Int. Agrophysics, 2003, 17, 71–75

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Influence of the storage of wheat flour on the physical properties of gluten

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Received November 12, 2002; accepted January 28, 2003

A b s t r a c t. The influence of the length of time wheat flour is stored on the quantity of washed out gluten and on its water absorption and rheological properties was determined. Wheat flour, with an 11.5 % moisture content, was kept at a temperature 22.5°C for 32 weeks. The changes in the sorption properties were tested by means of a Glutomatic 2200 apparatus, to determine the content of water absorbed and non-absorbed in gluten freshly washed out, and the changes in rheological properties on the basis of the value of the gluten index (IG).

The lengthening of the flour storage period caused a gradual diminution of the quantity of the washed out gluten as well as an increase in the GI value. Depending on the wheat cultivar, sorption properties underwent profitable or unfavourable changes as a result of flour storage. For cv. Roma with low IG, a decrease was noted in the content of water non-absorbed in gluten, meanwhile the content of water absorbed remained at the same level for the whole storage period. For cv. Igna with high IG, a decrease was observed in the absorbed water content and an increase in retention of non-absorbed water, indicating a worsening of the sorption properties of gluten.

K e y w o r d s: wheat flour, storage, wet gluten, water absorption, Glutomatic

INTRODUCTION

The baking qualities of wheat flour are altered to a considerable extent by the conditions and duration of its storage. In optimum storage conditions, the baking properties of flour improve. The water absorption of flour increases, the rheological properties of dough improve and its ability to retain gas and give volume to the bread increases [15].

These profitable changes take place mainly owing to the oxidation of the gluten proteins that are a very important component of wheat flour. In the course of flour storage, a gradual decrease is observed in the content of the sulphydryl groups (-SH) as a result of the formation of disulfide bonds (-S - S-) between the polypeptide chains of gluten proteins [2,17]. This leads to an increase in the polymerisation degree of these proteins as the flour storage period lengthens [16]. These processes speed up considerably, and their effect strengthens when the flour is kept in a raised temperature [1,13,14]. Similar effects are achievable more quickly with flour to be stored for lengthy periods, by the addition of oxidative substances, e.g., ascorbic acid, to the freshly milled flour [5].

The oxidation processes which take place in stored flour also affect the physical properties of the gluten washed out from it. The investigations of Srivastava and Haridas [13] showed a considerable decrease in the quantity of gluten as a result of the lengthening of the storage time. However, this needs studying to characterise both the quantitative and qualitative changes to which gluten is subjected during the storage of wheat flour. In particularly one needs to know the influence of storage time on the sorption and rheological properties of gluten, which affect directly the quality of dough and bread.

The sorption properties of gluten are mostly estimated in an indirect way by determining the water absorption of flour. However, this measurement does not show clearly, which, from the components present in flour (e.g., the starch or gluten), is responsible for the resulting changes in the sorption properties of flour. Such possibilities are given by way of determining the quantity of water absorbed by gluten in the course of its washing out [8]. A standard and fully automated procedure of washing out is used for that aim [4] and always protects the equal conditions of this process; the differences in the quantity of absorbed water by the gluten

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depend exclusively on its sorption properties. Accordingly to the proposed way, the water content in the gluten is measured twice, first after washing it out, and then after centrifugation. On this basis, the content in freshly washed out gluten of non-absorbed water, that lost owing to centrifugation, as also the content of absorbed water, which remains in the gluten after centrifuging are determined .

The usefulness of the sorption indices defined in this way was confirmed by the results of the studies so far [7–10]. They have indicated that the non-absorbed water content is a gluten feature especially determined by the genotype of the wheat cultivar. This feature is changed both during grain maturation and in the pre-harvest period and also results from the technological treatments used, such as: drying the grain, or moistening it before milling. Simultaneously, the content of water non-absorbed in the gluten affects its rheological properties unfavourably.

The main aim of the present undertaking was to determine the changes in the quantity of washed out gluten and the changes in its qualitative features, such as: the content of water absorbed and non-absorbed and the gluten index, during the 8 monthly storing of wheat flour. The characteristics of these changes are the subject of this paper.

MATERIALS AND METHOD

In the investigations, two Polish cultivars of winter (cv. Roma) and spring (cv. Igna) wheat characterised, respectively as weak and strong gluten were used. Grain samples with stabilized moisture (11.5 ± 0.5% w.b.) were milled in a laboratory mill (Lab Mill 3100, Perten Instruments AB). The wheat meal thus obtained was placed in hermetic containers, and kept for the whole storage period at a constant room temperature (22.5 ± 0.5°C).

Samples of meal for analysis were taken at fortnightly intervals up to the 12th week inclusively, as well as additionally after 18 and 32 weeks of storage. While collecting the meal samples, the contents of the containers were stirred to aerate them. This is essential to maintain oxidation in the course of storage.

The washing out of the gluten from the whole wheat meal and the determination of the gluten index (IG) were conducted according to standard ICC No 155 [4], using Glutomatic 2200 apparatus (Perten Instruments AB). Having determined the gluten index, a constant weighed amount (2.1 ± 0.05 g) of freshly washed out gluten was applied during centrifugation. In this way, the differences in the centrifugal force forcing the gluten sample through the openings in the test sieve were avoided [6].

As a result of centrifugation, water is removed from the freshly washed out gluten, which here was named 'non-absorbed' water. Thus the centrifuged gluten, usually named 'wet' gluten, contains water, which was here named 'absorbed' water. Dry gluten, not containing water, was received by drying the centrifuged gluten. Quantities of wet and dry gluten were reported on a 14% grain moisture basis.

The non-absorbed water content in gluten freshly washed out was determined on the basis of the loss in weight of this gluten by the 1 min centrifugation (~2000 x *g*), applying centrifuge 2015. The absorbed water content in gluten freshly washed out was determined on the basis of a loss in weight of the centrifuged gluten by drying (150°C for 4 min) in a 'Glutork 2020' dryer.

All measurements were conducted in 4 repetitions. Within statistical analysis of the data, 95% confidence intervals for means (LSD) were calculated.

RESULTS

Changes in the quantity of wet and dry gluten

Lengthening the storage of wheat flour gradually influences the decreasing quantity of gluten washed out from it (Fig.1a and b). The quantity of wet gluten fell from 22.6 to 19.5% for cv. Roma and from 25.4 to 15.1% for cv. Igna, whereas the quantity of dry gluten ranged in intervals from 7.7 to 7.0% and from 8.5 to 5.7%, respectively.

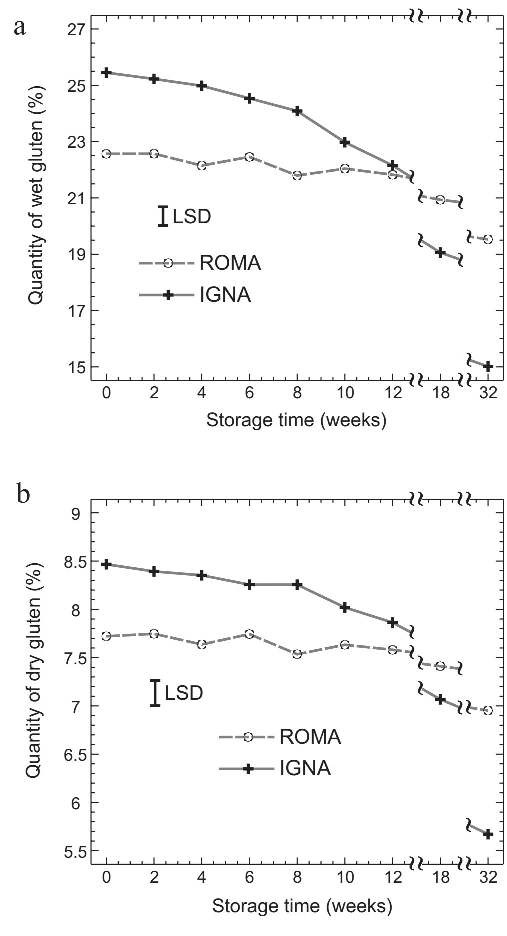

Fig. 1. Effect of the storage time of wheat flour of studied cultivars on the quantity of wet (a) and dry gluten (b).

These results show, that flour of the cv. Igna, was subject to considerably larger changes during storage. The decreases in the quantity of wet and dry gluten noted were several times higher than for cv. Roma.

Changes in the sorption properties of gluten

The characteristics of the changes in the contents of water absorbed and non-absorbed in freshly washed out gluten, as a result of wheat flour storage, is presented in Fig. 2a and b. For a certain period of storage, the content of gluten in the non-absorbed water was not subject to significant change. For cv. Igna this period was for 12 weeks and was twice as long as for cv. Roma (6 weeks). Over longer storage periods, the character of changes in the non-absorbed water content depended on the wheat cultivar. For cv. Roma, a gradual decrease was observed, from 4.2 to 2.1%, meanwhile for cv. Igna – there was a strong increase in the content of non-absorbed water, from 1.3 to 4.0%.

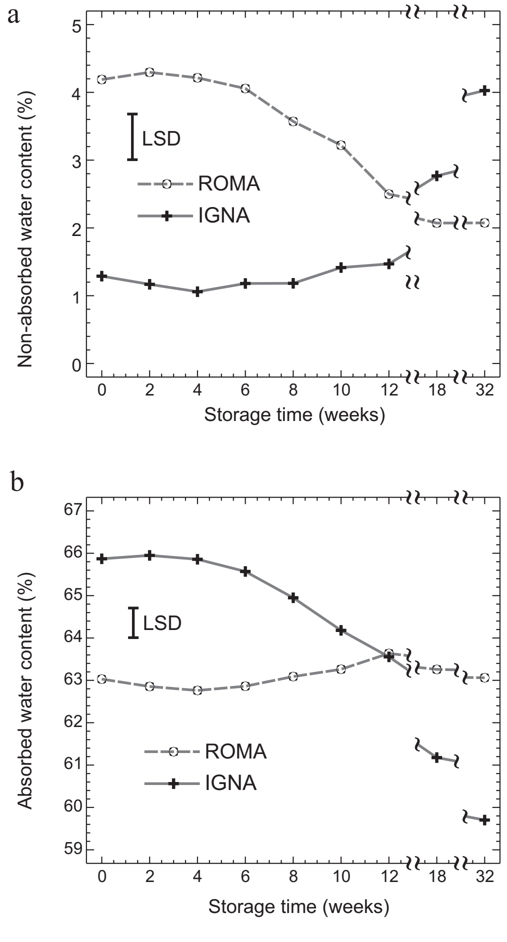

Fig. 2. Effect of the storage time of wheat flour of studied cultivars on the content of non-absorbed (a) and absorbed water (b) in gluten freshly washed out.

Significant changes in the absorbed water content as a result of flour storage occurred in the case of cv. Igna only (Fig. 2b). The ability of the gluten to absorb water decreased as the length of time of the storage increased. The absorbed water content in gluten freshly washed out decreased from 65.8%, at the beginning of the storage, to 59.7% after 32 weeks of its duration. The first significant falls of it occurred after 8 weeks of flour storage.

These results indicate the different effects of flour storage depending on the wheat cultivar. The storage of flour - strong in gluten (cv. Igna) – substantially worsened the sorption properties of this gluten. From one perspective it weakened its ability to absorb water, the absorbed water content significantly decreased; from the other perspective, the gluten retained in it considerable quantities of non-absorbed water. However, the storage of flour with weak gluten (cv. Roma) did not modify its ability to absorb water and moreover influenced the decrease of the content of non-absorbed water in gluten. These changes show a gradual improvement in the quality of the gluten as the storage time of the flour with the weak gluten increased.

The total content of the water stored in the freshly washed out gluten, assumed as the sum of contents of the absorbed and the non-absorbed water, decreased gradually with the lengthening of flour storage for both the cultivars studied. After 32 weeks of storage, these contents reduced by 2.1 and 3.4% for cv. Roma and cv. Igna, respectively. Whereas at the beginning of storage the total content of water was identical (67.2%) for both cultivars.

Changes in the rheological properties of gluten

The influence of the storage time of wheat flour on the rheological properties of gluten freshly washed out expressed by the gluten index (IG) is presented in Fig. 3. Values of the gluten index increased proportionally to the length of the storage period. A significant increase of IG values was observed after 8 and 10 weeks of storage for cv. Roma and Igna, respectively.

Gluten of the cv. Roma, with a clearly lower IG strengthened considerably. IG values increased from 53%, at the beginning of storage, to 87% after 32 weeks duration. For cv. Igna these values increased from 90 to 97%, respectively.

The results presented clearly show the trend of the gluten to strengthen the rheological properties as the storage time of the flour increases. This special advantage results from the storage of flour with the weak gluten (cv. Roma). As a result of extending the storage time, the gluten clearly improves its rheological properties. This means that regulating the duration of storage of particular flour batches, it is possible to obtain the properties of the gluten desired. However, the flour with the very strong gluten (cv. Igna), should not be kept for a long time because a too strong gluten makes this flour less useful for baking.

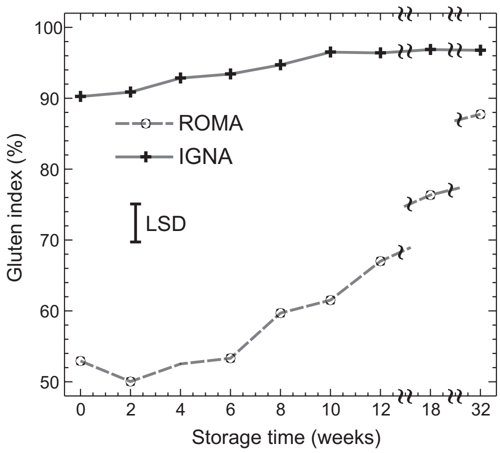

Fig. 3. Effect of the storage time of wheat flour of studied cultivars on the gluten index.

The strengthening of gluten during flour storage corresponds to the decrease in the quantity of the washed out gluten and to a lowering of the total water content. However, for two cultivars examined opposite tendencies were observed in relationships of mechanical strength of gluten against a content of non-absorbed water in it. In the case of cv. Roma the mechanical strength of gluten increased with a decrease in the non-absorbed water content, while for cv. Igna the strength increased with an increase in the content of this kind of water.

DISCUSSION

The storage of wheat flour is one of the most important enterprises being undertaken for the effective use of its baking potential. Therefore special attention is focused on the study of the chemical processes taking place in stored flour and their influence on its baking properties.

In this article, the results presented characterise these processes from the point of view of their influence on water absorption and the rheological properties of gluten as well as on its quantitative changes. As proved, the 4 week storage of flour did not significantly change the properties of the gluten studied regardless of the wheat cultivar. Longer storage affected both unfavourably, causing an essential decrease in the quantity of washed out gluten, and profitably, contributing to a considerable increase in the mechanical strength of the gluten (IG). During flour storage, the character of changes in the sorption properties of the gluten depended on the wheat cultivar. For cv. Roma with low IG, the improvement of these properties appeared in the form of a decrease in the content of non-absorbed water. However, for cv. Igna with high IG, together with the lengthening of flour storage, a gradual loss in the ability of the gluten to absorb water was noted. During the whole period of storage – 32 weeks – for the cv. Roma, no significant changes in absorbed water content were stated.

These results show the great importance of the genotype of the wheat cultivar in determining the predisposition of any given flour for storage. This also confirms the investigations of Pirozi and Germani [11], which showed the different responses of wheat cultivars to the processes undergone during the storage of flour. The author's earlier investigations [8] conducted on the same cultivars, indicated that the drying of the grain of cv. Igna at a temperature range of 80–90°C caused an increase in the content of non-absorbed water in washed out gluten – as did the lengthy storage of the flour – with a simultaneous decrease in absorbed water content. These kinds of changes did not take place in the case of cv. Roma.

The content of non-absorbed water, retained by the gluten in the course of its washing out, as showed in the earlier [7–10] and present investigations of the author, is subject to considerable fluctuation. The mechanism of this phenomenon has not been recognized so far. Yet microscopic investigation of Freeman *et al.* [3] disclosed that freshly washed out gluten has a reticulate structure within which water deposits form. It could be supposed that the results of the measurement of the non-absorbed water content of the gluten depend directly on the quantity of water stored in these deposits.

Studying the advantages which flow from flour storage, it is indispensable to know the reaction of single wheat cultivars and to separate the groups of cultivars with similar predispositions to storage. Investigating the different cultivars, it is often possible to receive mutually preclusive results. For example, the investigations of Seguchi *et al.* [12] and Wang and Flores [15] show an improvement in the baking quality of wheat flour as a result of the lengthening of its storage. In turn other investigations [13,14] show the rather negative influence of storage on many technological indicators, such as: the quantity of gluten, the amount of sedimentation, water absorption of the flour, amylolytic and proteolytic activity as well as dough yield and bread volume.

The results of the present investigations confirm the above mentioned thesis and show clearly that wheat cultivars differ indeed vis-`a-vis the predisposition of the flour to long storage. The flour produced from the grain of cultivars with strong gluten (cv. Igna) is not predisposed to long storage. Unfavourable effects include the reduced water absorption of the gluten and its increased stiffness, which do not permit such flour to be used for bakery purposes. However, the storage of flour of weak gluten (cv. Roma) results in a row of advantages. Such gluten, by not losing its sorption abilities, improves the rheological properties, affecting the baking properties of the flour advantageously.

CONCLUSIONS

Storage of wheat flour for 4 weeks did not influence changes in the properties of the gluten studied. Longer storage caused significant changes in the value of all indicators.

The storage of the flour affected the decrease in the quantity of gluten washed out from it; the rheological properties (IG) also improved as the period lengthened. The cultivar with the high IG (cv. Igna) characterised itself considerably by a greater decrease in the quantity of gluten as a result of flour storage, while the cultivar with the low IG (cv. Roma) showed a larger increment in IG value.

The sorption properties of gluten were modified both the cultivars studied in different ways.

For cv. Igna, with the lengthening of storage, the non-absorbed water content in the gluten increased significantly, and the content of absorbed water decreased. Thus for cv. Roma, useful changes were noted in the form of a de- crease in the non-absorbed water content and the absorbed water content in the gluten was not subject to significant changes for the whole storage period.

The results indicate that the storage of flour characterising itself as strong gluten (cv. Igna) loses its sorption properties significantly. However, the storage of weak gluten (cv. Roma) flour clearly improves its sorption and rheological properties.

This gives the way for the management of the desirable properties of gluten by selecting the appropriate lengths of flour storage periods.

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