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The effect of exposing wheat and rye grains to infrared radiation on the falling number and moisture content in the flour

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Summary. The work presents the results of research on the effect of processing wheat and rye grains with infrared radiation on the falling number in flour. The research material was provided by wheat of "Waluta" variety and rye of "Dańkowskie Diament" variety. The grain was moisturized to 14, 16 and 18% and exposed to infrared radiation for the period of 0, 30, 60, 90 and 120 s at the temperature of 150°C. Next, the samples were milled and the falling number in the obtained flour was determined. On the basis of study results it was recorded that heating the grain with infrared radiation prior to milling resulted in a significant increase in the value of the falling number, as well as in lower moisture of the flour.

Key words: wheat, rye, falling number, infrared radiation.

INTRODUCTION

Falling number is one of indicators determining the bread making quality of flour. This value is expressed in seconds which are equivalent to the mixing time and the time needed by a viscosimetric stirrer to reach the bottom in hot starch pap. The value of the falling number is affected by the amylolytic activity of flour. Alpha- and beta-amylase occurring in flour are enzymes which break the starch down. Their excessive activity leads to decomposition of starch into simple sugars, which deteriorates the bread making quality of flour [17].

The main reason for high amylase activity, and for low value of the falling number, is pre-harvest germination within the grain head. This happens in a situation when unfavorable weather conditions delay the harvest. High temperature and moisture in the air activate alpha- and beta-amylase, as well as proteases, which leads to degrading proteins and starch [16]. Frequently, grain which was originally meant for consumption has to be qualified for feed manufacturing. This is an unfavorable phenomenon, particularly in the face of worldwide food problems (according to FAO, in 2010 there were 925 m people suffering malnutrition) [6]. The factors which affect the falling number include:

- altitude – the falling number increases as elevation increases,
- nitrogen fertilization rate – the falling number increases or decreases,
- late maturity of alpha-amylase – the falling number decreases,
- fungicide treatment – the falling number declines,
- fusarium infection – minor decrease in the falling number [8].

One of the methods used to process plant materials, such as cereal grain, legume seeds and cocoa seeds are heating them with infrared radiation. This enables us to develop desired qualitative features in the product. Using this method for processing cereal grains affects, among others, modifying physical properties in the products of milling, and also energy consumption of milling or granulometric composition [3, 4, 5, 7, 18]. Therefore, some attempts have been made to improve the quality of cereal through exposing it to infrared radiation [14, 15].

PURPOSE AND METHODS

The aim of the study was to determine the relationship between the time of exposing wheat and rye grains of different moisture to infrared radiation and the activity of amylases present in the flour produced from those grains, as well as flour moisture.

The material studied was the grain of spring wheat of "Waluta" variety and of winter wheat of "Dańkowskie Diament" variety. Before starting the analyses the moisture of the grain was determined (according to PN-86/A-74011 norm), which was ca. 12%. Then the samples were moisturized up to 14, 16 and 18% [10].

After moisturizing and mixing the grain, the sample was stored in a tightly closed container placed in a cooling chamber at the temperature of ca. 4°C. In order to obtain equal required moisture in the whole volume the sample was shaken several times each day. An hour prior to measurement, the sample was taken out of the cooling chamber to make its temperature uniform with that of the environment.

The grain prepared in this way was next exposed to infrared radiation in a laboratory device for IR processing of grainy plant materials [1, 2]. After reaching the temperature of 150°C, the grain was supplied in a single layer onto the conveyor belt moving below the radiators. The speed of conveyor belt's movement was adjusted in such a way that the grain should stay within the radiation area for the time of 30, 60, 90 and 120 s. Then the grain was ground with the help of Brabender Junior laboratory mill.

After completing the milling process, the moisture of the obtained flour was determined according to PN-86/A-74011 [10] and the falling number was calculated following PN-ISO 3039 [13].

RESULTS

Figures 1 and 2 present how the time of exposing cereal grains to infrared radiation affects the value of the falling number of flour obtained from that cereal.

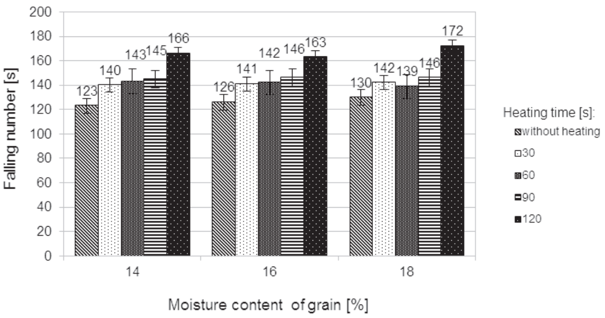

Fig. 1. Falling number of rye flour, depending on the time of heating the grain

The data presented in Figure 1 reveal that the lowest value of the falling number was recorded for rye flour obtained from the grain which had not been exposed to thermal processing. Depending on the moisture of the grain, the falling number for this flour ranged between 123 and 130 s,

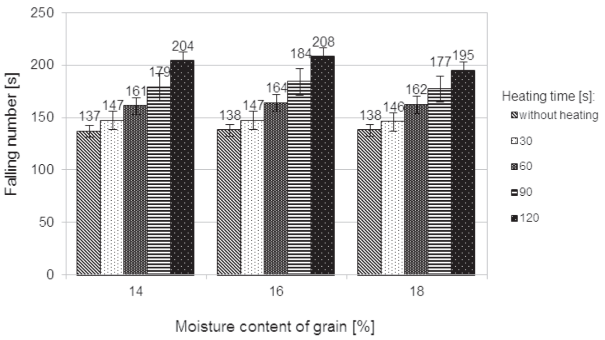

Fig. 2. Falling number of wheat flour, depending on the time of heating the grain

which suggests average activity of alpha-amylase and, at the same time, its low bread making utility. Heating the grain, irrespective of its initial moisture, clearly resulted in a higher value of the falling number. The highest increase in this value was observed when the grain had been heated for 120 s. This resulted in the falling number reaching the level of 163-172 s.

Wheat flour obtained from the grain which had not been thermally processed was characterized by the falling number at the level of 137 to 138 s, depending on the initial moisture, which, according to PN-A-74022:2003 [11], makes it useless as a material for making bread. Using infrared radiation led to increasing the value of the falling number. It was observed that each time prolonging the heating time by 30 s within the range of 30 to 120 s clearly contributed to increasing the value of the falling number, irrespective of the initial moisture of the grain. Maximum values of the analyzed parameter were noted after heating the grain for 120 s and they ranged from 195 to 208 s, depending on the initial moisture of the grain.

The changes observed in the falling number of flour suggest a clearly lower activity of the amylases present in that flour, which is directly reflected in bread making quality of the flour. The obtained values will qualify flour for making bread [11].

Figures 3 and 4 present the effect of the time of heating cereal grains with IR on the content of moisture in the flour produced from those cereals.

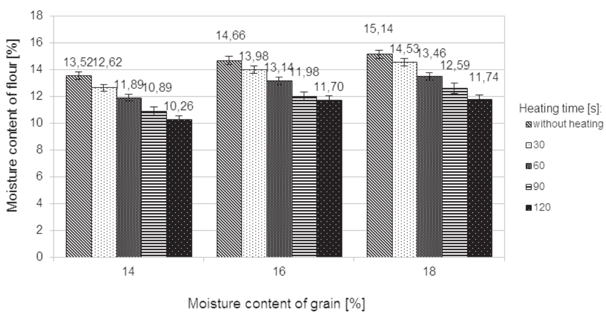

Fig. 3. Moisture content of rye flour, depending on the time of heating the grain

The moisture of flour obtained from rye which had not been thermally processed ranged from 13.52 to 15.14%. In each of the analyzed variants the moisture of the flour was lower than the moisture of the grain. This resulted from partial evaporation of water during and immediately following milling. Prolonging the time of exposing the grain to heating resulted in decreased flour moisture. Heating the grain for 120 s let us reduce the moisture of the flour to the level of 10.26% for the grain of initial moisture amounting to 14%, and to 11.74% for the grain of initial moisture of 18%. According to the Polish Norm for rye flour [12], the required moisture must not exceed 15%. In our analyses this value was exceeded only in the flour obtained from the grain of initial moisture of 18% which had not been subject to heating. The product of milling reached the value of moisture equal to 15.14%.

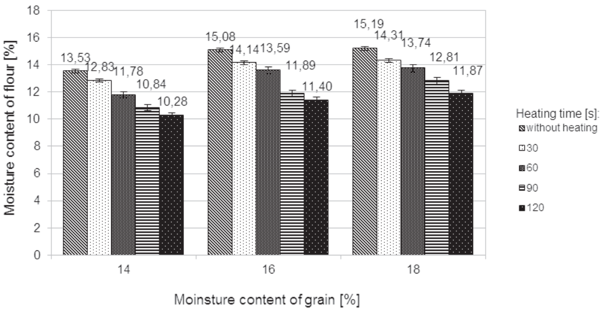

Fig. 4. Moisture content of wheat flour, depending on the time of heating the grain

The moisture of wheat flour obtained from grain which had not been thermally processed ranged from 13.53 to 15.19%. Irrespective of the initial moisture of the grain, prolonging the time of exposing the grain to heating resulted in decreased moisture of flour. With the longest variant of processing the grain for 120 s, the moisture of the flour was noted at the level of 10.28% to 11.87%. Considering the Polish Norm, the requirements regarding acceptable moisture were not met by the flour obtained from the grain with the moisture of 16% and 18% which had not been subject to heating, since the values exceeded the level of 15%.

STATISTICAL ANALYSIS

The experiment was performed in the system of three-factor cross-classification. The experimental factors considered were two varieties of grain, three levels of moisture (14%, 16%, 18%) and four processing periods (30 s, 60 s, 90 s and 120 s). The experiment also involved control groups (unprocessed) created by the grain of two varieties with three analyzed moisture levels. As the model for the experiment, the following linear model was adopted:

$$y_{ijkl} = \mu + \alpha_j + \beta_k + \gamma_l + \alpha\beta_{jk} + \alpha_{\gamma jl} + \beta_{\gamma k_l} + \alpha\beta\gamma_{jk_l} + e_{ijkl},$$

where:

y_{ijkl} – moisture of flour (or the falling number) of *j-this* grain variety with *k-this* moisture undergoing *l-this* processing time,

μ – mean moisture of flour,

a_j – effect of *j-this* grain variety,

b_k – effect of *k-this* grain moisture,

g_l – effect of *l-this* processing time,

ab_{jk} – effect of interaction of *j-this* grain variety with *k-this* grain moisture,

$a\,g_{jl}$ – effect of interaction between *j-this* grain variety and *l-this* processing time,

$b\,g_{kl}$ – effect of interaction between *k-this* grain variety and *l-this* processing time,

e_{ijkl} – experimental error.

For the needs of the adopted experimental model, we verified hypotheses regarding the significance of the particular components of the model. To verify those hypotheses, we used multivariate analysis of variance because we were analyzing two features of grain which were correlated (r_S=-0.68). Wilk's and F Snedecore's tests were applied as test functions. The results of the calculations are presented in the table below.

None of the zero hypotheses assuming the lack of significance of the considered effects of the model was rejected (p = 0.000), so it was concluded at the significance level of 0.01 that both grain variety and grain moisture, as well as processing time, result in a significant variation of at least one of the examined properties: grain moisture or the falling number.

In order to verify which of the analyzed agents significantly diversifies the values of these properties, one-dimensional tests of variance analysis were performed (Table 2).

Table 1. Multivariate analysis of variance for the analyzed flour properties

Effect	Test	Value	F	Effect df	Error df	p
Free term	Wilksa	0,000	524765,590	2,000	29	0,000
Species	Wilksa	0,016	865,707	2,000	29	0,000
Moisture content	Wilksa	0,016	101,019	4,000	58	0,000
Heating time	Wilksa	0,000	326,771	8,000	58	0,000
Species*Moisture content	Wilksa	0,522	5,577	4,000	58	0,001
Species*Heating time	Wilksa	0,042	28,200	8,000	58	0,000
Moisture content*Heating time	Wilksa	0,414	2,007	16,000	58	0,028
Species*Moisture content*Heating time	Wilksa	0,274	3,302	16,000	58	0,000

Table 2. One-dimensional tests of significance for flour moisture and falling number

Effect	Moisture content F	Moisture content p	Falling number F	Falling number p
Free term	551241,8	0,000	369072,2	0,000
Species	4,7	0,038	1715,9	0,000
Moisture content	873,8	0,000	1,2	0,329
Heating time	1216,1	0,000	1229,7	0,000
Species*Moisture content	1,1	0,359	11,6	0,000
Species*Heating time	2,1	0,110	142,7	0,000
Moisture content*Heating time	3,4	0,007	1,2	0,340
Species*Moisture content*Heating time	3,4	0,006	3,9	0,003

The tests did not reveal any interaction between the variety of the grain and its moisture, or between the variety and heating time that would be significant for flour moisture. At the significance level of 0.01 it may be claimed that flour moisture for both varieties changed similarly along with changed grain moisture, as well as along with changed processing time (Table 2).

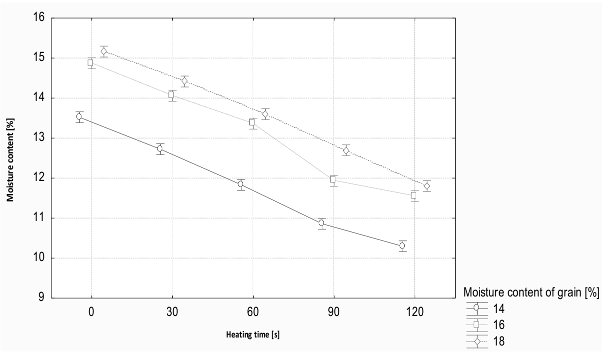

Fig. 5. Changes in the value of mean flour moisture for grain at the analyzed moisture levels, depending on heating time

As far as the falling number is concerned, the analyzed levels of grain moisture and the interaction between grain moisture and heating time turned out to be insignificant. At the significance level of 0.01, it may be claimed that the analyzed levels of grain moisture do not result in any significant variation of the falling number. Additionally, it may be assumed that the falling number in the flour of particular initial level of grain moisture changed in the same way along with the change in processing time (Fig. 6).

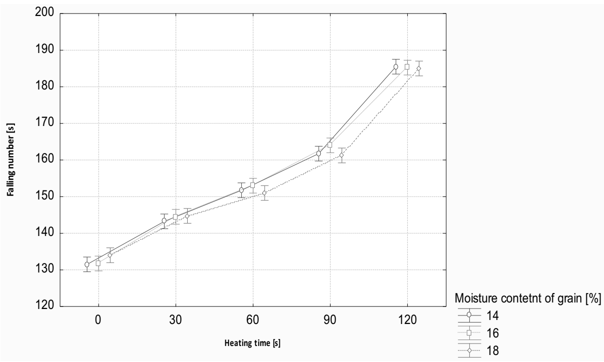

Fig. 6. Changes in the value of the falling number for grain at the analyzed moisture levels, depending on heating time

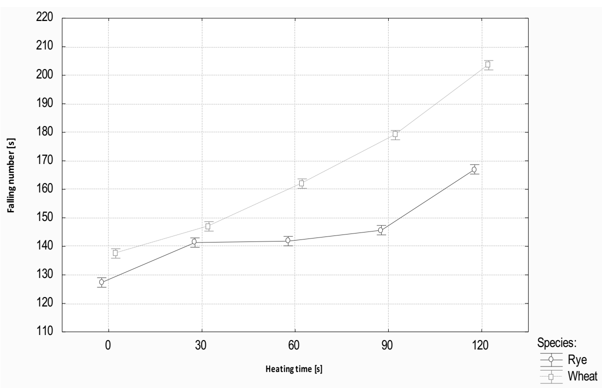

Fig. 7. Changes in the value of the falling number for wheat and rye, depending on heating time

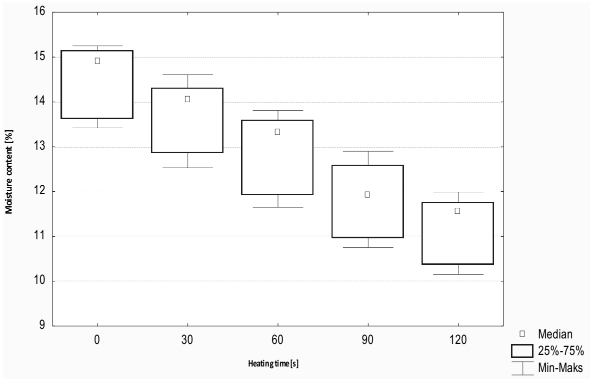

Fig. 8. Box plot diagrams for flour moisture, depending on heating time

Flour moisture decreased along with prolonged heating time and the character of changes in moisture was similar to linear (Fig. 8).

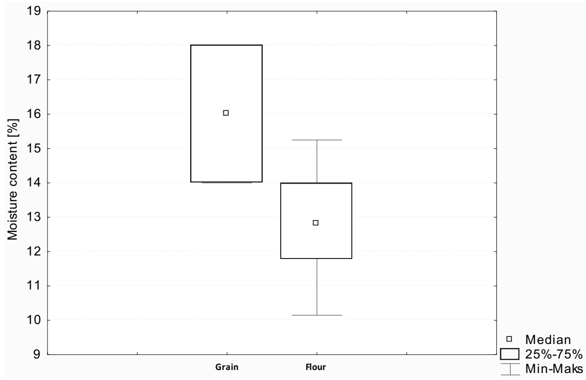

Fig. 9. Flour moisture and initial grain moisture

Half of the analyzed grain samples with the moisture of 14% to 18% were characterized by flour moisture at the level of 12% to 14% (Fig. 9). The numbers in individual sub-classes amounting to n=2 were too low to determine if the assumptions for the variance analyses, i.e. normality of distribution and homogeneity of variances for studied properties had been fulfilled. The F Test is highly resistant to deviations from normality [9].

Table 3. Contrast evaluations

Contrast	Evaluation	Statistical error	t	p	-95% Confidence Interval	+95% Confidence Interval
Moisture content	8,363	0,173	48,342	0,000	8,010	8,717
Falling number	-114,000	2,555	-44,619	0,000	-119,218	-108,782

Irrespective of variance analysis tests, we performed a planned comparison of mean moisture and the falling number in flour from the grain that had not been subject to processing with the mean value of these properties in flour from the grain heated for 30, 60, 90 and 120 s.

In order to do this, we analyzed significance for the following contrast: $4 \cdot \mu_0 - \mu_{30} - \mu_{60} - \mu_{90} - \mu_{120}$, where μ_t are mean values of a property for respective heating periods (t=0; 30;

60; 90; 120). The value of this comparison for flour moisture was significant (p=0.000) and it amounted to 8.36% (2.9% on the average). Also, the difference between the value of the falling number in unprocessed grain and the falling number in heated grain was statistically significant (p = 0.000) and it was -114 (-28.5 on the average). The mean value of the falling number was statistically lower for the flour from unprocessed grain, as compared with the falling number in the flour from heated grain.

On the basis of the contrast analysis it may be claimed that the process of grain heating results in a statistically significant reduction in flour moisture, while it causes a statistically significant increase in the falling number (Table 3).

CONCLUSIONS

The following conclusions were drawn on the basis of the studies discussed above:

1. Heating wheat and rye grains with infrared radiation leads to a statistically significant increase in the falling number of flour.
2. Both with wheat and rye grains, a statistically significant decrease is observed in the moisture of the flour obtained from heated grain.
3. The initial moisture of grain does not affect the value of the falling number in the analyzed cereals.
4. Heating grain with infrared radiation may be an effective method of increasing the value of the falling number and, consequently, the bread making quality of flour.

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WPŁYW OGRZEWANIA ZIARNA PSZENICY I ŻYTA PROMIENIAMI PODCZERWONYMI NA LICZBĘ OPADANIA I WILGOTNOŚĆ MĄKI

Streszczenie. W pracy przedstawiono wyniki badań wpływu obróbki promieniami podczerwonymi ziarna żyta i pszenicy na liczbę opadania uzyskanej następnie mąki. Materiałem badawczym była pszenica odmiany Waluta oraz żyto odmiany Dańkowskie Diament. Ziarno dowilżono do 14, 16 i 18% i poddano obróbce promieniami podczerwonymi przez okres 0, 30, 60, 90 i 120 s w temperaturze 150°C. Następnie dokonano przemiału próbek i oznaczono liczbę opadania uzyskanej mąki. Na podstawie wyników badań stwierdzono, że ogrzewanie ziarna promieniami podczerwonymi przed przemiałem powoduje istotny wzrost wartości liczby opadania oraz spadek wilgotności mąki.
Słowa kluczowe: pszenica, żyto, liczba opadania, obróbka promieniami podczerwonymi.