. Встановлення оптимальних режимів роботи хлібопекарських печей // Наукові праці ОНАХТ, Вип. 45. – Одеса, 2014. – С.61–65.

30. Проєктування підприємств харчової промисловості: навчальний посібник / В.М. Федорів, М.С. Стечишин, А.В. Мартинюк, Н.К. Медведчук – Київ: Видавництво «Центр учбової літератури», 2025. –394 с.

Анотація. *У статті досліджуються процес поділу пшеничного тіста, який є критичним етапом у хлібопекарському виробництві. Проаналізовано вплив фізико-механічних властивостей тіста, зокрема вологості та консистенції, на точність маси тістових заготовок, рівень налипання тіста на обладнання та цілісність структури після поділу. Експериментально оцінено роботу тістоподільних машин різного типу (поршневі, ротаційні, вакуумні) та визначено оптимальні умови для забезпечення якісного поділу. Отримані результати дозволяють запропонувати технічні та технологічні рішення для підвищення ефективності та стабільності процесу, що є актуальним для удосконалення промислових ліній виробництва хлібобулочних виробів. Як показали дослідження, при інтенсивній механічній обробці тіста перед поділом точність поділу досягається при порівняно низькому* *тиску внаслідок попереднього видалення вуглецевої кислоти з тіста. Для виявлення раціональних параметрів робочого процесу тістоподільника нами проведені дослідження, в яких зразки тіста заводського приготування стискували в експериментальній камері, а потім округлювали вручну.*

Метою статті є оцінка процесу поділу тіста на заготівки перед формуванням із запропонуванням шляхів оптимізації процесу з урахуванням сучасних тенденцій у хлібопекарській промисловості.

Ключові слова: *пшеничне тісто, поділ тіста, структура тіста, тістоподільна машина, в'язко-пластичні властивості, хлібопечення.*

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