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## PRODUCTION OF SPECIFIC FLOUR FOR FROZEN PRODUCTS BY FLOUR STREAMS BLENDING

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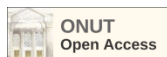
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**Abstract.** The bakery industry requires specific quality flours to manufacture different products. For the production of frozen products, strong flour with specific quality indicators is required, which is caused by the deterioration of the structural and mechanical properties of the dough after defrosting, decrease in the gas-holding capacity and dimensional stability of the dough blanks. Based on the literary review and a priori information the following quality indicators are recommended for flour for frozen products: whiteness >54 units, protein content >12.0%, gluten content >28.0%, GDI in the range of 70–80 units, starch damage in the range of 19–22 UCD, WAC >57%, W >260·10<sup>-4</sup> J and P/L ratio in the range of 0.8–1.2. Milling process of the wheat generates different flour streams that differ in composition, particle size, functional and baking properties. Further all flour mill streams are blended in one straight grade (single grade milling) or multiple flour grades (split milling). Research in the article is to investigate the quality indicators of flour mill streams for further formation of specific flour for frozen products. For the research, samples of flour were taken from each milling system of the flow diagram during milling of the two hard red winter wheat samples (HW1 and HW2 with protein content 13.3 and 12.2% respectively). Based on the analysis of the quality indicators of flour milling streams and their comparison with the requirements for flour for frozen products, it was established that none of the flour milling streams meets all the flour quality indicators for frozen products – flour streams from systems B3 and B2 have the closest quality indicators. Selected individual flour milling streams that are of great interest as streams for blending for flour for frozen products. As a result of comparing the flour quality indicators obtained at various stages of the technological process with the requirements for flour quality indicators for frozen products flour, the optimal percentage of flour patent yield for frozen products составляет 33.2% for HW1 and 20.5% for HW2.

**Key words:** wheat flour, mill streams, quality indicators, rheological properties, frozen products.

### Introduction. Formulation of the problem

The bakery industry requires specific quality flours to manufacture different products. Over the past 10 years, the production and commercial use of frozen dough has grown significantly due to a number of advantages: expanding the range of finished products, speeding up production and increasing shelf life [1-3]. But, on the other hand, the production of frozen dough imposes new requirements on the flour industry for all components of the dough (grain and flour obtained from it, yeast), equipment, packaging and transport.

The type of wheat flour used for frozen foods is critical to giving them the desired baking characteristics after long-term frozen storage. For the production of frozen products, strong flour with specific quality indicators is required, which is caused by the deterioration of the structural and mechanical properties of the dough after defrosting and a decrease in the gas-holding capacity and dimensional stability of the dough blanks [4].

The term "flour strength" refers to its ability to form dough that has certain structural and mechanical properties (elasticity, plasticity, viscosity) during

ripening, proofing, and in the baking process. Strong flour contains a lot of proteins, has high water absorption capacity, and forms a high content of gluten. Dough made from strong flour slowly acquires its optimal rheological properties, retains them well during ripening and proofing, has high gas and shape retention capacity, is dry to the touch, elastic, well amenable to mechanical processing during rounding and pumping [5]. The dough blanks, formed from it, keeps their shape well during proofing and baking, do not blur, and increase in volume sufficiently.

The number of frozen products is going to grow exponentially, in particular, in Ukraine [6]. Long-term assessment of the quality of flour for frozen bakery products in Ukraine showed its absence in the range of Ukrainian plants [7]. This is due to differences in the requirements for the Ukrainian range of flour (high-grade or patent flour, first clear or first-grade flour, second clear or second-grade flour) and flour for frozen bakery products. This problem can be solved using a technological method of producing flour of a given quality [8], namely through the selection of certain individual mill streams. Flour streams differ in yield, have a different set of indicators of whiteness, ash content, contain a different ratio of anatomical parts of the grain (endosperm and brans), and also differ in a set of indicators that evaluate baking properties, such as protein content, gluten content and GDI, starch damage content, W, P/L, WAC, etc. [9].

This differences between flour mill streams obtained during the milling process have been studied for several years. These differences pertain to characteristics such as protein content and its distribution [10], gluten content and GDI [11,12] ash content [13] rheological properties of dough obtained from such flours [14], the distribution of  $\alpha$ -amylase [15], physicochemical and microstructure differences [16], physicochemical and rheological properties [17]. Some work is related to the evaluation of the impact and quality of mill streams for various end-use products: influence of flour mill streams on cake quality [15], split milling of a wheat for diversified end-use products [18].

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#### **Analysis of recent research and publications**

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Wheat as the most important bread crop is an essential source for human nutrition and of all cereals has the widest range of species and varieties [19].

Wheat milling is a complex mechanical process of gradual milling [20] and sequence of many types of grinding and sieving processes [11]. Flour is obtained by a gradual size reduction through the different amount of break, sizing and reduction rolls to ensure maximum removal of bran and germ and the resulting endosperm particles are subsequently separated from the bran and germ particles using plansifters and purifiers to get fine white flour [21].

Milling plants produce different types of flours to satisfy the different needs of end-use products [22].

Flour requirements specifications are different for the various bakery products [23]. Many years of research have established that the chemical composition of grain and its technological properties depend to a certain extent on the characteristics of the type and variety of wheat, as well as on the growing conditions. And the chemical composition of flour and its quality indicators are determined by the chemical composition of the grain, the grade and yield of the flour [24].

There are two methods that flour properties and quality can be manipulated during processing, including during production of flour for frozen products. In both methods the grain quality plays a key role.

1st method – by adjusting the total yield of flour during its single-grade (straight) milling from grain of a certain quality. Particle size is dictated by the amount of grinding and the choice of sieve apertures employed throughout the process [25]. In practical terms the mill operator will manipulate flour particle size by controlling the extent of grinding (break release) on the roller mills and by choosing various aperture size combinations in the sieving equipment [26,27]. This method not common in Ukraine, although it has been used at some Ukrainian mills recently. Flour obtained after removing maximum amount of bran and germ, accounts 72–75% of wheat grain and called straight grade flour [28].

2nd method – by forming the quality of flour from different mill streams with multiple-grade milling, that distributed in Ukraine, when milling the ordinary wheat (a mixture of unknown grain varieties). Approach practiced in different countries – split milling or stream splitting, especially in those that either import or produce only one type of wheat or mill only limited wheat mixes, or for the milling of the different wheat for the particular flour end us [18].

Despite the large number of wheat varieties, the use of particular varieties in a certain region is restricted by the adaptation to growth conditions [29]. One of the most useful tools to produce specific quality flour, where high quality or special variety wheat is not available, is by the selection of certain individual mill streams, where a given group of similar or complementary streams are blended for particular end use. Flour mill streams blending is based on the needed quality indicators for final flour, as each flour mill stream has different characteristics to suit for the flour of various purposes. In milling – endosperm is first separated from the bran layers and then ground into a high number of milling streams flour. The flour is usually combined into a single composite product, the quality of which depends on the proportions and characteristics of the various mill streams. The system of gravity pipelines, through which flour flows from under the sifters, is arranged in such a way that the flour can be sent to any auger for collection, mixing and transporting it for further control. The formation of flour grades consists in mixing individual flour streams

from different milling systems into ready-made commercial grades. Ash content, whiteness, gluten content and particle size of flour are taken into account when forming usual flour grades. In addition to the basic quality indicators, determining in flour mill streams following quality indicators as: starch damage, water absorption capacity, deformation energy, P/L and other rheological dough properties – makes it possible to produce a various purposes flour and flour grades [30]. All flour mill streams collected from each system of the flow diagram are blended to get straight grade flour, while streams constituting this flour are separately known as patent, middle-cut and clear flour. Millers combine different flour fraction to get various purposes flour that satisfies customer needs. Patent flour is a combination of milled fractions having similar color and low ash content [21].

In order to select the mill streams, it is necessary to know their quality indicators, which depend on the types of products that are extracted in the mill and their yield, type of wheat [31] used for milling and the flow diagram of the mill. Knowledge of these characteristics assists in obtaining flours suitable for different end-use purposes. Many researches on the suitability of mill streams for different preparations is concerned with bread [32,33], cakes [34,35], biscuits and pastries [36], noodles [37]. As for frozen products were investigated the impact of quality indicators of common flour on the finished products: impact of flour protein content and freezing conditions on the quality of frozen dough [38], effects of ingredients and processing conditions on the frozen dough bread quality [39], little attention has been paid to the quality of the streams and the possibility of obtaining such flour by mixing individual flour streams.

The study will help in maintaining control milling efficiency as well as blending to produce specific flour for frozen products.

**The purpose of the work** is to investigate the quality indicators of flour mill streams for further formation of specific flour for frozen products.

**To achieve the goal**, the following tasks have been set:

- to investigate the quality of flour streams from all systems of the flow diagram;
- select streams based on the results of analysis for flour blending;
- to form flour with the specified quality parameters flour for frozen products;
- to compare the quality of the developed flours with recommended values for frozen products.

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#### Research materials and methods

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**Samples.** In this study, two hard red winter wheats with different characteristics were used: HW1, HW2. Initial wheat quality indicators for HW1 were following: test weight – 785 g/l, vitreousness – 45%, ash content – 1.56%, protein content – 13.3%, Falling number – 350 sec; for HW2: test weight – 775 g/l,

vitreousness – 40%, ash content – 1.58%, protein content – 12.2%, Falling number – 370 sec.

**Milling.** These wheats were tempered and industrially milled, at a mill with a capacity of 60 tons/day, operating according to the flow diagram of two-grade milling: with the yield of patent flour from 45% to 55%, 1-st grade flour from 75% to 77%. Flour at this milling plant is obtained from such systems: four Break systems (B1–B4), one Grading system (CC), one Sizing system (C1), four Reduction systems (C2–C5). The first and second Break systems are divided into two systems (A and B each one have ½ roller machine), which provides wide opportunities for setting the modes of grinding systems, all other grinding systems have ½ roller machine and one sifter section (B3–B4, C1–C5). From the sifter on all systems, it is provided to receive two flour mill streams (except systems B3, C1). The total number of flour streams from all systems – 18, that divided, for evaluation and comparison, into the following group:

B1–B3 – Primary Break systems; C2, C3 – Primary Reduction systems; B4, C5 – Tail-end Break and Reduction systems, respectively; CC – Primary Grading systems; C1 – Sizing system; C4 – Middlings Reduction system.

**Grain quality indicators.** Test weight of grain determined according to ISO 7971. To determine the vitreousness of wheat, a grainscope DSZ–3 (OLIS, Ukraine) was used according to the GOST 10987. Moisture content of cereals and derived products performed by drying cabinet FD 53 (BINDER, Germany) according to ISO 712. Ash content defined as the residue remaining after controlled incineration according to ISO 2171. Protein content determined by Kjehldal method according to ISO 20483. Falling number method performed using Alphatec FN (FOSS, Denmark) according to ISO 3093.

**Flour quality indicators.** 18 flour streams samples were taken at different stages of the flow diagram and the main quality indicators were determined in the flour streams: moisture content using drying cabinet FD 53 (BINDER, Germany) according to ISO 712, whiteness determined on TZU TEP–II–6 (Ukraine) device according to GOST 26361, protein content by Kjehldal method according to ISO 20483), gluten content by hand washing method using TL–2 (OLIS, Ukraine) dough mixer and GDI (gluten deformation index) on the IDK–3MU (OLIS, Ukraine) device according to GOST 27839. Starch damage was determined on SDmatic (CHOPIN, France) device by amperometric method according to ISO 17715. Water absorption capacity (WAC) was determined on Mixolab (CHOPIN, France) within 45 minutes according to ISO 17718. Rheological properties were determined by using an alveograph NG (CHOPIN, France) following the ISO 27971. A computer software program automatically recorded the following alveograph parameters: resistance to extension (P),

dough extensibility (L), curve configuration ratio (P/L ratio), the deformation energy (W) and elasticity (P200/P ratio).

**Statistical Analysis.** All analyses were conducted in triplicates and results were reported in average mean (with rounding of significant digits). Statistical processing of the results was carried out using Microsoft Excel Software.

### Results of the research and their discussion

Raw materials with high baking properties should be used to obtain flour for frozen products. However, the patent flour produced by flour-mills in accordance with the GSTU 46.004-99 does not meet the requirements for the production of flour for frozen products, so bakery industry makes certain requirements for the production of such flour. Based on the literary review and a priori information, we summarized the data and formed a table of indicative indicators of base flour for traditional bread and for frozen products (Table 1).

**Table 1 – Quality and rheological requirement indicators comparison**

Quality Indicator	Recommended value for traditional technology bread	Recommended value for flour for frozen products
Whiteness (Wh), unit	> 58	> 54
Protein content (PC), %	> 11.0	> 12.0
Gluten content (GC), %	> 26.0	> 28.0
Gluten deformation index GDI, unit	60–80	70–80
Starch damage (SD), UCD	22–24	19–22
Water absorption capacity (WAC), %	> 56.0	> 57.0
Deformation Energy (W), $10^{-4}J$	> 220	> 260
P/L ratio	0.8–1.2	0.8–1.2

Whiteness – one of the main technological characteristics that help determine the grade of flour in flourmills. According to the industry standard GSTU 46.004-99 "Wheat flour. Technical conditions" the whiteness of patent flour should be no less than 54 units. This indicator is also important for flour for frozen products, for obtaining patent flour and an attractive final product for the consumer.

On the Primary Break systems (B1, B2, B3) and the Primary Reduction systems (C2, C3), the whiteness (Fig. 1.) of the flour is higher: for HW1 by 20–25 units and for HW2 by 25–35 units, as compared to the Tailing systems of the break and the reduction processes.

Reducing the whiteness of the flour obtained on the Tailing systems indicate a significant content of the peripheral grain parts that contain pentosans and non-gluten proteins, which have affected the baking properties of these streams.

Highest values of the whiteness obtained in 8 mill streams (55–64 units) for HW1 and in 9 mill streams (56–64 units) for HW2. For evaluation of the baking properties of all flour mill streams needed fully detailed studies of the other quality indicators.

Proteins play a key role in bread baking. After adding water, a dough is formed, which is structured by gluten. Gluten proteins associated with lipids are responsible for the viscoelastic properties of the dough. These properties make the dough able to retain gases produced by the action of yeast, resulting in a porous product containing an elastic pulp after baking. Processes that affect the proteins will also affect the resulting quality. The flour recommended for frozen bakery products has a protein content from 12.0% to 14.0% [40], although classic baking is made from flour containing 11.0% protein. European recommendations suggest flour with 12.5% protein and about 30.0% crude gluten content [24].

In general, the protein content values (Fig. 2.) in Reduction mill streams obtained from both wheat were lower (on 0.8–5.3%) compared to Break mill streams and there was no particular trend observed in the Reduction mill streams. The protein content of the Primary Reduction streams ranged between 11.3–11.8% and 10.2–10.8% for HW1 and HW2 respectively. Highest results of protein content obtained from the following mill streams: B3, B4, C5. This could be due to increasing concentration of peripheral endosperm, which is rich in protein.

Since the HW1 grain had higher protein content, the values for protein contents of its Break and Reduction mill streams were also higher (in 1.1–1.3 times) when compared with that of corresponding mill streams obtained from HW2. Therefore, the number of mill streams with recommended value for frozen products for protein content (>12.0%) was 9 for HW1 grain versus 2 for HW2.

The main indicators of the quality of flour, which evaluate the protein–proteinase complex and characterize the baking properties, are the gluten content and gluten deformation index (GDI). Flour obtained on different systems of the flow diagram has a different chemical composition and therefore differs significantly in the gluten content (Fig. 3.) and GDI. The gluten content had high values in the first individual flour streams obtained on the all milling stage. This is explained by the fact that with the moving of a product through the flow diagram, the concentration of peripheral parts increases.

Flour obtained from Reduction systems characterized by lower gluten content – 25.1–27.4% for HW1 and 25.3–26.4% for HW2. When values of gluten content in flour from Break systems for HW1 and HW2 were in the range of 24.7–36.6% and 24.2–33.8% respectively.

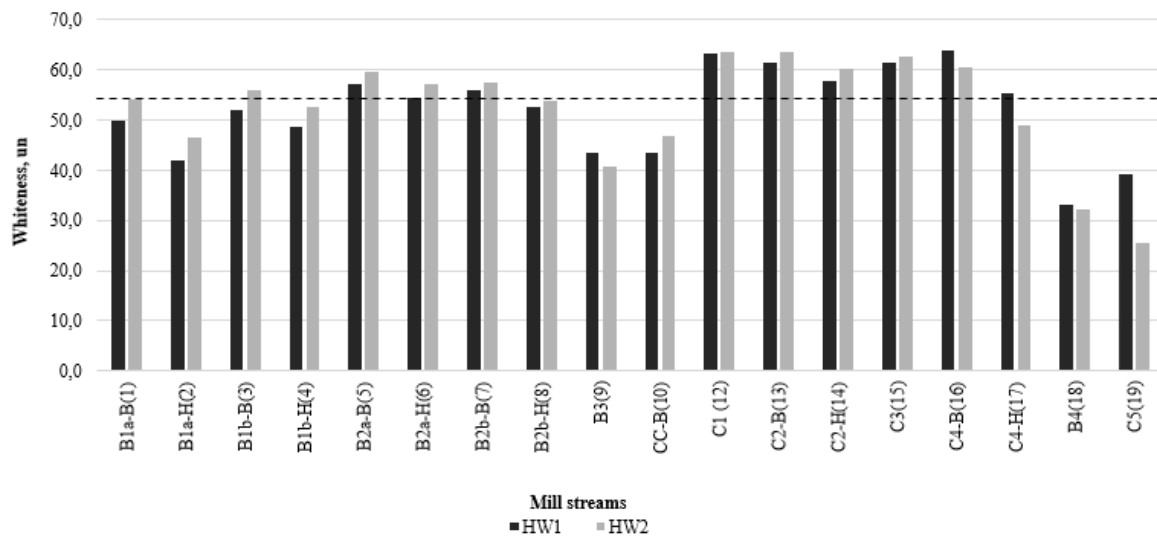


Fig. 1. Whiteness of flour streams

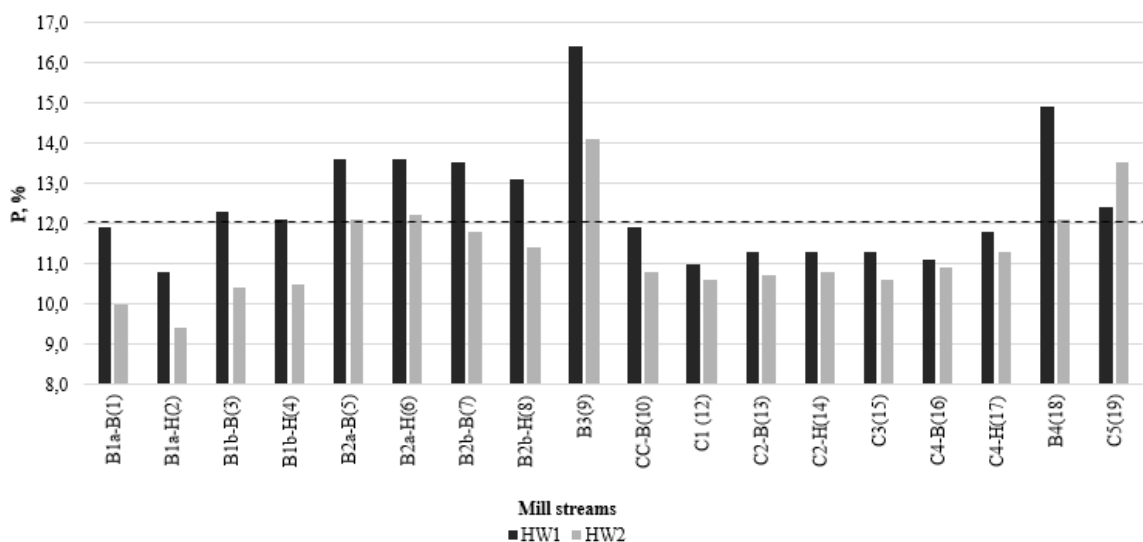


Fig. 2. Protein content of flour streams

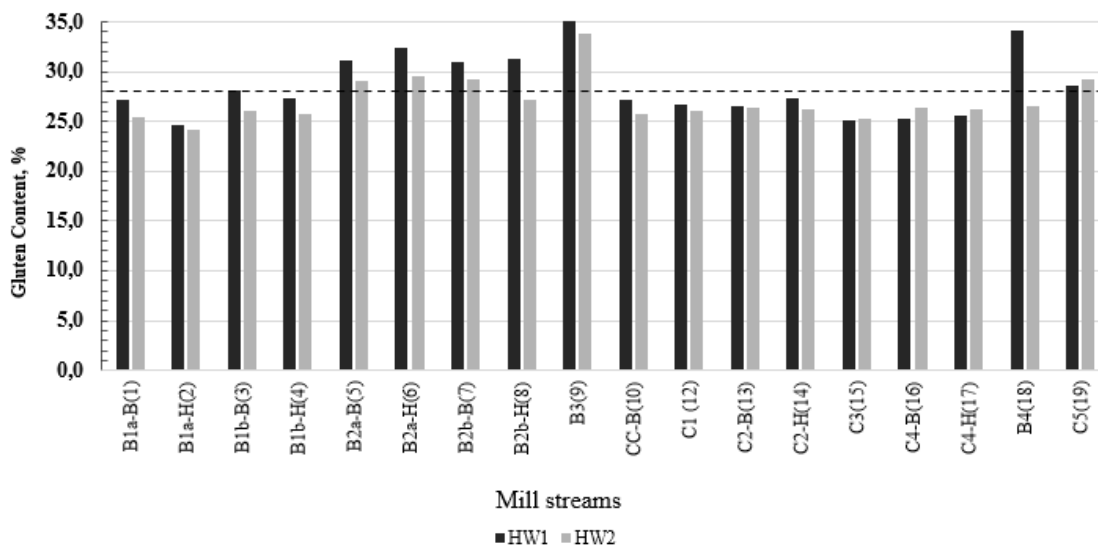


Fig. 3. Gluten content of flour streams

The highest values of the gluten content were obtained: for HW1 – 36.6% (B3), 34.1% (B4) and 32.4% (B2a–H); for HW2 – 33.8% (B3), 29.6% (B2a–H) and 29.2 % (B2b–B). The difference in gluten content on the same system for the two grain samples is explained by the different grain behavior during milling.

The amount of mill streams with recommended value of the gluten content for frozen products (>28.0%) for the HW1 were higher – 8 mill streams versus 5 – for HW2, due the initial protein and gluten content in grain.

The gluten deformation index (GDI) of wheat flour depends on many conditions and is an indicator that is much more variable than the gluten content, although there is a close relationship between both of these indicators. The recommended value of GDI for specific flour for frozen products is 70–80 units.

The structural and mechanical properties of gluten in flour streams changed significantly (Fig. 4.) depending on the group of technological process systems by quality. On the Primary Breaking and Grading systems, GDI varied from 68 units (B2a–B) up to 84 units (B3) for HW1 and from 64 units (B1a–H) to 80 units (B3) for HW2. On Primary Sizing and Reduction systems, gluten had lower but constant values of elastic properties (64–74 units) for HW1 and (62–66 units) for HW2. Tailing systems are characterized by high GDI values (83–85 units for HW1 and 79–81 units for HW2), that is, gluten has more elastic properties in terms of physical properties.

The content of damaged starch is an important indicator of baking quality. Knowledge of the content of damaged starch, is very important for predicting the milling conditions and manifestation of starch properties (water absorption capacity, rheological and gelatinization properties) [41]. Damaged starch more susceptible to enzymatic hydrolysis, has increased ability to absorb water [42]. Intact starch granules can absorb water up to 40% of their weight, while damaged – absorb up to 300%. Too much starch damage can

cause production problems and lead to a decline in bread quality such as reduced volume, poor texture and cell structure, grey crumb and dark crust color, etc. [43].

Starch damage depends on the kind of wheat milled, the flow diagram and milling rolls adjustment [44]. Hard wheat flour typical has higher starch damage then flour produced from soft wheat. The content of damaged starch grains in flour for frozen products should not exceed 19.0–22.0 UCD to reduce the destruction of starch grains and accumulation of sugars immediately after mixing, which can activate yeast.

Primary Break flours had the lower values (15.4–20.6 UCD for HW1 and 13.8–21.6 UCD for HW2) and Primary Reduction flours (20.8–21.9 UCD for HW1 and 18.1–19.9 UCD for HW2) – the higher values of starch damage (Fig. 5); these values increased as the product moved down through the Reduction system. An increase of starch damage was noted in Tailing systems (for HW1: B4 – 22.8 UCD, C5 – 24.5 UCD; for HW2: B4 – 22.8 UCD, C5 – 24.3 UCD) where finer flour was produced. All flour mill samples had starch damage low enough for industrial milling, which led to a decrease in water absorption capacity (Fig. 6).

One of the latest instruments used to determine the rheological quality of dough is Mixolab [45]. The water absorption capacity (WAC) of flour depends, firstly, on the presence of pentosans contained in the aleuronic layer and in the bran; secondly, on the protein content (the higher the protein content, the higher the value of the WAC is); thirdly, on the content of damaged starch grains, which depends on the operating modes of rollers mills [30]. The water absorption capacity of the flour should be within 55–60% to limit the content of free water in the dough, for flour for frozen products WAC should be higher than 57%. At the same time, the water content should ensure the swelling of the biopolymers of the dough. For HW1 – 10 flour mill streams corresponded to the specified range, despite – 5 mill streams for HW2.

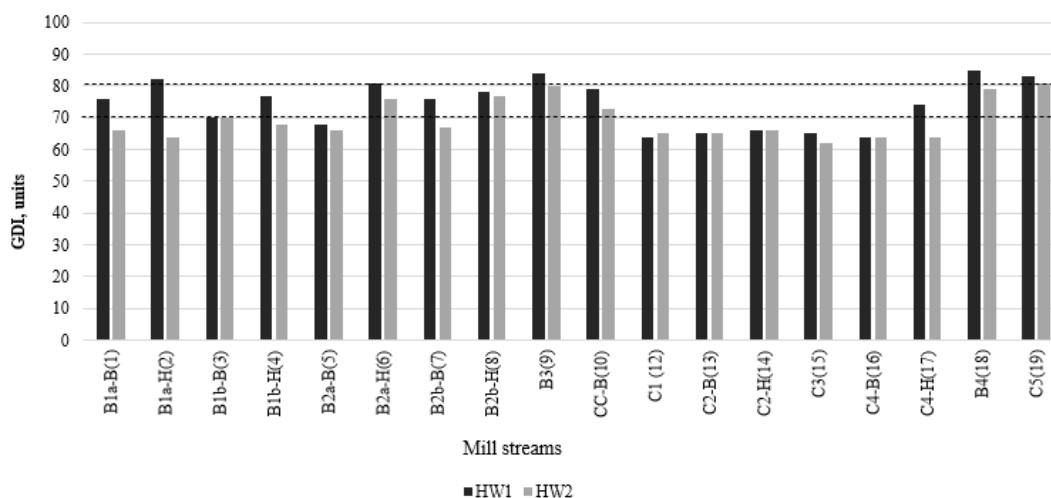


Fig. 4. GDI of flour streams

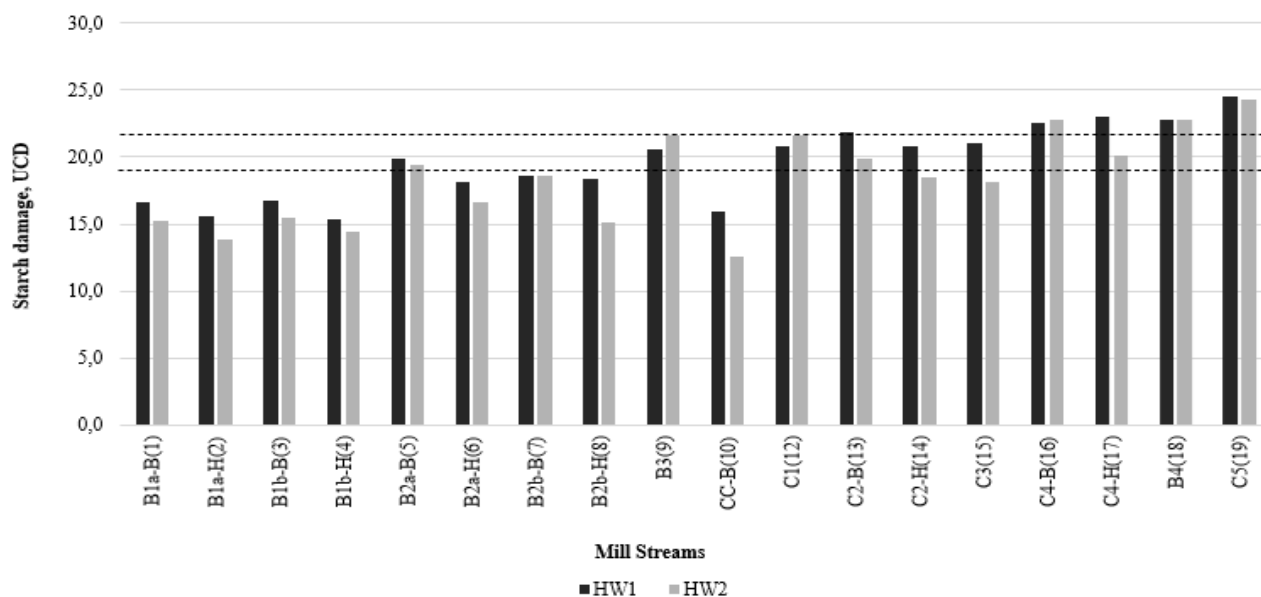


Fig. 5. Starch damage of flour streams

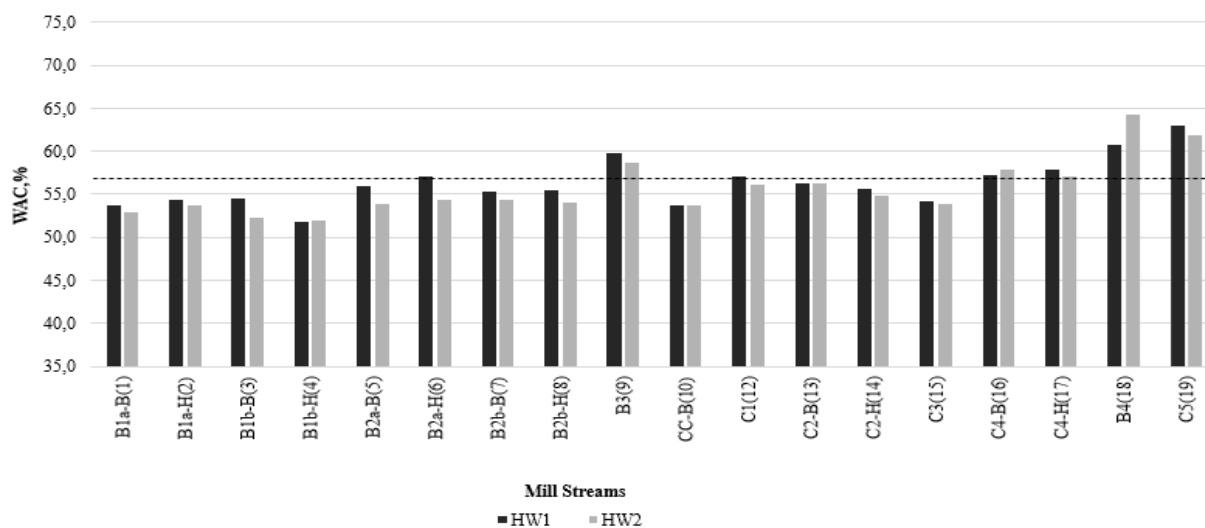


Fig. 6. Water absorption capacity (WAC) of flour streams

The highest values of WAC are obtained from the Tailing Break and Reduction systems (for HW1 – 60.8% and 63.0% respectively; for HW2 – 64.2% and 61.8% respectively). Higher water absorption can be associated with the influence of starch damage but also with the effect of flour particle size because smaller particles have larger total surface area. All flour mill streams from HW1 has higher values of water absorption capacity due the differences in initial grain quality indicators, such as protein content and vitreousness which correlated with some results reported in the literature [46,47].

Alveograph has been used to evaluate bread making quality of wheat flours [48]. The recommended value for frozen products deformation energy (W) is not less than  $>260 \cdot 10^{-4}$  J. According to the obtained results (Fig. 7), W values in 15 flour streams were in

the range  $263\text{--}384 \cdot 10^{-4}$  J for HW1 wheat and in 11 flour streams – from 274 to  $437 \cdot 10^{-4}$  J for HW2. Highest results for both wheat samples were in B3 ( $384 \cdot 10^{-4}$  J for HW1 and  $437 \cdot 10^{-4}$  J for HW2), C2-B ( $318 \cdot 10^{-4}$  J for HW1 and  $315 \cdot 10^{-4}$  J for HW2), B2a-B ( $368 \cdot 10^{-4}$  J for HW1 and  $342 \cdot 10^{-4}$  J for HW2) and C4-B ( $307 \cdot 10^{-4}$  J for HW1 and  $326 \cdot 10^{-4}$  J for HW2).

The P/L ratio according to the alveograph recommended value for frozen products is 0.8–1.2. Mill streams from HW1 shown (Fig. 8.) higher P/L ratio results (0.70–1.21 for Break systems, 1.27–2.39 for Reduction systems, 1.18–3.92 for Tailing systems), when for HW2 it shown lower results on 0.01-0.51 for Break systems, on 0.14-0.89 for Reduction and higher for Tailing systems on 1.61-3.51. Amount of the mill streams from HW1 that was in the range 0.8–1.2 – 6 mill streams and for HW2 – 7 mill streams.

After analyzing of the obtained results of flour mill streams quality indicators and comparing them with the requirements for flour for frozen products it can be concluded: no flour mill streams fit all quality indicators for flour for frozen product, the closest values were obtained for flour streams from B2, B3 systems for both wheat samples.

B3 is the first most suitable mill stream for blending flour for frozen products due to the highest deformation energy ( $W - 384 \cdot 10^{-4}$  J) (Fig. 8), protein content (16.4%) and a correspondingly high gluten content (36.6%), but a fairly high GDI (84 units), which indicates excessive elasticity for flour for frozen products; high water absorption capacity (WAC – 59.8%), and the main indicator that forms the grade of flour and consumer properties – whiteness has a low value (43.6 units).

Flour mill streams obtained from B2 system are similar in results, but deformation energy is less on  $5-94 \cdot 10^{-4}$  J and insufficient water absorption capacity (<57%), protein – less on 3.2%, gluten content – less on 4.2–5.7%, but at the same time has higher values of whiteness – on 8.8–13.7 units. B2a-B shown high W result ( $368 \cdot 10^{-4}$  J for HW1 and  $342 \cdot 10^{-4}$  J for HW2), protein (13.6% for HW1 and 12.1% for HW2) and

gluten content (31.2% for HW1 and 29.0% for HW2). Therefore B2a-B and close to it B2a-H, B2b-H are the second most suitable mill streams for blending.

C2 among of Reduction systems has the highest value of deformation energy ( $W - 318 \cdot 10^{-4}$  J), whiteness compared to B2 and B3 higher on 4.2–8.8 and 17.9 units respectively, but worse in terms of protein content (11.3%) and gluten content (26.5–27.4%), has a low GDI value (65 units) and medium WAC value (55.6–56.2%).

C1 Sizing system also has a high whiteness of 63.2 units, good value of the deformation energy ( $W - 281 \cdot 10^{-4}$  J), but insufficient protein content (11.0%), gluten content (27.0%) and GDI (64 units), which is leveled out by using of the flour mill streams from Break systems (B2, B3).

Tailing Break (B4) and Reduction (C5) systems characterized by low whiteness (33.1 and 39.1 units respectively), higher than recommended (70–80 units) GDI values (83 and 85 units respectively). B4 compared to C5 has higher deformation energy ( $305 \cdot 10^{-4}$  J despite  $254 \cdot 10^{-4}$  J) and a suitable P/L ratio (1.18 despite 3.92), as well as high values of protein (on 2.5%) and gluten content (on 5.5%).

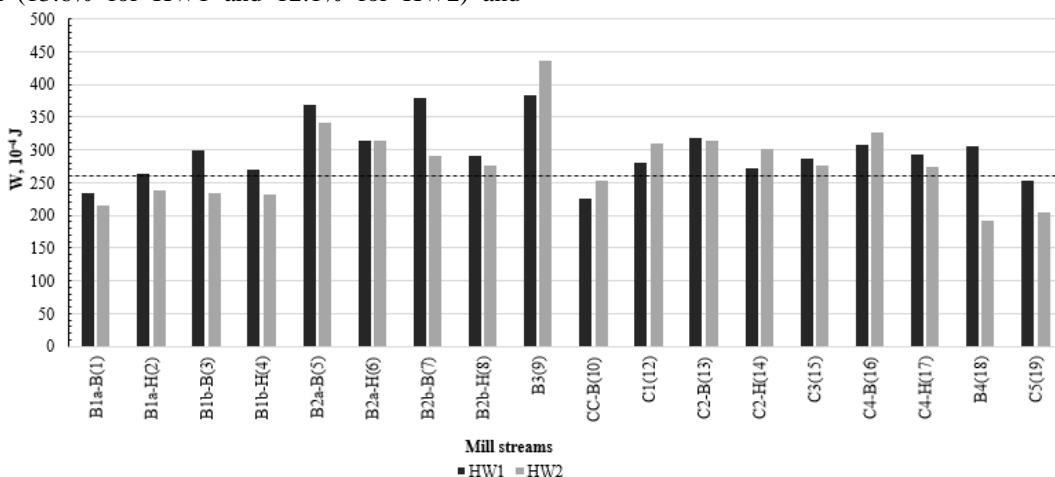


Fig. 7. Deformation energy (W) of flour streams

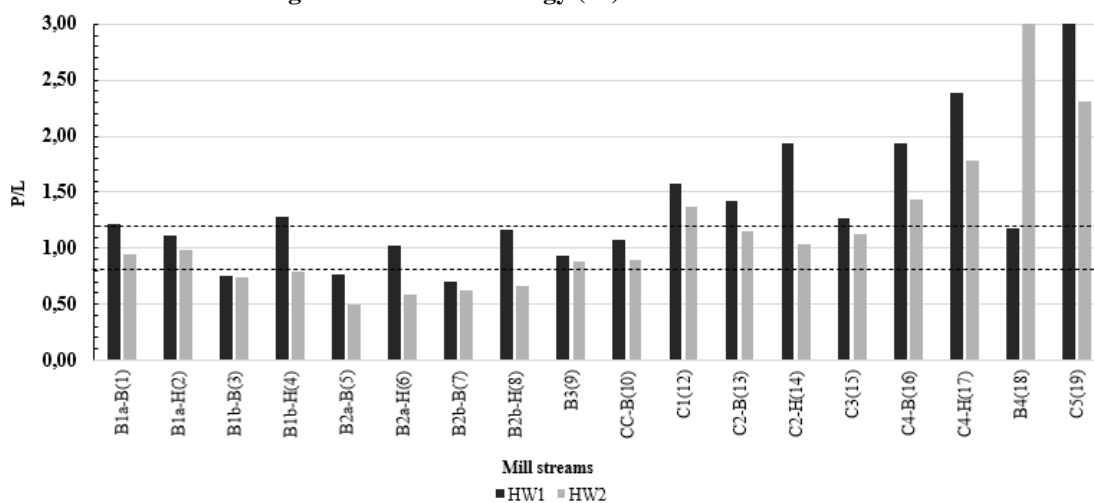
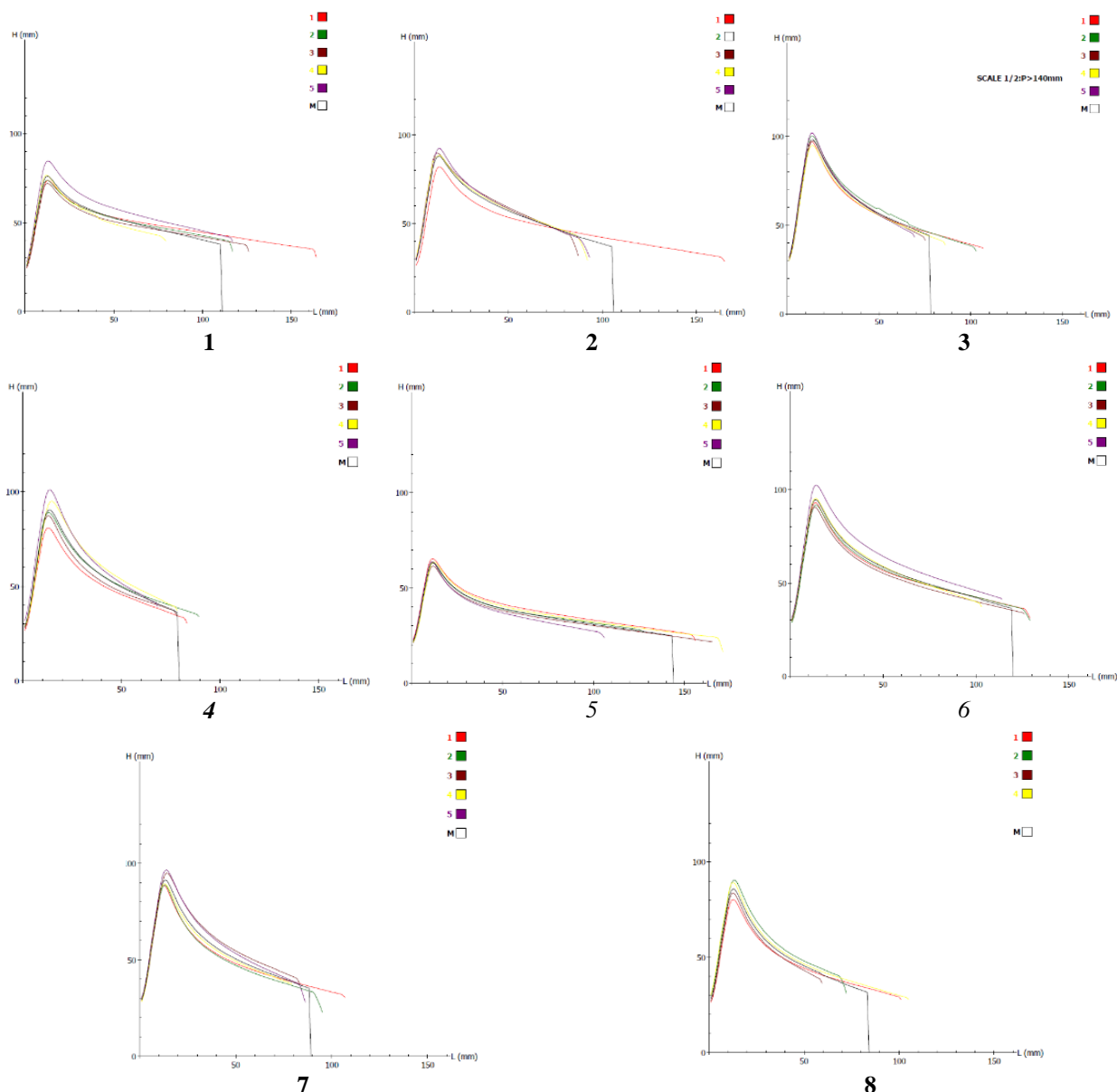


Fig. 8. Curve configuration ratio (P/L) of flour streams



HW1: 1 – B2a-B, 2 – B3, 3 – C2-B, 4 – C3; HW2: 5 – B2a-B, 6 – B3, 7 – C2-B, 8 – C3

Fig. 9. Alveograms of some flour streams

These flour mill streams, according to the results obtained, are of great interest as flour mill streams for blending for flour for frozen products.

With standard flour grades forming on the plant mill, flour from HW1 and HW2 wheat does not meet all requirements for frozen flour. Patent flour obtained from wheat with a higher protein content – HW1, despite the high deformation energy ( $300 \cdot 10^{-4}$  J), had protein content in patent flour – 11.8%, gluten content – 27.2%, insufficient water absorption capacity – 55.4%; protein and gluten content in first – grade flour has more suitable higher values (12.6% and 28.8% respectively), but low whiteness (49.6%). Wheat HW2 with lower protein content showed correspondingly lower values for both of flour grades (protein content for patent flour and first – grade flour – 11.0% and 11.7% respectively, gluten content for both flours <28.0%, with fairly good values of

deformation energy –  $294 \cdot 10^{-4}$  J and  $263 \cdot 10^{-4}$  J respectively).

Based on the above for HW1 the following mill streams were selected for blending and obtaining flour for frozen products: B3, B2a-B, B2a-H, B2b-H, B4, C1 and C2-B; for HW2 were used B3, B2a-B, B2a-H, C2-B. Blending these streams allows obtaining flour of the required quality.

### Conclusion

As a result of comparing the flour quality indicators obtained from samples HW1, HW2 at different stages of the technological process with the requirements for flour quality indicators of flour for frozen products, the optimal percentage of flour yield, while maintaining the profitability of production, was established flour for

frozen products and first – grade flour for each grain sample (Table 2).

According to our proposed options, it became possible to obtain flour that meets all the recommended indicators for flour for frozen products (whiteness >54 units, protein content >12.0%, gluten content >28.0%, GDI in the range of 70–80 units, starch damage in the

range of 19–22 UCD, WAC >57%, W >260·10<sup>-4</sup> J and P/L ratio in the range of 0.8–1.2). The yield of patent flour for frozen products will be 33.2% for HW1 and 20.5% for HW2. The decrease in flour yield for HW2, with similar quality indicators, is associated with lower values of initial quality indicators of HW2.

Table 2 – Options for the formation of flour grades on the mill plant

Flour type	Sample	Yield, %	Wh, un.	PC, %	GC, %	GDI, un.	SD, UCD	WAC, %	W, 10 <sup>-4</sup> J	P/L
<b>Standard for the plant Forming flour</b>										
Patent flour	HW1	49.0	58.8	11.8	27.2	68	20.4	55.4	300	1.26
First – grade flour		27.6	49.6	12.6	28.8	75	21.4	57.9	296	1.72
Patent flour	HW2	50.0	60.3	10.9	26.4	66	18.6	54.8	294	1.06
First – grade flour		26.6	46.7	11.7	27.1	71	20.5	58.2	263	1.92
<b>Forming flour for frozen products</b>										
Patent flour for FP	HW1	<b>33.2</b>	<b>53.8</b>	<b>12.8</b>	<b>29.8</b>	<b>72</b>	<b>21.2</b>	<b>57.4</b>	<b>323</b>	<b>1.20</b>
First – grade flour		43.4	56.7	11.6	26.2	69	20.4	55.5	280	1.58
Patent flour for FP	HW2	<b>20.5</b>	<b>58.0</b>	<b>12.4</b>	<b>28.9</b>	<b>70</b>	<b>20.9</b>	<b>56.5</b>	<b>335</b>	<b>1.22</b>
First – grade flour		56.1	54.7	11.9	27.1	70	20.7	56.2	283	1.59

Note: FP – frozen products; Wh – whiteness; PC – protein content; GC – gluten content; GDI – gluten deformation index; WAC – water absorption capacity; W – deformation energy; P/L – curve configuration ratio

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## ВИРОБНИЦТВО СПЕЦІАЛЬНОГО БОРОШНА ДЛЯ ЗАМОРОЖЕНИХ ПРОДУКТІВ ШЛЯХОМ ЗМІШУВАННЯ ПОТОКІВ БОРОШНА

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**Анотація.** Хлібопекарська промисловість потребує борошна специфічної якості для виробництва різних продуктів. Для виробництва заморожених виробів необхідне сильне борошно зі специфічними показниками якості, що зумовлено погіршенням структурно-механічних властивостей тіста після розморожування, зниженням газоутримуючої здатності та формостійкості тістових заготовок. З літературного огляду та апріорної інформації рекомендовано наступні показники якості борошна для заморожених виробів: білість >54 од., вміст білка >12.0%, вміст клейковини >28.0%, ІДК в діапазоні 70–80 од., пошкодження крохмалю в діапазоні 19–22 UCD, WAC >57%, W >260·10<sup>-4</sup> Дж і співвідношення P/L в діапазоні 0.8–1.2. При помелі пшениці утворюються різні потоки борошна, які відрізняються за складом, розміром частинок, функціональними та хлібопекарськими властивостями. Далі усі борошномельні потоки змішуються в один сорт борошна (односортний помел) або декілька сортів борошна (багатосортний помел). Дослідження в статті полягають у вивченні показників якості борошномельних потоків для подальшого формування спеціального борошна для заморожених виробів. Для дослідження було відібрано зразки борошна з кожної системи технологічного процесу під час помелу двох зразків червоної твердозерної озимої пшениці (HW1 і HW2 з вмістом білка 13.3 і 12.2% відповідно). На підставі аналізу показників якості борошномельних потоків та їх порівняння з вимогами до борошна для заморожених виробів встановлено, що жоден з борошномельних потоків не відповідає всім показникам якості борошна для заморожених продуктів – найбільш близькими показниками володіють потоки борошна із систем В3 та В2. Обрано окремі борошномельні потоки, які представляють інтерес як потоки для змішування борошна для заморожених виробів. У результаті порівняння показників якості борошна, отриманих на різних етапах технологічного процесу, з вимогами до показників якості для борошна для замороженої продукції, оптимальний відсоток виходу борошна вищого сорту для замороженої продукції становить 33.2% для HW1 і 20.5% для HW2.

**Ключові слова:** пшеничне борошно, потоки борошна, показники якості, реологічні властивості, заморожені продукти.