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V. Liubych, Dr of Agricultural Sciences, Professor, E-mail: LyubichV@gmail.com
https://orcid.org/0000-0003-4100-9063
ResearcherID: W-8897-2018
Scopus Author ID 57190382174
V. Zheliezna, PhD of Agricultural Sciences, Senior Teacher, E-mail: valieriia.voziian07@gmail.com
https://orcid.org/0000-0002-1874-2155
ResearcherID: AAL-5479-2020
Scopus Author ID: 57195525104
Uman National University of Horticulture, 1, Institute Street, Uman, Cherkasy region, 20305, Ukraine
Tel. +38047 4432011

EFFECT OF WATER-HEAT TREATMENT ON SPELT GRAIN FLOUR QUALITY

Abstrakt

Studies have shown that the ash content of products after the first grinding was lower compared to the the second grinding. This is due to a decrease in the quality of intermediate product coming to the second grinding. The variation coefficients of analytical replicates for the results after the first grinding varied from 4,65 to 14,18, and for the results after the second grinding - from 2,44 to 13,43. This indicates little or slight variation. Therefore, the average data from the study results can be used for mathematical modeling.

The theory of correct distribution of the sample data was rejected, and therefore the relationship between the parameters of water-heat treatment and ash content of flour was carried out using nonparametric statistics (determining Spearman correlation coefficient).

With 95 % probability, it can be argued that there was an inverse correlation between the water-heat treatment parameters and ash content.

The lowest ash content of flour after the first grinding of spelt grain can be obtained with the highest grain moisture content and the maximum duration of its softening. The correlation and influence of the factors were determined using beta and partial correlation coefficients. For the first grinding, the highest moisture content and influence on the flour ash content had the grain moisture content before grinding. The effect of moisture on milling products during the second pass resulted in a greater impact compared with softening duration. In general, flour ash content in a production using two milling systems is mostly influenced by grain moisture content. Obviously it can be explained by the fact that the formation of microcracks in a bruchid endosperm depends on the tensile forces between water and its structural parts. Moisture increase weakens the bonds between shells and endosperm of grain, which helps them to better separate during the second grinding.

Therefore, the response of spelt wheat grain to water-heat treatment is similar to the known regimes for the soft type of soft wheat grain.

The tendency of flour whiteness change, depending on the modes of water-heat treatment, varied similarly to the ash content.

Key words: *spelt wheat, flour, water-heat treatment, ash content, flour whiteness.*

Introduction

Wheat is the most widely grown crop in the word because of its unique protein characteristics. Now there is an active 'search', revival, improvement and introduction into production of 'antique cereals' – forgotten grain cereals. One of these species is spelt wheat (*Triticum spelta L.*), an ancient, almost extinct species of wheat with a hexaploid chromosome set (2n = 42) [1, 2]. Spelt wheat is undemanding to growing conditions, so it is common in organic farming in most Western European countries (Germany, Belgium, Switzerland, France, Spain) and the United States. [3, 4]. The high adaptive properties of this culture have been confirmed by studies of 22 research institutes in nine countries of the European Union participating in SESA project [5].

Spelt wheat is almost a perfect combination of the vitamins, minerals, proteins, carbohydrates and fats essential for human body. Compared to soft wheat, it is richer in proteins, unsaturated fatty acids and dietary fibers [6, 7]. Organic substances contained in spelt have a high level of solubility, so they are easily and quickly absorbed by the human body [8]. Its grain contains special soluble carbohydrates – micropolysaccharides, which are able to strengthen the immune system, lower cholesterol and regulate blood coagulation processes [9, 10]. The peculiarity of spelt wheat grain is the balanced placement of valuable components in the shells and endosperm, which makes it possible to use simple and complex grain grindings [11, 12].

Literary review

Compared to soft wheat, spelt wheat grain has thicker shells that are less tight to the aleurone layer [13]. However, the groove of spelt wheat grain is wide and reaches about half of the cross section of endosperm and is relatively big in the top part [14, 15].

Spelt flour is inferior to wheat by the baking quality, but it can be useful in the manufacture of bakery products of improved chemical composition, for dietetic nutrition [16, 17]. High quality characteristics and soft-grain consistency of spelt grain provide high quality confectionery and grits with excellent taste properties. Thus, the complex of useful features and properties of

spelt wheat determined its widespread practical use and encouraged for different scientific researches [18]. Flour quality depends on the technological properties of grain. Yield and quality of flour vary depending on weather and agrotechnical conditions of cultivation [19]. The conversion of spelt wheat into flour will help to expand the range of this product. In addition, it has high biological value [9, 12].

In a context of market economy, the main indicator of effective enterprise performance is the demand for products, which is formed to a greater extent by the quality of manufactured products. Marketing techniques and promoting of low quality products can only produce short-term sales improvements. Therefore, the optimization of flour production from new varieties of spelt wheat grain was carried out taking into account the main indicators of flour quality (ash content and linen), which predetermine the quality of the manufactured bakery products.

Formulation of the problem

The aim of the study is to determine the effect of water-heat treatment on the quality of spelt wheat flour.

To solve this goal, the following tasks were set: to conduct literature review and scientific experiment, make a statistical analysis of the obtained data, make mathematical models, establish the optimal parameters of water-heat treatment depending on flour quality.

Materials and methods

The experimental part of the work was carried out in the laboratory of 'Quality evaluation of grain and grain products' of the Department of Technology of Storage and Processing of Grain of Uman National University of Horticulture. For research, we used spelt winter wheat grain of Zoria of Ukraine variety. Flour quality was investigated depending on water-heat treatment (Table 1). To do this, the grain was used with a moisture content of 13,0 % to 17, 0% with an interval of 0,5 %, softened from 5 h to 30 h with an interval of 5 h.

Table 1 – Experiment scheme 'Moistening and softening effect of spelt wheat grain on yield and quality of flour

Indicator	Levels and step variation								
Grain moisture	13,0	13,5	14,0	14,5	15,0	15,5	16,0	16,5	17,0
Duration of softening, h	–	–	–	–	5; 10; 15; 20; 25; 30				

For laboratory grinding of spelt wheat grain, MVR-000342.90 roller machine was used, which allows to obtain wheat flour in accordance with DSTU 46.004-99 of wheat flour. The technical characteristics of the roller machine are shown in Table 2. The minimum weight of grain sample should be 1 kg.

The principle of roller machine operation is that grain after water-heat treatment is loaded into the receiving hopper 2 (Fig. 1). Through the feed valve 3 grain is directed to the roller 4.

Table 2 – Technical characteristics of roller machine

Indicator	Value
Productivity (raw), kg/h	320–350
Installed power, kW	7,5
Weight, kg	350
The yield of flour,%	75–85

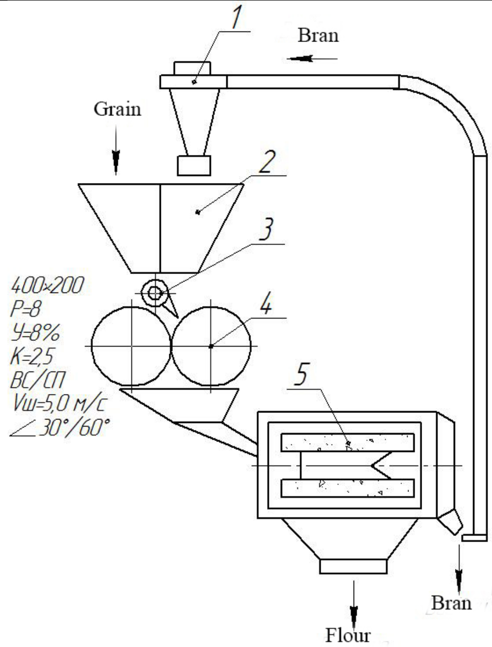

Fig. 1 - MBR-000342.90 flow diagram

After grinding the receiving product is separated on a sieve separator 5 of a drum type. The separator descent, if necessary, is directed to re-treatment through the pneumatic conveyor system 1.

The relationship between quality indicators of spelt wheat flour was determined by correlation (Multiple Regression, Correlation matrices) and variance (ANOVA) methods using Statistica 10 and Microsoft Office 2010. To properly evaluate the relationship power, Cheddock correlation coefficient was used: 0,1–0,3 – insignificant relationship; 0,3–0,5 – moderate; 0,5–0,7 – significant; 0,7–0,9 – high; 0,9–0,99 – very high; 1 – functional.

Measurements accuracy and data reliability were mathematically substantiated at each stage of the research. The replicates of each experiment were treated with descriptive statistics to determine variation coefficient. In case of poor data variation of the samples of each experiment, their average was determined, which was used for mathematical modeling. The arrays of data, obtained from the averages, were checked for correct distribution. Correctly distributed data were processed by basic statistics methods and incorrectly distributed – by non-parametric ones. Correlation and regression analyses were used during statistical processing. Obtained functional dependencies were checked for the absence of autocorrelation by Darbin–Watson statistics method [20].

Due to the duplication of experiments, the reproducibility of experimental data was checked. The hypothesis of noise dispersion persistence was tested

using the Kohren criterion [20]. Testing of this hypothesis allowed to assert the homogeneity or heterogeneity of a number of variances. Mathematical modeling used data in which the number of variances was homogeneous.

The method of full factorial experiment is based on the assumption that any continuous function under study $y=f(x_1, x_2,...,x_n)$ with all derivatives at a given point with $x_{01}, x_{02}, ..., x_{0n}$ coordinates can be decomposed into Taylor series:

$$y=\beta_0+\beta_1x_1+\beta_2x_2+...+\beta_Hx_H+\beta_{21}x_1x_2+$$
$$+\beta_{(n-1)}x_{(n-1)}x_n+\beta_{11}x_1^2+\beta_{22}x_2^2+...+\beta_{nn}x_n^2, \quad (1)$$

where β_0 – the value of response function at the origin $x_{01}, x_{02},..., x_{0n}$ [15].

Results and discussion

Studies have shown that ash content of the products after the first grinding was lower than after the second one. This is due to a quality deviation of the intermediate product coming into the second grinding.

The variation coefficients of analytical replicates for the results after the first grinding varied from 4,65 to 14,18, and for the results after the second one – from 2,44 to 13,43. This indicates little or minor variation. Therefore, the average data from the research results can be used for mathematical modeling. The theory of correct distribution of sample data was rejected, and therefore the relationship between the parameters of water-heat treatment and flour ash content was carried out using nonparametric statistics (determining Spearman correlation coefficient).

With 95 % probability, it can be stated that there was an inverse correlation between the parameters of water-heat treatment and ash content (Table 3).

Table 3 – Correlation coefficients Spearman

Indicator	Duration of softening, h.	Grain moisture, %
Ash content in flour after first grinding, %	-0,664552*	-0,739161*
Ash content in flour after second grinding, %	-0,636434*	-0,886380*

Note: Significantly p <0,05.

The relationship between water-heat treatment and flour ash content can be described by the following linear dependencies:

$$Z_1=1,641249–0,061686X_1–0,005239X_2 \quad (2)$$

$$Z_2=1,813573–0,064253X_1–0,003174\ X_2 \quad (3)$$

where Z_1 and Z_2 – ash content after the first and second grindings;

X_1 – grain moisture, %

X_2 – duration of softening, min.

An important indicator of mathematical model quality is the presence or absence of autocorrelation of residuals. As a result of statistical analysis, the Darbin-Watson method found a positive autocorrelation of the residuals of the 3^d^ function. This meant that the selected model was incorrect or lacked of a statistically significant relationship. For the first equation, the autocorrelation of residuals was not detected.

Taking into account the high statistical reliability of first equation, the corresponding dependence can be represented graphically (Fig. 2). The lowest flour ash content after the first grinding of spelt grain can be obtained with the highest grain moisture content and the maximum duration of its softening.

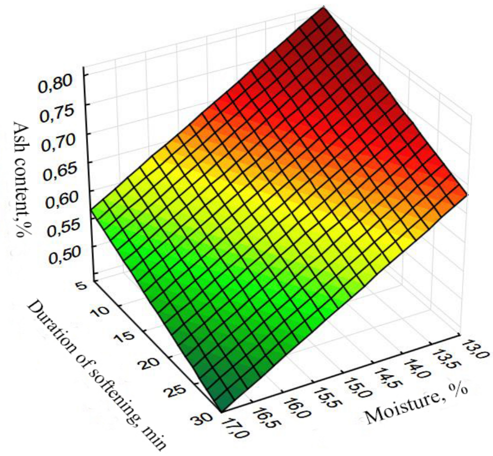

Fig. 2 – Relationship between parameters of water-heat treatment of spelt wheat grain and flour ash content after the first grinding

The correlation and influence of the factors were determined using beta and partial correlation coefficients (Fig. 3). For the first grinding, grain moisture content before grinding had the highest influence on flour ash content.

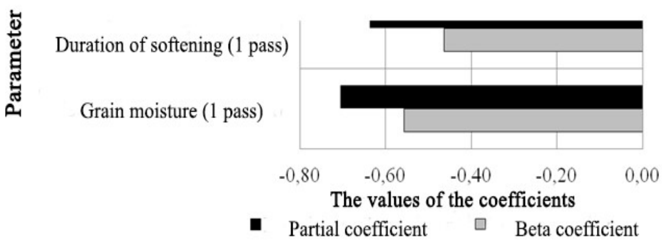

Fig. 3 – Results of correlation analysis of dependencies between the parameters of water-heat treatment and ash content after the first grinding

The parameters dependence of water-heat treatment and ash content after the second grinding was shown by the second-order equation according to Taylor's theory:

$$Z_2=3,346981–0,257682X_1–0,014978X_2+0,006044X_1^2+0,00076X_1X_2. \quad (4)$$

The theory of residuals autocorrelation of the 4^th^ function was rejected because DW_U (1,58045) <DW (1,854882) <4-DW_U (1,58045) statement was true and all others were false. High reliability of the 4^th^ function was statistically proved (Multiple R = 0,989562227, Multiple R^2 = 0,979233402, Adjusted R^2 0,975525081, F(5,28) = 264,063812, p = 1,2063897 10^{-22}).

After graphical representation of the 4^th^ function, it was found that the effect of moisture and the duration of its effect on grain during the second grinding were similar to the first one (Fig. 4). The influence of

moisture on the milling products during the second pass resulted in a greater effect than the duration of softening. In general, flour ash content in a production using two milling systems is most influenced by grain moisture content. Obviously it can be explained by the fact that the formation of microcracks in grain endosperm depends on forces between water and its structural parts. Moisture content increase weakens bonds between shells and grain endosperm, which helps them to separate better during the second grinding.

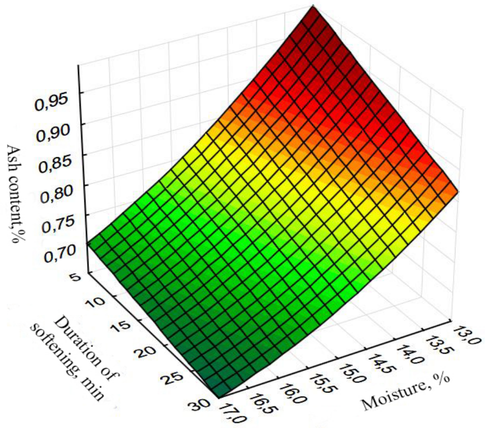

Fig. 4 – Relationship between the parameters of water-heat treatment of spelt wheat grain and flour ash content after the first grinding

Therefore, the reaction of spelt wheat grain to water-heat treatment is similar to the known regimes for soft-milled wheat grain type.

The tendency of flour whiteness change depending on the modes of water-heat treatment varied similarly to ash content. Due to the fact that the sample data were not correctly distributed, the relationship between factors was found using non-parametric statistics methods (Table 4). According to Cheddock scale, the relationship between flour whiteness and the duration of softening was directly noticeable, and with grain moisture content - straight high, which made it feasible to carry out further studies.

Table 4 – Spearman correlation coefficients

Indicator	Grain moisture, %	Duration of softening, h
Flour whiteness after first grinding, unit in.	0,833471*	0,585085*
Flour whiteness after second grinding, unit in.	0,894232*	0,579903*

Note: Significantly p <0,05.

The theory of linear dependence between these indicators was rejected because the residuals of obtained models had autocorrelation. After interpreting the dependencies in the form of second-order functions, it was found that the formula of the dependence of flour whiteness after the first grinding, moisture content and duration of softening had autocorrelation of residuals similar to linear. This indicates that relevant models may have unaccounted for significant variables that influenced the process, model cycle, process performance could respond to delayed conditions, and so on. Therefore, to calculate partial correlation coefficients for the corresponding dependence, look for relationships and the power of effect was inappropriate.

The mathematical relationship between flour whiteness of spelt wheat and the parameters of water-heat treatment is given in the 5 formula.

$$W = -149{,}516+19{,}324X_1+2{,}229X2-0{,}484X_1^2-0{,}01X_2^2-0{,}112X_1X_2. \quad (5)$$

де W – flour whiteness, unit in.;

X_1 – grain moisture, %;

X_2 – duration of softening, h.

The graphical representation of function shows that the duration of softening had the greatest influence on flour whiteness at the lowest grain moisture content (Fig. 5). At the moisture content of 14,0–17,0 %, the effect of softening duration decreased.

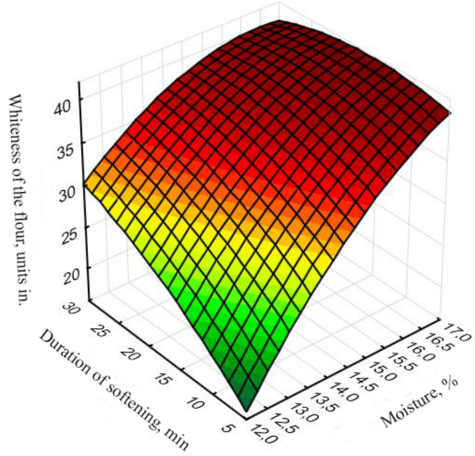

Fig. 5 – Relationship between the parameters of water-heat treatment of spelt wheat grain and flour whiteness

The research results were unevenly distributed, so the use of non-parametric statistics was a priority. It was assumed that there was a straight line connection between the coefficient of endosperm use (Coef. U) and the duration of softening, whereas the tendency to change depending on moisture content was curvilinear. Curvilinear dependencies were also observed between the parameters of water-heat treatment and complex efficiency criterion (Complex U). Therefore, the approximation was performed using second- and third-order polynomials.

Moisturizing and the duration of softening of spelt wheat grain influenced the flour yield. So, at 13,0–14,5 % grain moisture content, flour yield was 82,0–83,3 %. Grain moisturizing to the content of 15,0 % increased its yield up to 83,9 % during 5–hour softening, but it was the highest for 10–15 hours of moistening – 84,2–85,3 %. A similar tendency was found for grain moisturizing up to 15,5 %. Moisturizing of spelt wheat grain to 16,0–17,0 % moisture content reduced flour yield to 81,3–83,0 %. Therefore, it is optimal to moisten grain to 15,0–15,5 % moisture content and with softening for 5–10 hours. As a result of regression analysis, statistically significant regression coefficients were determined and mathematical models were formed:

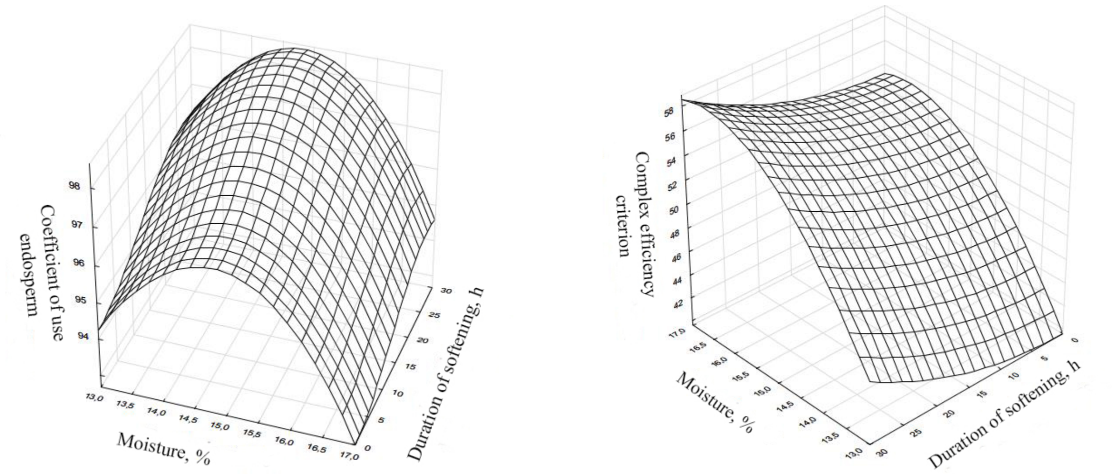

Fig. 6 – Relationship between the parameters of water-heat treatment and efficiency of flour milling

Coef. $$U = 41{,}22451+0{,}75545X_1^2+0{,}00874X_2^2-0{,}03397X_1^3-0{,}00022X_2^3 \quad (6)$$

Complex $$U=-67{,}3908+1{,}3336X_1^2+0{,}0059X_2^2-0{,}0539X_1^3 \quad (7)$$

where X_1 – grain moisture, %; X_2 – duration of softening, h.

Graphical representation of 2^d and 3^d functions is shown in Fig. 6.

It has been proved that the greatest effect on the performance of flour production was due to grain moisture content. Thus, increasing moisture content from 13,0 % to 15,0 % rose endosperm use coefficient from 94,5 % to 99,0 or more by 4,5 points. High endosperm use coefficient was at 15,5 % spelt wheat grain moisture content. Further increase in moisture content to 16,0–17,0% had a negative effect on this indicator, as it decreased to 93,7–95,6 %. In all studied samples, increase in the duration of softening at grain moisture content of 15,0–15,5 % increased the endosperm use coefficient.

Conclusions

Therefore, there is high correlation between the parameters of water-heat treatment of spelt wheat grain and flour quality. The use of water-heat treatment significantly influences the complex criterion of flour milling production efficiency. Grain moisturizing and softening contribute to an increase in the complex criterion by 22–40 % compared to 13 % moisture content (40,8 %). Its largest value was recorded by the longest duration of softening – 57,0–57,2 %. It is the lowest in grain moisture content before grinding – 13,0–14,5 % – 40,8–46,8 %.

The use of water-heat treatment causes an improvement in spelt wheat grain flour production process. It improves the processing of spelt wheat by classic technology. According to the performance indicators of flour milling production in low productivity enterprises, moisturizing of spelt wheat grain is optimal up to 15,0–15,5 %, followed by its softening for 10–15 hours. It is advisable to further study the effect of crushing and water-heat treatment parameters of the developed flour milling process on spelt wheat grain.

REFERENCES

1. *Shelepov V. V., Chebakov N. N, Vergunov V. A., Kochmarskyj V. S Pshenycza: ystoryya, morfologyya, byologyya, selekcyya. K.: MYP ym. V. N. Remesla. 2009. 543 s.*
2. *Mikos M., Podolska G. Wartość technologiczna pszenicy orkisz w zależności od wybranych czynników agrotechnicznych // Ogólnopolska Konferencja pt.: hodowla, uprawa i wykorzystanie pszenicy orkisz (Triticum aestivum L. ssp. spelta) w warunkach zmian klimatu. Puławy. 2011. P. 28–30.*
3. *Neeson R. Organic spelt production // Industry & Investment NSW. 2011. P. 1–8.*
4. *Gorn E. Luchshe chem psheny`cza, no… Fermerske gospodarstvo. 2008. № 4 (372). S. 21–22.*
5. *Lapchynskyj V. V. Analiz ekologo-geografichnyx osoblyvostej centriv poxodzhennya Triticum spelta i perspektyvy poshyrennya kultury v Ukrayini. ScienceRise. 2016. 4 (1 (21)). S. 34–38.*
6. *Escarnot E., Jacquemin J-M., Agneessens R., Paquot M. Comparative study of the content and profiles of macronutrients in spelt and wheat, a review. Biotechnology, Agronomy, Society and Environment. 2012. Vol. 16 (2). – P. 243–256.*
7. *Feng Y., Qu R., Yang Y. Rich haplotypes of Viviparous-1 in Triticum aestivum L. subsp. spelta with different abscisic acid sensitivities. J Sci Food Agric. 2017. Vol. 97. P. 497–504. doi: 10.1002/jsfa.7751.*
8. *Warechowska M., Warechowski J., Tyburski J., Siemianowska E. Ocena wartości przemiałowej ziarna orkiszu. Ogólnopolska Konf. pt.: Hodowla, uprawa i wykorzystanie pszenicy orkisz (Triticum aestivum L. ssp. spelta) w warunkach zmian klimatu. 2011. P. 45–46.*
9. *Liubych V. V., Zheliezna V. V., Ulianych I. F. Vplyv zvolozhuvannia ta vidvolozhuvannia zerna pshenytsi spelty na vykhid boroshna. Visnyk Kharkivskoho natsionalnoho tekhnichnoho universytetu silskoho hospodarstva imeni Petra Vasylenka. Kharkiv. 2019. S. 101–108.*
10. *Peressini D., Braunstein D., Page J. et al. Relation between ultrasonic properties, rheology and baking quality for bread doughs of widely differing formulation // J Sci Food Agric. 2017. Vol. 97. P. 2366–2374.*
11. *Koutroubas S. D., Fotiadis S., Damalas C. A. Biomass and nitrogen accumulation and translocation in spelt (Triticum spelta L.) grown in a Mediterranean area. Field Crops Research. 2012. № 127. P. 1–8.*

12. Fadeev L. Spelta – pryshlo ee vremia. Zernovi produkty i kombikormy. 2017. Tom 17. № 1. S. 4–8. https://doi.org/10.15673/gpmf.v17i1.308
13. Pospišil A., Pospišil M., Svečnjak Z., Matotan S. Influence of crop management upon the agronomic traits of spelt (Triticum spelta L.). Plant soil environ. 2011. № 57 (9). P. 435–440.
14. Zhyhunov D. O., Voloshenko O. S., Khorenzhyi N. V. Porivnialne doslidzhennia pokaznykiv yakosti tsilnozernovoho pshenychnoho ta speltovoho boroshna vitchyznianoho vyrobnytstva. Zernovi produkty i kombikormy. Vol. 18. I.3. 2018. S. 15–20. https://doi.org/10.15673/gpmf.v18i3.1071
15. Podolska G., Boguszewska E., Mikos M. et al. Wartość technologiczna ziarna i mąki Triticum spelta L., Triticum durum i Triticum aestivum L. w zależności od dawki azotu i niedoboru wody w glebie // Ogólnopolska Konferencja pt.: Hodowla, uprawa i wykorzystanie pszenicy orkisz (Triticum aestivum L. ssp. spelta) w warunkach zmian klimatu. Puławy. 2011. P. 31–33.
16. Zielinski H., Ceglinska A., Michalska A. Bioactive compounds in spelt bread // Eur.Food Res. Technolol. 2008. № 226. P. 537–544.
17. Hospodarenko H. M., Liubych V. V., Polianetska I. O., Zheliezna V. V. Boroshnomelni vlastyvosti zerna sortiv pshenytsi spelty zalezhno vid umov mineralnoho zhyvlennia. Visnyk Umanskoho NUS. Uman. №1. 2019. S. 129–134. https://doi.org/10.31395/2310-0478-2019-1-129-134
18. Su W. H., Sun D. W. Facilitated wavelength selection and model development for rapid determination of the purity of organic spelt (Triticum spelta L.) flour using spectral imaging. Talanta. 2016. Vol. 155. P. 347–357.
19. Zhyhunov D. O., Kovalova V. P., Moroz A. I. Vyznachennia pokaznykiv yakosti boroshna z riznykh system tekhnolohichnoho protsesu pry sortovomu pomeli pshenytsi. Zernovi produkty i kombikormy. 2017. Vol.17. I. 4. S. 30–36. https://doi.org/10.15673/gpmf.v17i4.763
20. Rudenko V. M. Matematychna statystyka. Kyiv: Tsentr uchbovoi literatury. 2012. 304 s.

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В. Любич, д-р с.-г. наук, професор, E-mail: LyubichV@gmail.com
https://orcid.org/0000-0003-4100-9063, ResearcherID: W-8897-2018
Scopus Author ID 57190382174
В. Желєзна, канд. с.-г. наук, ст. викладач E-mail: valieriia.voziian07@gmail.com
https://orcid.org/0000-0002-1874-2155, ResearcherID: AAL-5479-2020
Scopus Author ID: 57195525104
Уманський національний університет садівництва, м. Умань

ВПЛИВ ВОДНОТЕПЛОВОЇ ОБРОБКИ НА ЯКІСТЬ БОРОШНА З ЗЕРНА ПШЕНИЦІ СПЕЛЬТИ

Анотація

У результаті проведених досліджень встановлено, що зольність продуктів після першого розмелювання була нижчою порівняно із другим розмелюванням. Це зумовлено зниженням якості проміжного продукту, що надходить на друге розмелювання. Коефіцієнти варіаціювання аналітичних повторностей для результатів після першого розмелювання змінювались від 4,65 до 14,18, а для результатів після другого розмелювання – від 2,44 до 13,43. Це свідчить про невелике або незначне варіювання. Отже середні данні результатів досліджень можна використовувати для математичного моделювання. Теорію правильного розподілення даних вибірок було відхилено, а тому встановлення зв'язку між параметрами водотеплового оброблення та вмістом золи у борошні здійснювали методами непараметричної статистики (визначення коефіцієнта кореляції Spearman). З ймовірністю 95 % можна стверджувати, що між параметрами водотеплового оброблення та вмістом золи існував обернений кореляційний зв'язок.

Найнижчий вміст золи у борошні після першого розмелювання зерна спельти можна отримати за найвищої вологості зерна та найбільшої тривалості його відволожування. Зв'язок і вплив чинників встановлювали за допомогою бета та парціальних коефіцієнтів кореляції. Для першого розмелювання найвищий зв'язок та вплив на вміст золи у борошні мала вологість зерна перед розмелюванням. Дія вологи на продукти розмелу під час другого проходу зумовлювала більший вплив порівняно з тривалістю відволожування. У цілому на вміст золи у борошні на виробництві, що використовує дві розмельні системи найбільший вплив зумовлює вологість зерна. Очевидно це пояснюється тим, що утворення мікротріщин в ендоспермі зернівки залежить від сил натягу між водою та структурними її частинами. Збільшення вологості послаблює зв'язки між оболонками й ендоспермом зерна, що сприяє кращому їх відділенню за другого розмелювання. Отже, реакція зерна пшениці спельти на водотеплове оброблення подібна до відомих режимів для м'якозерного типу зерна пшениці м'якої. Тенденція зміни білизни борошна залежно від режимів водотеплового оброблення змінювалась подібно вмісту золи.

Ключові слова: *пшениця спельта, борошно, водотеплове оброблення, вміст золи, білизна борошна.*

ЛІТЕРАТУРА

1. Шелепов В. В., Чебаков Н. Н, Вергунов В. А., Кочмарський В. С. Пшеница: история, морфология, биология, селекция. К.: МИП им. В. Н. Ремесла. 2009. 543 с.

2. *Mikos M., Podolska G. Wartość technologiczna pszenicy orkisz w zależności od wybranych czynników agrotechnicznych // Ogólnopolska Konferencja pt.: hodowla, uprawa i wykorzystanie pszenicy orkisz (Triticum aestivum L. ssp. spelta) w warunkach zmian klimatu. Puławy. 2011. P. 28–30.*
3. *Neeson R. Organic spelt production // Industry & Investment NSW. 2011. P. 1–8.*
4. *Горн Е. Лучше чем пшеница, но… Фермерське господарство. 2008. № 4 (372). С. 21–22.*
5. *Лапчинський В. В. Аналіз еколого-географічних особливостей центрів походження Triticum spelta і перспективи поширення культури в Україні // ScienceRise. 2016. 4 (1 (21)). С. 34–38.*
6. *Escarnot E., Jacquemi J-M., Agneessens R., Paquot M. Comparative study of the content and profiles of macronutrients in spelt and wheat, a review // Biotechnology, Agronomy, Society and Environment. 2012. Vol. 16 (2). P. 243–256.*
7. *Feng Y., Qu R., Yang Y. Rich haplotypes of Viviparous-1 in Triticum aestivum L. subsp. spelta with different abscisic acid sensitivities // J Sci Food Agric. 2017. Vol. 97. P. 497–504. doi: 10.1002/jsfa.7751.*
8. *Warechowska M., Warechowski J., Tyburski J., Siemianowska E. Ocena wartości przemiałowej ziarna orkiszu // Ogólnopolska Konf. pt.: Hodowla, uprawa i wykorzystanie pszenicy orkisz (Triticum aestivum L. ssp. spelta) w warunkach zmian klimatu. 2011. P. 45–46.*
9. *Любич В. В., Желєзна В. В., Улянич І. Ф. Вплив зволожування та відволожування зерна пшениці спельти на вихід борошна // Вісник Харківського національного технічного університету сільського господарства імені Петра Василенка. Харків. 2019. С. 101–108.*
10. *Peressini D., Braunstein D., Page J. et al. Relation between ultrasonic properties, rheology and baking quality for bread doughs of widely differing formulation // J Sci Food Agric. 2017. Vol. 97. P. 2366–2374.*
11. *Koutroubas S. D., Fotiadis S., Damalas C. A. Biomass and nitrogen accumulation and translocation in spelt (Triticum spelta L.) grown in a Mediterranean area // Field Crops Research. 2012. № 127. P. 1–8.*
12. *Фадеев Л. Спельта – пришло ее время // Зернові продукти і комбікорми. 2017. Том 17. № 1. С. 4–8. https://doi.org/10.15673/gpmf.v17i1.308*
13. *Pospišil A., Pospišil M., Svečnjak Z., Matotan S. Influence of crop management upon the agronomic traits of spelt (Triticum spelta L.) // Plant soil environ. 2011. № 57 (9). P. 435–440.*
14. *Жигунов Д. О., Волошенко О. С., Хоренжий Н. В. Порівняльне дослідження показників якості цільнозернового пшеничного та спельтового борошна вітчизняного виробництва // Зернові продукти і комбікорми. Vol. 18. I.3. 2018. С. 15–20. https://doi.org/10.15673/gpmf.v18i3.1071*
15. *Podolska G., Boguszewska E., Mikos M. et al. Wartość technologiczna ziarna i mąki Triticum spelta L., Triticum durum i Triticum aestivum L. w zależności od dawki azotu i niedoboru wody w glebie // Ogólnopolska Konferencja pt.: Hodowla, uprawa i wykorzystanie pszenicy orkisz (Triticum aestivum L. ssp. spelta) w warunkach zmian klimatu. Puławy. 2011. P. 31–33.*
16. *Zielinski H., Ceglinska A., Michalska A. Bioactive compounds in spelt bread // Eur.Food Res. Technolol. 2008. № 226. P. 537–544.*
17. *Господаренко Г. М., Любич В. В., Полянецька І. О., Желєзна В. В. Борошномельні властивості зерна сортів пшениці спельти залежно від умов мінерального живлення. Вісник Уманського НУС. Умань. №1. 2019. С. 129–134. https://doi.org/10.31395/2310-0478-2019-1-129-134*
18. *Su W. H., Sun W. Facilitated wavelength selection and model development for rapid determination of the purity of organic spelt (Triticum spelta L.) flour using spectral imaging. Talanta. 2016. Vol. 155. P. 347–357.*
19. *Жигунов Д. О., Ковальова В. П., Мороз А. І. Визначення показників якості борошна з різних систем технологічного процесу при сортовому помелі пшениці. Зернові продукти і комбікорми. 2017. Vol.17. І. 4. С. 30–36. https://doi.org/10.15673/gpmf.v17i4.763*
20. *Руденко В. М. Математична статистика. Київ: Центр учбової літератури. 2012. 304 с.*

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