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Influence of wheat N-fertilization and grain moistening on the physical properties of wet gluten

A. Miś and S. Grundas*

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, P.O. Box 201, 20-290 Lublin 27, Poland

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A b s t r a c t. The influence of wheat N-fertilization and grain moistening on some chosen physical properties of wet gluten have been studied by means of the Glutomatic System. The study material were grain samples of four Polish wheat cultivars (*Triticum aestivum* L.) grown at two N-fertilization levels (50 and 150 kg N ha^{-1}). Grain samples for moistening were placed for 6 h between the layers of blotting paper imbibed with distillate water. Then, glutomatic determinations such as quantity and moisture content of wet gluten, gluten index (GI) and thickness of a dry gluten cake were carried out on the grain samples dried at room temperature and on the non-moistened grain.

Increasing fertilization levels resulted in a significant decrease of GI and thickness of the dry gluten cake as well as lower losses in the moisture level as measured by centrifuging wet gluten. Application of a moistening treatment improved gluten quality which was reflected in a significant increase in GI and thickness of the gluten cake. It was also observed in the lower shares of the non-bound water in the freshly washed out gluten. Moreover, a strong relation of the GI value and moisture content in the wet gluten was found.

K e y w o r d s: wheat, grain moistening, wet gluten, gluten index, glutomatic system

INTRODUCTION

Gluten is a major part of wheat grain protein which is most important for breadmaking. However, its properties are influenced by various factors observed both during plant growth and grain processing [7,8,12]. A comprehensive recognition of these factors should allow to create gluten characteristics crucial for the production of acceptable end products.

One of issues relating to the above problem is research on the effects of an increasing nitrogen fertilization of wheat plants on the wet gluten strength. It is known that the higher N-fertilization, the higher gluten content. However, we may ask whether gluten strength changes as well, and if so, to what extent? Literature on this subject is not available.

Another interesting problem is the effect of grain moistening on wet gluten quality. This treatment, commonly used before wheat milling and known as conditioning (or tempering), is very advantageous for millers as it increases total flour yield [1]. It is that such moistening processes cause deep, physical changes in the grain endosperm mostly in a form of fine cracks. They result in slackening and weakening of grain structure [3,6,11]. However, there are not results on the possible influence of grain moistening on the physical properties of wet gluten.

Therefore, the objective of the present studies was to provide answers to the above questions. Standard procedures [4], and the procedures proposed by Miś [5] and the present authors for testing wet gluten quality by the Glutomatic System were applied.

MATERIALS AND METHODS

The studied material were samples of wheat grain (*Triticum aestivum* L.) harvested in 1995 from the experimental plots of the Institute of Agrophysics, Lublin. The samples included 4 Polish cultivars of winter (Almari and Begra) and spring wheat (Omega and Sigma), grown at two levels of N-fertilization (50 and 150 kg N ha^{-1}).

Grain of each sample was separated into two parts. One part was control material (non-moistened). The other part was subjected to moistening by placing one layer of kernels between thick layers of blotting paper fully imbibed with distillate water. Moistening time was constant for all the

*Corresponding author e-mail: mis@demeter.ipan.lublin.pl

grain samples and was equal to 6 h. The length of this period was chosen on the basis of previous studies [9,10], which indicated that already after 12 h of moistening there are biochemical changes in the form of an increase in the α-amylase activity.

After moistening, excess water was removed from kernels by means of dry blotting paper. Then, grain samples were dried at room temperature to obtain same moisture level as before moistening (11±0.5%). The dried samples and the control material were ground on a Lab Mill 3100, Perten Instruments AB, Huddinge, Sweden.

Specimens of whole wheat meals with constant dry matter equivalent to 10 g of meals at 14% moisture content were collected for washing out gluten. The processes of washing, centrifugation and drying of wet gluten were conducted using, respectively, a Glutomatic 2200, a Centrifuge 2015 and a Glutork 2020. All these testing devices were produced by Perten Instruments AB, Huddinge, Sweden.

Determinations of the wet gluten content and the gluten index (GI) were made according to the ICC Standard No. 155 [4]. One modification from previous studies [5] was introduced to the procedure of gluten index determination. Constant weighed amounts of the wet gluten equal to 2 ± 0.1g were used for centrifugation. This procedure eliminates effects of the variable centrifugal force on the gluten ball and makes the GI determination more objective

Moisture content of the wet gluten was calculated on the basis of weight difference in the freshly washed out gluten and gluten after drying at 150°C for 4 min (Glutork 2020). The weight of a dry gluten cake was assumed as the weight of its dry matter. Loss in the moisture content of wet gluten by centrifugation was determined by measuring the weight difference between gluten before and after centrifugation. Additionally, thickness of the dry gluten cake formed in the Glutork 2020 was measured with the accuracy of 0.01 mm by a digital slide caliper VIS, model MAUaE 150.

Measurements of all the parameters were made in two parallel cycles and in 3 repetitions. For higher reliability of statistical results, grain moistening was made in 3 repetitions, i.e., measurements of all the parameters of moistened grain were made in 9 repetitions.

The data obtained were statistically analysed using variance analysis for three factors, i.e., wheat cultivar, N-fertilization level and moistening treatment. There were calculated the 95% confidential half-intervals for mean values and coefficients of determination (r^2) for simple regression models describing relations between a few parameters determined.

RESULTS AND DISCUSSION

Wet gluten content

As shown in Fig.1A, the wet gluten content in wheat grain depended first of all on the level of nitrogen in the plant growth medium and on the genotype of wheat cultivar. An increase in N-fertilization from 50 to 150 kg N ha^{-1} caused an increase in the wet gluten content by 4% on the average. All the studied cultivars responded to higher fertilization level with similar intensity. When compared to the fertilization, cultivar influenced differentiation in the wet gluten content slightly less. The mean content of wet gluten in the studied wheat cultivars ranged from 24% (Omega) to 27% (Almari). The applied moistening treatment of wheat grain did not have any significant influence on the quantity of gluten washed out. Only a tendency towards an inverse effect of this treatment on winter (cv. Almari) and spring wheat (cv. Omega) was observed.

Gluten index

Changes in the strength of wet gluten expressed by the gluten index (Fig. 1B) were influenced mainly by the cultivar. The mean values of the GI for the wheat cultivars

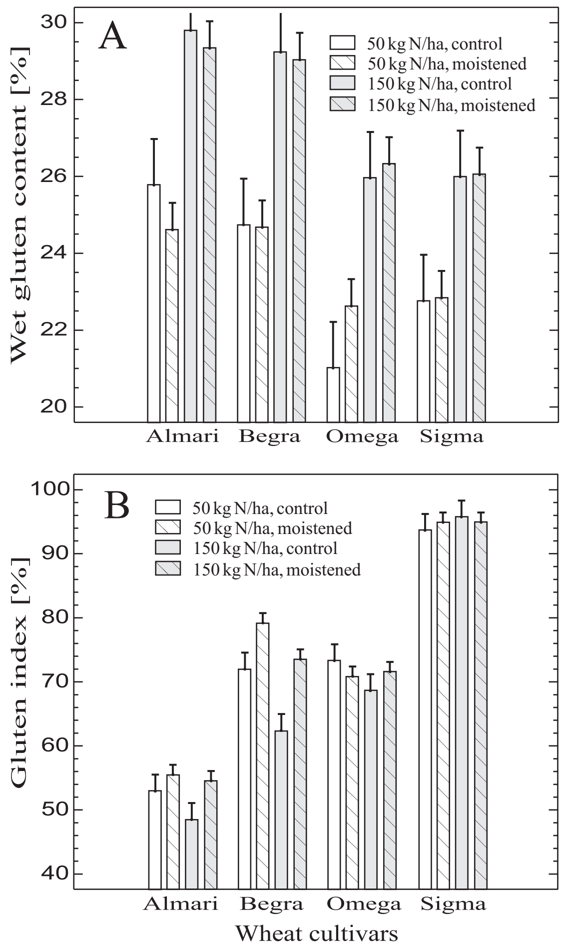

Fig. 1. Changes in the wet gluten content (A) and gluten index (B) of the studied cultivars in relation to N-fertilization and moistening.

ranged from 53% (Almari) to 95% (Sigma). Such a wide cultivar differentiation can indicate a very strong association of this gluten feature and a genotype of the wheat cultivar. Two other factors, i.e., nitrogen fertilization and moistening treatment influenced gluten index far weaker. An increased N-fertilization caused a significant decrease in the GI, 3 % on the average. It meant worsening of gluten quality. In contrast, grain moistening improved gluten quality. Gluten from the moistened grain, as compared to the non-moistened grain, was characterized by higher GI, by 4% on the average. Cv. Begra was particularly susceptible to these changes. Moreover, a distinctly stronger effect of moiste- ning on the improvement of wet gluten quality took place at higher fertilization levels (150 kg N ha^{-1}). In this case, the treatment resulted in a GI higher than 10%. Wet gluten of spring wheat cultivars were not liable to significant changes as a result of the increased N-fertilization and moistening. It shows that wet gluten with higher strength (e.g., cv. Sigma) is additionally more resistant to the modifying activity of plant growth and grain processing.

Moisture content and its loss by wet gluten centrifugation

During washing out, the gluten absorbs and stores different quantities of water which can also affect its strength. Mean moisture content of wet gluten before centrifugation (Fig. 2A) ranged from 66.9% (Sigma) to 70.3% (Almari). This range of among cultivars (3.4%) became more than twice narrower (1.5%) after centrifugation of wet gluten. It was as a consequence of different losses in the wet gluten moisture by centrifuging (Fig. 2B). Mean losses in the moisture content ranged from 0.5% (Sigma) up to 2.4% (Almari). The above results prove that the cultivars with stronger gluten, i.e., higher GI (Sigma), are also characterized by the lower moisture content of wet gluten and lower moisture losses by centrifuging. Moistening treatment resulted in a decrease in the moisture content of wet gluten by 0.8% on the average, and in the loss of moisture by centrifuging by 0.6% on the average. However, moisture content did not depend on the level of N-fertilization. An increases in N-fertilization influenced losses in the moisture content during centrifugation only by 0.4% on the average.

Thickness of dry gluten cake

Physical properties of wet gluten can also be examined by high temperature which is an essential factor inseparably associated with bread baking. In this kind of test, thickness of a dry gluten cake was determined as a quality parameter characterising the response of wet gluten to the high temperature (150°C) and at the same time, to the pressure exerted by steaming water (Fig. 3). Among the studied cultivars, Begra was distinguished by the thickest cake (1.51 mm).

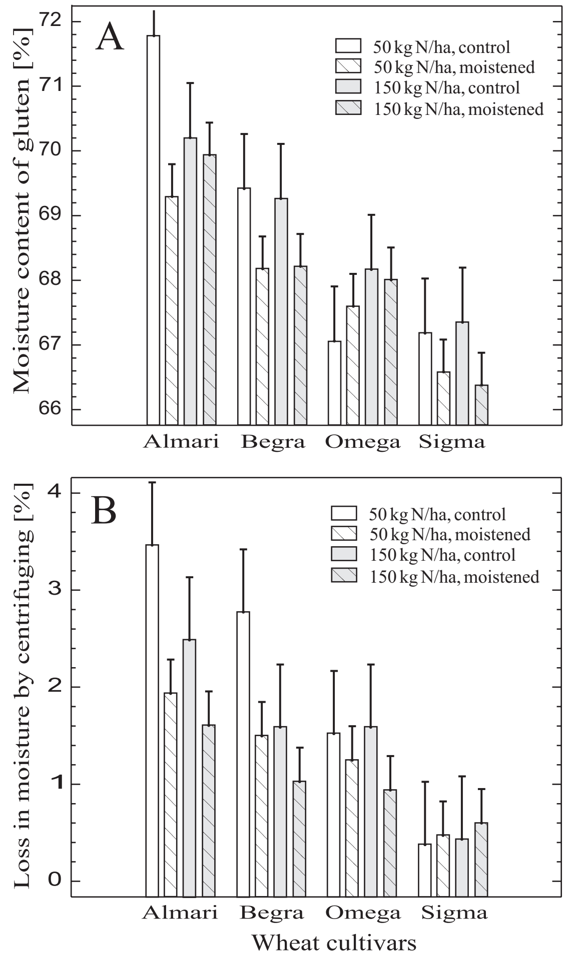

Fig. 2. Changes in the moisture content (A) and its loss in wet gluten centrifuging (B) for the studied cultivars in relation to N-fertilization and moistening.

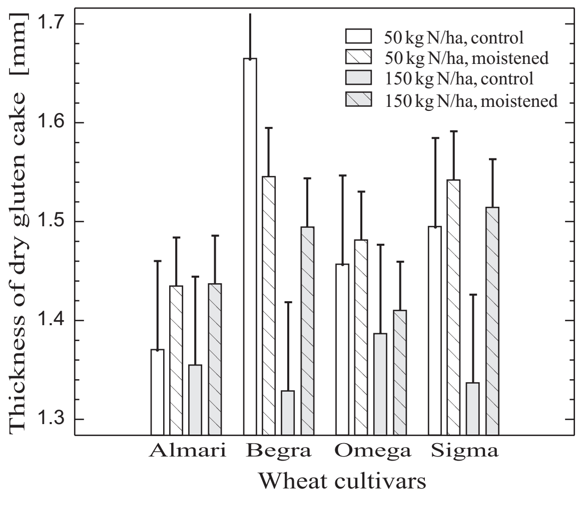

Fig. 3. Changes in the thickness of the dry gluten cake of the studied cultivars in relation to N-fertilization and moistening.

The ranking of other cultivars showed that the higher the gluten index of the cultivar, the thicker its dry gluten cake. An increased N-fertilization clearly contributed to the decrease in cake thickness. A particularly distinct effect of fertilization was observed for wheat cultivars with strong (Begra and Omega) and very strong wet gluten (Sigma). In contrast to the fertilization effect, grain moistening caused a significant increase in the thickness of the dry gluten cake. The highest increased in the thickness (up to 0.18 mm) as a result of this treatment was observed for cv. Sigma and Begra grown at the higher fertilization level (150 kg N ha^{-1}).

Importance of the moisture for the wet gluten strength

To characterize the role of moisture in the formation of wet gluten strength, the relationship between the gluten index and the moisture content of the wet gluten as well as the relation between moisture losses by centrifugation and the initial content in the wet gluten were plotted on the graphs (Figs 4 and 5).

As may be seen in Fig. 4, values of the gluten index decreased as the moisture content in wet gluten increased. In other words, the strength of wet gluten was lower when the gluten stored higher quantities of moisture. The observed, negative correlation between these features clearly indicates a weakening effect of moisture on wet gluten strength. In Fig. 5, we can see that losses in the moisture by centrifuging were proportional to the moisture content of the wet gluten before centrifugation. This relation shows that the higher the moisture content in wet gluten, the higher the loss in the moisture by the centrifugation.

Explanation of the relations described above can be associated with the presence of some moisture strongly absorbed by the gluten protein and non-bound water in the wet gluten material. This latter kind of moisture was described in detail by Freeman *et al.* [2], who studied the structure of wet gluten which was washed out by the same Glutomatic technique with a light microscope. Pools of water with single starch granules were found in the reticulate material of wet gluten.

It is obvious that the non-bound water stored in the pools can be easily removed from gluten by centrifugation. Therefore, measurements of losses in the moisture content by centrifuging wet gluten can be assumed as an objective quantitative measure of this kind of water.

As shown in Fig. 2B, the quantity of non-bound water (loss in moisture content) was related to wheat cultivar, moistening treatment and the fertilization level. The cultivars with stronger gluten (higher GI) stored less non-bound water (lower loss). Also grain moistening made the amount of non-bound water within gluten material lower. An increase in N-fertilization that did not cause any changes in the moisture content, resulted in a decrease in the share of its non-bound form. Nevertheless, the strength (GI) of such gluten was lower. It can indicate that the fertilization affects also different properties of wet gluten, e.g., changes in protein composition reported by Wooding *et al.* [8] and Wrigley and Bekes [12].

The above facts clearly indicate a considerable effect of moisture, especially in the form of non-bound water, on the formation of strength properties responsible for the wet gluten behaviour at the course of centrifugation. Moisture slackens gluten material and as a medium with very low stickiness can make wet gluten passing through the sieve holes much easier. In this way, moisture can influence a decrease of the gluten index value together with an increase in its content in wet gluten.

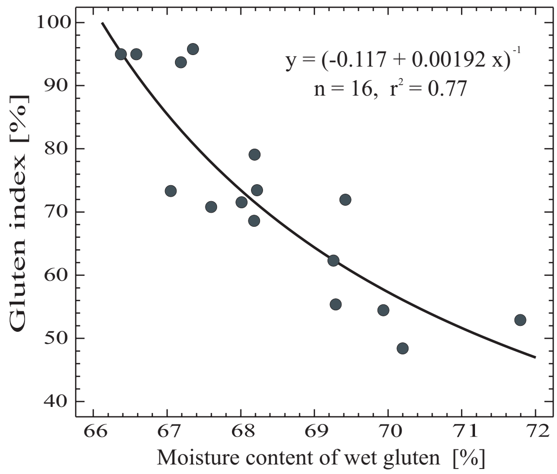

Fig. 4. Relation between moisture content of wet gluten and gluten index.

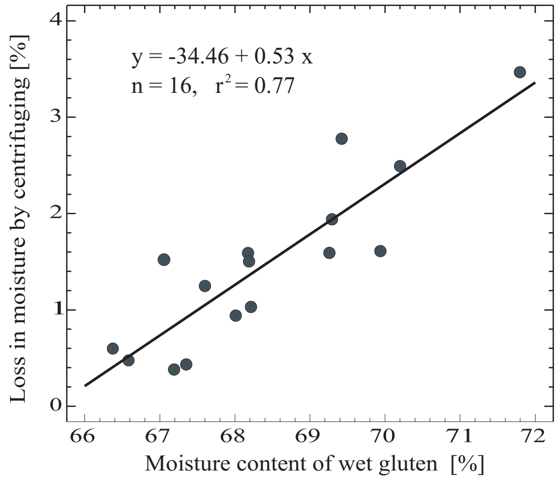

Fig. 5. Relation between moisture content and its loss by centrifuging.

CONCLUSIONS

Application of the Glutomatic System for the evaluation of physical changes in wet gluten as a result of an increased N-fertilization of wheat plants and by grain moistening allowed to draw the following conclusions.

1. Most of the tested features of wet gluten are mainly determined by the genotype of wheat cultivar. It differentiates gluten index which seems to be the most important parameter for the qualitative evaluation of wet gluten.

2. Other studied factors influence properties of wet gluten much less. An increase in N-fertilization, rising in the gluten content of wheat grain, cause a distinct worsening of its quality. It results in the lower values of gluten index and thinner cakes of dry gluten.

3. Grain moistening exerted favourable influence on the changes in wet gluten properties. It decreased moisture content by decreasing the share of the non-bound water which is lost during centrifugation without decreasing the quantity of wet gluten. However, the most favourable effect of grain moistening is improvement in the wet gluten strength. It increases, first of all, gluten index and the thickness of the dry gluten cake.

4. The present studies clearly indicate great importance of wet gluten moisture for gluten strength forming characteristics. Gluten index distinctly decreases as the moisture content of wet gluten increases.

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