Chemical and Biochemical Changes during Microwave Treatment of Wheat

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Abstract

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The effect of microwave (MW) heating on the changes in wet gluten content, Gluten Index, Falling Number and amylographic characteristics was studied in sprouted wheat grain. Different moistures of wheat in two ranges of 10–11% and 15–17% and two end temperatures of MW heated samples (60 and 80°C) were applied to wheat samples. Falling Number and Gluten Index increased with increasing absorbed energy during MW heating, whereas gluten content decreased. Amylographic maximum increased due to α-amylase inactivation progressively with increasing absorbed energy as well. The greatest relative changes occurred when the end temperature of MW heated samples 80°C and moisture 15% were used. An improvement effect on the baking quality of sprouted wheat was found due to an increase in amylographic maximum with higher energy doses and higher end temperatures of MW heated samples. It was a consequence of Falling Number increase and Gluten Index increase with lower energy doses. The negative effect of higher energy doses was proved in a decrease in wet gluten content.

Keywords: sprouted wheat; microwave treatment; Falling Number; gluten

Currently attention is paid to a possible use of microwave (MW) heating for the drying of cereal grain, rice or pulses. Heat from the kernel surface is transferred by conduction to the inner endosperm if the usual convention drying of grain with hot air is used. This method of drying is time consuming with low economic effectiveness since heat conductivity of wheat kernel is rather low, similarly to insulating materials. MW heating allows drying grains to a permitted limit moisture without deteriorating effects on its composition or properties (CAMPANA *et al*. 1986). MACARTHUR and D'APPOLONIA (1982) studied the influence of MW heating and grain moisture on wheat conditioning prior to milling and optimisation of semolina yield as well. Some deteriorating changes can occur as a result of high doses of MW treatment.

MATERIALS AND METHODS

Technique of microwave treatment: Parameters of a MW oven Whirlpool MT 243/UKM 347 (Norrköpping, Sweden) were as follows: frequency 2450 MHz, pulsed variable MW rated values of power output – 90, 160, 350, 500, 750, 850 and 1000 W, inner space volume 25.4 l, without sample rotation during measurement. Before the samples are treated, pre-heating of the oven has to be done to achieve a heating process standard. For this purpose a volume 2 l of water was heated in the oven, using a maximum power output for 5 min. The absorbed power according to BSEN 60705 test (International Standard BSEN 60705 – Methods for measuring the performance of microwave ovens for household and similar purposes) was determined every day as well. Load of water for this test is 350 ± 5 g, initial water temperature 10 ± 2°C. The mean value of absorbed power (n = 22) corresponding to the rated power output 350 W was 298.42 W; standard deviation 8.5 and coefficient of variation (relative standard deviation) 2.85% (SKULINOVÁ *et al*. 2002).

A special polyethylene container with bottom dimensions 100 × 150 mm was used for MW treatment. Weight of single sample was 200 g, height of sample layer in the container was 20 mm. The container with sample was put in the middle of the oven, MW power output was set and the sample let heat until the desired end temperature of heated sample was reached. Then the power output of the oven was switched out and the sample was left in the oven for 1 min more to homogenise the temperature in kernels. The container was taken from the oven, the sample was hand-mixed with lab spoon and returned to the MW oven. The whole process was repeated five times so that a homogeneous temperature of the sample was reached.

Temperature measurement: An instrument NoEMI of the fiber-optic temperature system with a table unit ReFlex and two optic fibers (Nortech Fibronic Inc., Canada) allows to read out temperature at any point of the sample in the range of temperatures from –40°C to +250°C. Reaction time for temperature reading is 0.25 s. The fibers are made suitable for the conditions inside the MW oven. The instrument can be connected to a computer and data can be registered in table-processor Reflection 4 for Windows, Version 4.21 (1990–1994) compatible with MS Excel (Walker Richter & Quinn, Inc.). The surface temperature of sample was measured with one probe placed 50 mm to the right from the middle, just in the position with the highest temperature. Location of a temperature sensor was 2 mm below the sample surface. A detailed scheme of the temperature sensor position was demonstrated in our previous paper (SKULINOVÁ *et al*. 2002).

Preparation of wheat samples: In order to standardise the sprouting of wheat samples, wheat kernels were let soak in water of temperature 16°C for 2 hrs and then sprout in a laboratory. Wheat was placed to a thermostatic box for 16 h at 20°C. Sprouted samples were carefully predried in a convection air-drier at 40°C for different time until their moisture was either 10–11% or 15–17%. All samples were milled at the automatic laboratory flourmill QC-109 (Labor MIM, Hungary) simulating flour-milling process. Resulting white flour is similar to plant-processed wheat flour with ash content close to 0.5% and yield between 40–60% depending on wheat milling quality. Bran were subsequently milled at laboratory mill Retsch ZM 1000 (with 1500 r.p.m. and the sieve with mesh 0.5 mm).

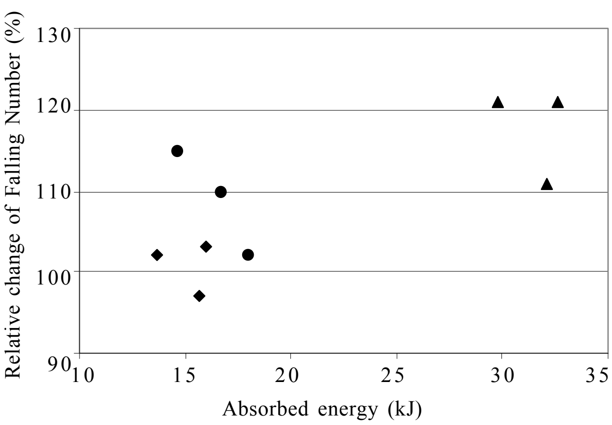
Determination of dry matter: Automatic drying electronic weights Precisa HA60 (Switzerland) were used for determination of dry matter content. The end temperature of drying can be set in the range of 40–250°C and the percentage of dry matter content is automatically shown at a display.

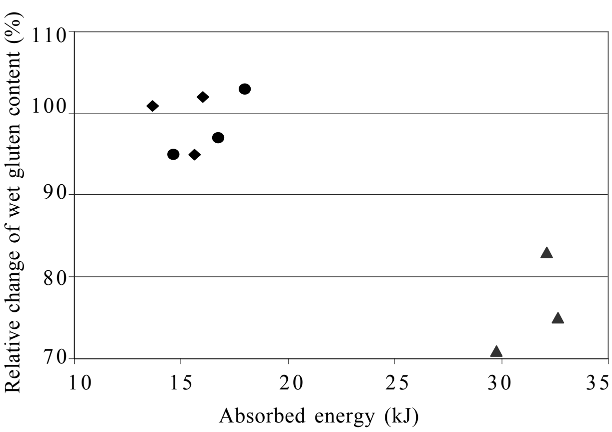
Gluten content and Gluten Index determination: Wet gluten quantity as well as quality was determined by washing gluten from wheat meal at automatic washer Glutomatic 2200 and by centrifugation of washed gluten at Centrifuge 2015 (two instruments supplied by Perten Instruments, Sweden). Gluten washing is standardised in ICC Standard No. 155 (1994), AACC Standard No. 38-12 – Wet gluten and Gluten Index, Perten Instruments (1993).

After washing off from meal or flour gluten is put on a special sieve and centrifuged under standard conditions. Depending on the rheological properties, a part of gluten passes through the meshes of the sieve. The part of gluten that did not pass through a sieve is expressed as the percentage of total washed gluten and is defined as Gluten Index (GI). Optimum values of GI for good-quality wheat flour are approximately between 85 to 92%. The lower the value of GI, the worse the baking quality of wheat or flour. The values such as 60 or 40% point to very low quality of flour that should not be used for baking.

Standard deviation of repeatability $s(r)$ for gluten content determination was lower than 0.56% and for GI determination it was lower than 5.24%. Standard deviations of reproducibility $s(R)$ were lower than 1.0% and 8.3%, respectively.

Falling Number (FN) determination: A special standard falling-body viscometer Falling Number 1400 was used for the measurement (Perten Instruments 1993). The method of measurement is described in Standard ČSN ISO 3093 – Determination of Falling Number. In principle, flour suspension in a measuring cell is heated in boiling water.





◆ 60°C, moisture content 10%; ● 60°C, moisture content 17%; ▲ 80°C, moisture content 15%

Fig. 1. Relation between relative change in Falling Number and absorbed energy

Fig. 2. Relation between relative change in wet gluten content and absorbed energy

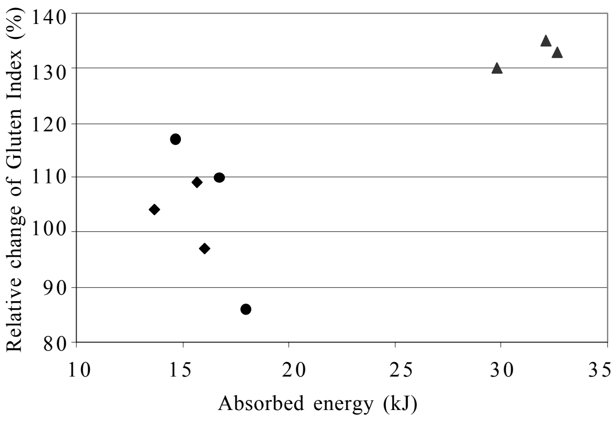


Fig. 3. Relation between relative change in Gluten Index and absorbed energy

Flour starch is gelatinising and, in standard conditions, the time of body fall in gelatinising suspension is automatically measured after a standard distance of the fall. Optimum value of FN for wheat flour of good baking quality is 220 s. The starch of such flour has not been damaged very much and has a normal amylase activity. Low FN values (160 s and less) for wheat flour show an extremely high amylolytic activity of flour or considerable damage to starch with degradation of its macromolecule. Starch has a lower capacity to bind water in gel and consequently a lower viscosity. High values of FN (e.g. 350–400 s) mean that starch is not damaged, but the amylolytic activity of flour is too low for the needs of bakery processing. Amylolytic enzymes cause usual damage to starch, but some damage can also be due to high temperatures during drying and milling of wheat grain, high-pressure, etc. There is also a possibility of starch damage due to MW treatment.

RESULTS AND DISCUSSION

Relative changes in FN, gluten content and GI were used to evaluate the influence of absorbed MW energy. Absorbed MW energy (J) is expressed as absorbed power (W) corresponding to the rated power output multiplied by the time of treatment (s). The value of untreated sample was a basis for comparison (100%) of each group of samples. Statistical evaluation of measured values is shown in the following table:

Measured parameters	Range of measured values	Range of standard deviation	Range of relative standard deviation (%)
FN	115–164 s	1.08–8.62	0.88–7.52
Gluten content	23.2–29.6%	0.22–1.68	0.92–8.09
GI	59–80%	0.15–5.25	0.16–7.53

Each point, or each column in Figs. 1–6, represents the average value of 4 repeated measured data (HUBÁČKOVÁ 2001).

Changes in FN in dependence on absorbed energy for all samples with different moisture content and end temperatures of heated samples are shown in Fig 1. An increase in FN with the increasing absorbed energy is seen in the diagram for most samples. It can be deduced that due to heating during MW treatment, the activity of α-amylase decreased. Such an effect can be considered as a positive one. However, the FN increase was not significant in the samples with low moisture (10%). With higher moisture the FN increase was accented. Since protein is a substantial part of wheat gluten, its damage due to pro-

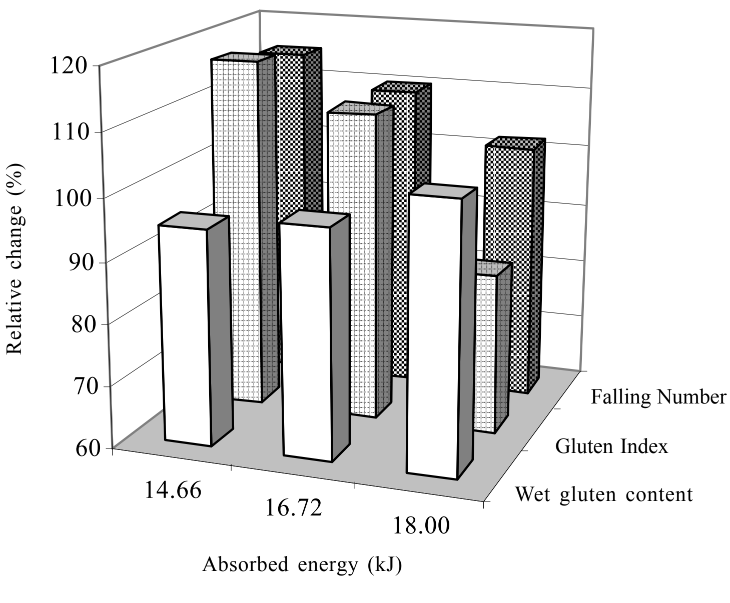


Fig. 4. Relation between relative changes in Fal-ling Number, wet gluten content, Gluten Index and absorbed energy – column graphs (end temperature of heated samples 60°C, moisture content 17%)

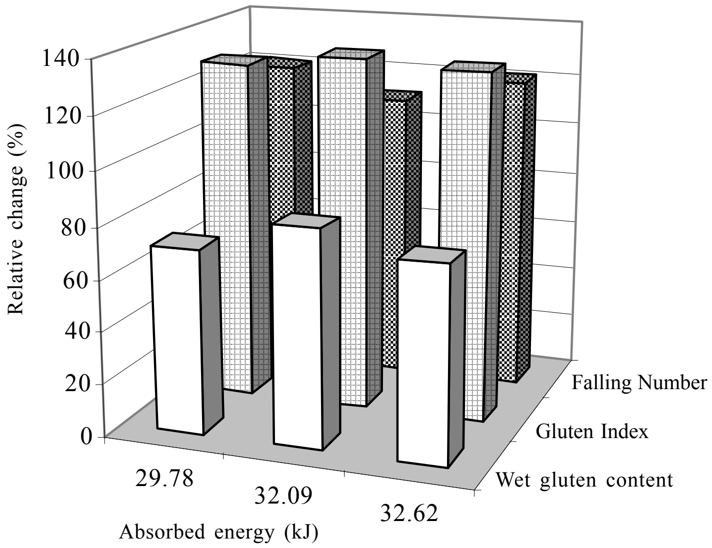


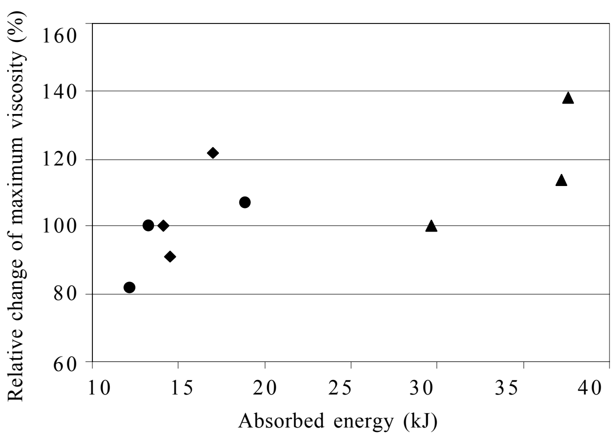
Fig. 5. Relation between relative changes in Falling Number, wet gluten content, Gluten Index and absorbed energy – column graphs (end temperature of heated samples 80°C, moisture content 15%)

tein denaturation at higher temperatures over 60°C can be expected. As it is seen in Fig. 2, wet gluten content decreased with higher absorbed energy, but the prevailing effect on a decrease in wet gluten content was the effect of high heating temperature rather than of high absorbed energy. A decrease in wet gluten content can probably be explained by the lower absorption of water in more heated gluten under the conditions of standard washing. A decrease in wet gluten content was almost 30% of the original value of untreated sample after sample heating to the end temperature of 80°C. Relative changes in gluten content are expressed as percentage of the value for untreated sample, similarly like in Fig. 1.

MW treatment can also affect the properties of wheat gluten. Gluten Index is a characteristic connected with swell wet gluten extensibility and rigidity. Relative changes in GI with increasing absorbed energy are shown in Fig. 3. Most of the GI values in the region of absorbed energy approx. 15 J slightly increased but it was not a general trend. A considerable increase in GI was obtained with the highest absorbed energy and heating to the end temperature of 80°C. However all these GI values were actually above 95% and it is more than optimum quality. Due heat denaturation, gluten is probably too rigid and less extensible.

Figs. 4 and 5 show relative changes in FN, GI and gluten content in three-dimensional diagrams in dependence on the absorbed energy. The diagrams illustrate different quality of grain heated to 80°C that is much more affected by heating than in grain heated to 60°C.

The effect of MW treatment on amylolytic enzymes and starch was studied by determining the viscosimetric properties of gelatinising starch with Amylograph. The starting temperature of gelatinisation and the temperature of viscosity maximum did not change significantly with the MW treatment, only the height of the amylographic maximum was enlarged with increased absorbed energy, as it is seen in Fig. 6. Samples heated up to the end temperature of 80°C showed a considerable increase in viscosity maximum (up to 40 % in comparison with the untreated sample). These changes can be explained by damage to starch macromolecule and by α-amylase inactivation.



◆ 60°C, moisture content 11%; ● 60°C, moisture content 16%; ▲ 80°C, moisture content 16%

Fig. 6. Relation between relative change in maximum amylographic viscosity and absorbed energy

CONCLUSION

The effects of MW heating on the changes in wet gluten content, GI, FN, and amylographic characteristics were studied in sprouted wheat grain. Different moistures of wheat in two ranges 10–11 and 15–17% and two end temperatures of heated samples (60 and 80°C) were applied to wheat samples. The following conclusions can be drawn:

– Gluten content decreased while FN and GI increased with increasing absorbed energy during MW heating; the greatest relative changes occurred if the end tempe-

rature of heated samples 80°C and moisture 15% were used.
– Amylographic maximum increased in wheat heated up to the end temperature of samples 80°C and moisture 15%; this increase was caused by α-amylase inactivation with increasing absorbed energy.
– Improvement effect on the baking quality of sprouted wheat was found as a result of an increase in amylographic maximum with higher MW energy doses and higher end temperature of the samples, as a result of an increase in Falling Number and also due to an increase in Gluten Index with lower energy doses; the negative effect of higher energy doses was due to a decrease in wet gluten content.
– All changes are more marked the higher the initial moisture of wheat and the longer the heating time.

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Souhrn

KAASOVÁ J., HUBÁČKOVÁ B., KADLEC P., PŘÍHODA J., BUBNÍK Z. (2002): **Chemické a biochemické změny při mikrovlnném ohřevu pšenice**. Czech J. Food Sci., **20**: 74–78.

Byl sledován vliv mikrovlnného ohřevu na změny čísla poklesu, obsahu mokrého lepku, gluten indexu a amylografických charakteristik u vzorků porostlé pšenice o vlhkostech 10–11 % a 15–17 % při konečných teplotách mikrovlnně ohřátých vzorků 60 a 80 °C. Se zvyšující se dodanou energií při mikrovlnném ohřevu dochází ke zvýšení čísla poklesu, ke snížení obsahu mokrého lepku a ke zvýšení gluten indexu. Se zvyšující se dodanou mikrovlnnou energií dochází k inaktivaci α-amylasy a následně ke zvýšení výšky amylografického maxima. Největší relativní změny byly zjištěny při konečné teplotě mikrovlnně ohřátých vzorků 80 °C a při vlhkosti pšenice 15 %. Z hlediska zlepšení pekařské kvality porostlé pšenice došlo vlivem mikrovlnného ohřevu k pozitivnímu zvýšení amylografického maxima, čísla poklesu a u některých vzorků i gluten indexu, vyšší dávky mikrovlnného záření však negativně ovlivňují obsah lepku.

Klíčová slova: porostlá pšenice; mikrovlnný ohřev; číslo poklesu; mokrý lepek

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