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INFLUENCE OF DRYING TEMPERATURES ON CHEMICAL COMPOSITION OF CERTAIN CROATIAN WINTER WHEATS

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Four Croatian winter wheat cultivars at 20% moisture were dried at temperatures of 50, 60, 70 and 100 °C until the moisture decreased to 14%. Two cultivars had improved quality, whereas two cultivars had lower quality characteristics. The examinations involved determination of seed germination, enzymatic activities and chemical indicators of grain properties. On the basis of the obtained results it could be concluded that the drying temperature of wheat should not exceed 50 °C in order to preserve biologically undamaged grain. Gluten of lower swelling ability increases sedimentation value at drying temperatures of 60 and 70 °C. For wheat samples with high quality gluten the wheat grain drying process at a temperature of 50 °C improved the wheat quality regarding the increased ability of gluten swelling. An increase in the drying temperature did not influence the characteristics of starch components. Diastatic and proteolytic activities of wheat decreased at a higher drying temperature.

Keywords: wheat, wheat drying, chemical composition, wheat quality

At the beginning of harvest wheat grain moisture content is often higher than 14%. The grain with moisture content higher than 14% is not suitable for quality storage. The preparation of those wheat for storage can be done by a drying process. The drying process must be provided under conditions which prevent deterioration of grain quality. Considerable research has been undertaken to investigate possible ways of drying, with alternative methods ranging from ambient air to high temperatures. Changes of grain properties by thermal treatment depend on the grain moisture, drying temperature and drying period (MÜHLBAUER, 1978).

Many authors reported about different optimal drying temperatures (WASSERMANN, 1978; LUPANO & ANÓN, 1987; CARDAS et al., 1988; RAGASIST, 1993). GHALLY and co-workers (1973) reported on heat damage of 15, 17 and 19% initial moisture content wheat dried with 60–188 °C air in a spouted-bed dryer. Germination,

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ash content, farinograph, extensiograph and baking tests were used as quality indicators. Changes of chemical and physical characteristics by thermal treatment have been discussed by NIERLE and co-workers (1978). All investigations showed that by drying temperature over 80 °C the wheat quality is impaired, i.e., thermal damage of the grain occurs.

Thermal damage implies mostly denaturation of proteins caused by thermal treatment. Thermo-stability of proteins depends on the grain moisture and gluten quality.

Many authors reported about quality changes in corn due to drying. MÜHLBAUER and CHRIST (1974), MÜHLBAUER and co-workers (1976). DEUBELIUS (1978) examined the effect of heated-air drying on the lysin content and protein quality of corn. PEPLINSKI and co-workers (1989) investigated the effects of hybrid and drying temperatures on the various properties and dry-milling response. PEPLINSKI and co-workers (1994) reported about changes in properties and physical quality in high-moisture corn, air-dried at 25–100 °C. They reported that drying under air temperature had little or no effect on any other physical or chemical characteristics studied, although these other properties had a very significant relationship with hybrid type.

HACKENBERGER & UGARČIĆ (1989) reported about specific behaviour of individual wheat varieties at various temperatures applied for wheat drying. They noticed that the drying process can be applied not only to avoid thermal damages but also to improve the technological quality of wheat (UGARČIĆ & HACKENBERGER, 1989).

Quality changes in grain due to drying can be determined by analytical methods. The aim of this study was to investigate the dependence of wheat grain quality on the drying temperature and to find out the possibilities of improving certain characteristics of wheat grain.

1. Material and methods

1.1. Kernel drying

Four samples of Croatian winter wheat cultivars (1997 harvest) were examined. Wheat samples were chosen in a way that two cultivars had improved quality (samples 1 and 2) whereas two cultivars had lower quality (samples 3 and 4) (Table 1). Criteria for quality determination were protein share, sedimentation value, gluten quality, rheologic and baking characteristics, etc, according to the Croatian wheat quality regulation (CROATIAN REGULATION for cereal and cereals products, 1992). Lots (1.5 kg) of cleaned wheat kernels at 10–13% moisture content were tempered to 18% moisture by adding water, held for 20 h, tempered to 20% moisture and held for 2 h. Then they were dried at the temperatures of 50, 60, 70 and 100 °C.

Table 1

Characteristics of wheat grain samples used in experiments

	Samples			
	1	2	3	4
Germination (%)	98	98	98	97
Yield of flour (%)	63.8	64.9	56.2	52.5
SDS – sedimentation value (ml)	69	55	42	39
Sedimentation value (Zeleny) (ml)	46	27	21	28
Protein content (%)	14.6	13.8	13.1	11.9
Starch content (%)	66.2	67.4	68.6	68.1
Damaged starch (%)	9.3	7.9	4.6	7.5
Diastatic activity (mg maltose)	4.61	5.06	2.13	2.69
Falling Number (sec)	366	358	326	419
Proteolytic activity (mg amino N)	2.45	4.21	2.12	2.82

The samples were dried in lab drier (Retsch, Type T61) in 6–8 cm thick stationary layer. The kernel temperature was measured with a temperature sensor (LM 335). The control samples were dried for 24 h at room temperature. Moisture was measured by moisture meter (Pfeuffer, HE 50) by taking samples every 30 minutes. Final moisture content of all samples ranged from 9.9 to 14.2%. The weight loss was determined by samples weighing before and after drying process. After the drying process, the warm samples were cooled at room temperature (25 °C). Cooled samples were then stored at 4 °C and brought up to 25 °C before testing was performed.

1.2. Analytical procedures

Germination was determined for 100 seeds in accordance with the Croatian regulation for seed testing. The flour yield was determined by milling using a laboratory mill (Brabender Quadrumat Junior). The kernels were prepared for examination by milling in a cyclone mill (Cyclotec) with 0.5 sieve mashes.

The nitrogen was determined by the Kjeldahl method (N×5.7). Capacity of gluten swelling was determinated by SDS-sedimentation values according to AXFORD and co-workers (1979) and by Zeleny method (ICC Standard method, 116/1, 1992).

The Ewers method was applied to determine the starch content while the quantity of damaged starch was calculated by the amylase number according to the findings of HAMPEL (1952). The total diastatic activity was defined by the WOODHEAT & WYATT (1960) method and the α-amylase activity was defined by the Hagberg Falling Number (ICC Standard method, 107/1). Proteolytic enzyme activity was determined by the formal titration (VAJIĆ, 1962). All results were expressed at moisture content of 14%.

2. Results and discussion

2.1. Physical properties

Germination ability is an important factor for the quality of seed wheat. Seed grain requires a high germination percentage. KREYGER (1972) determined the critical kernel temperature for a number of small grains as a function of equilibrium relative to humidity. Wheat germination is the least heat sensitive, followed by oats, corn and rye. Germination of all grains is more heat sensitive at high than at low moisture content. In our investigation the germination of the untreated control samples ranged from 97 to 98% (Table 1). It is indicated that all samples showed a high germination capacity. The rapid decrease of germination was observed at the drying temperature of 60 °C, which indicated that the grain was not biologically damaged by the drying temperature of 50 °C (Fig. 1).

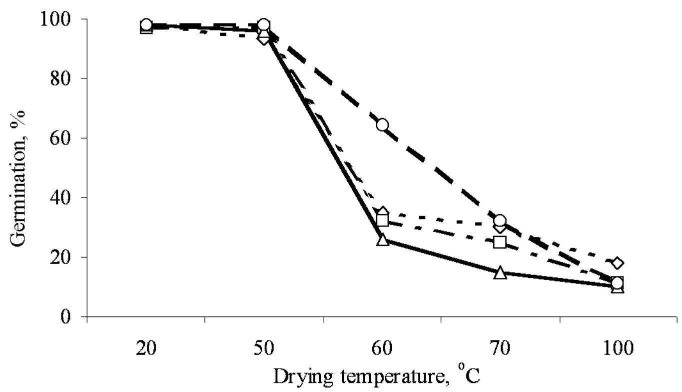

Fig. 1. Changes of grain germination with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

The investigated wheat samples contained 20% moisture at the start of drying. KÖKSEL and co-workers (1993) determined that most of the initial water was removed during the early stages of drying. The dehydration rate increased with increasing temperatures. They found that 12% of water was removed at 40 °C in the first 30 min. This percentage increased to 48% at 100 °C for the same period. The measurements of weight loss obtained for our wheat samples dried at different temperatures are given in Table 2. The weight loss ranged from 6.1 to 16.3%.

Table 2

Moisture content and weight loss at various drying temperatures

Parameters	Naturally dried kernels	Drying in laboratory drier			
Temperature	20 °C	50 °C	60 °C	70 °C	100 °C
Moisture content at the inlet (%)	20.1	20.3	20.0	20.5	20.8
Moisture content at the outlet (%)	11.5	14.2	11.1	9.7	9.9
Weight loss (%)	11.1	6.1	11.1	15.5	16.3

Table 3

Flour yield at various drying temperatures

Samples	Yield of flour (%)				
Temperature	20 °C	50 °C	60 °C	70 °C	100 °C
1	63.8	63.6	62.6	60.7	58.3
2	64.9	61.2	59.4	58.6	52.7
3	56.2	52.7	49.8	47.8	44.5
4	52.5	51.3	48.4	49.8	38.3

Flour yield is the most important technical and economical factor for milling. The samples had a low flour yield. Yield of flour decreased at drying temperatures higher than 70 °C (Table 3). It is especially pronounced at drying temperature of 100 °C for all wheat samples.

2.2. Effect of wheat drying temperature on chemical characteristics

The protein content of control samples of the blend winter wheat ranged from 11.9 to 14.6% in the dry matter while the SDS-sedimentation values ranged from 39 to 69 ml and the sedimentation value, according to Zeleny method from 21 to 46 ml (Table 1).

The protein content is used along with gluten swelling ability to establish the commercial value of wheat. With changes of drying temperatures protein content did not change significantly (Table 4). The obtained results are in accordance with CARDAS and co-workers (1988) and WASSERMANN (1978). Although they did not find differences in protein content of thermally treated wheat samples, it is considered that the differences in the protein content are the reflection of differences in morphological properties of kernels across the individual varieties. Wheat gluten is the water insoluble complex protein fraction separated from wheat flours. Glutenin and gliadin, the two major protein components of wheat gluten, interact in an aqueous system to produce a viscoelastic mass. The viscoelastic behavior of hydrated wheat gluten is crucial to bakery technology in which it results in the ability to form adhesive and cohesive masses, films and three dimensional film networks. It is generally accepted that higher temperatures cause damage to gluten proteins, resulting in lower baking quality. When wheat at 14% moisture content was heated for 36 min, gluten was damaged by temperatures in 70–85 °C range (KENT 1975). BECKER and SALLANS (1956) reported that the denaturation of gluten in wheat flour directly affects the loaf volume. Heat brings about three important changes; it increases the degree of aggregation of glutenins, it decreases the extractability of large glutenins aggregates, and it decreases the hydrophobicity of insoluble glutenins. Changes in the functionality of heat-treated wheat gluten proteins may be attributed to disulfide/sulfhydril interchange reactions (WEEGELS et al., 1994; ELIASSON et al., 1991).

The increase of drying temperature of the wheat grain causes changes of SDS-sedimentation values (Fig. 2). These changes depended on the gluten quality. JEANJEAN and co-workers (1980) reported that heat treatment of gluten reinforced the strength of hydrophobic bonds and aggregation of gluten molecules appeared. The results obtained indicated specific changes of gluten for each variety. It could be confirmed that the bonds in the aggregation protein complex are weak and, moreover, the quality of the wheat flour is easily affected by the thermal treatment, unlike the samples of high sedimentation value (samples 1 and 2) whose ability of gluten swelling decreased at higher drying temperatures. The ability of gluten swelling decreased in all samples at the drying temperature of 100 °C.

Table 4

Changes of protein content with drying temperatures

Samples	Protein content (% dry mat.)				
Temperature	20 °C	50 °C	60 °C	70 °C	100 °C
1	14.6	14.3	14.7	14.1	14.1
2	13.8	13.1	13.5	13.3	12.0
3	13.1	12.7	12.6	12.4	12.6
4	11.0	11.7	11.7	11.7	13.1

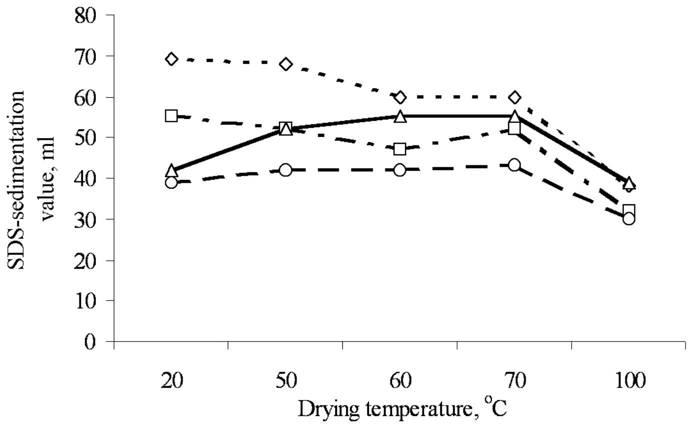

Fig. 2. Changes of SDS-sedimentation value with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

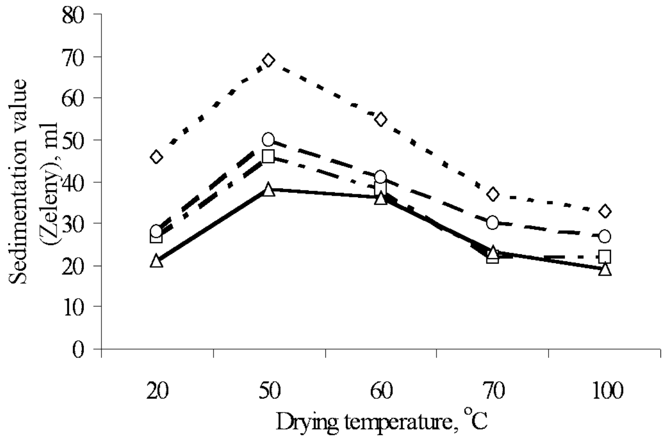

Fig. 3. Changes of sedimentation value (Zeleny method) with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

All samples dried at 50 °C indicated the rise in sedimentation value (Zeleny method) (Fig. 3). The sedimentation value for samples dried at 70 °C was similar to values for untreated samples. Since the sedimentation value is an indicator of the gluten swelling capacity it can be concluded that the impairment of gluten qualities was evident at a drying temperature higher than 70 °C. The changes of gluten qualities were bigger by high quality gluten in relation to the low quality gluten. It is proved that the low quality wheat gluten was less hydrophobic than the high quality wheat gluten. Hydrophobic link increased by heating which resulted in different abilities of gluten swelling (LUPANO & ANÓN, 1987). These changes enabled improvement of wheat quality by grain drying up to 60 °C.

Starch, as the most represented component of the wheat grain significantly influences the wheat quality due to its structure and physical state. The starch content ranged from 66.2 to 68.6%. An increase of the drying temperature did not effect starch components.

KÖKSEL and co-workers (1993) investigated the influence of wheat-drying temperatures on the birefringence and X-ray diffraction patterns of wet-harvested wheat starch. With drying temperatures of 80 and 100 °C, 95% of the starch granules retained strong birefringence. They found out, that the amount of water in the wheat sample during higher temperature drying may not be sufficient to cause swelling and gelatinization. The physical constraints of the endosperm cells may also limit the swelling of the starch granules. They concluded that the retention of birefringence during wheat drying is due to the lack of water and to the physical protection of starch by the kernel and endosperm cells (Table 4).

During wheat milling, some starch granules are mechanically damaged. Lesions are quantitatively more or less important according to nature, conditioning, mechanical treatment, etc. The degree of starch damage of flour has technical consequences, differently appreciated in baking industries (bakeries, biscuit industries, pasta production), so it is important to control starch damage. The level of starch damage is related to kernel hardness or vitreousness of the parent wheat. The level of starch damage is low for soft wheat. Since proteins are tied to starch (attached proteins), together with starch damage, gluten grate on the surface of starch granules is also damaged. This leads to a reduced ability to retain gas during fermentation. The influence of starch damage on the rehydration rate of doughs and on the rate of enzyme activity and its effect on viscosity measurement has been observed previously by BAKKER and co-workers 1978).

The percentage of the damaged starch decreased by all samples due to temperature increase up to 60 °C (Fig. 4).

According to the flour yield, protein content and starch damage results it was evident that the two investigated samples might have been classified as hard wheat (samples 1 and 2), whereas two samples might have been classified as soft wheats (samples 3 and 4), (Table 1).

Table 5

Changes of starch content with drying temperatures

Samples	Starch content (% in dry mat.)				
Temperature	20 °C	50 °C	60 °C	70 °C	100 °C
1	66.2	65.6	67.4	66.3	67.8
2	67.4	67.0	66.4	66.1	68.2
3	68.6	69.4	68.7	67.7	65.1
4	68.1	68.9	69.0	67.7	65.1

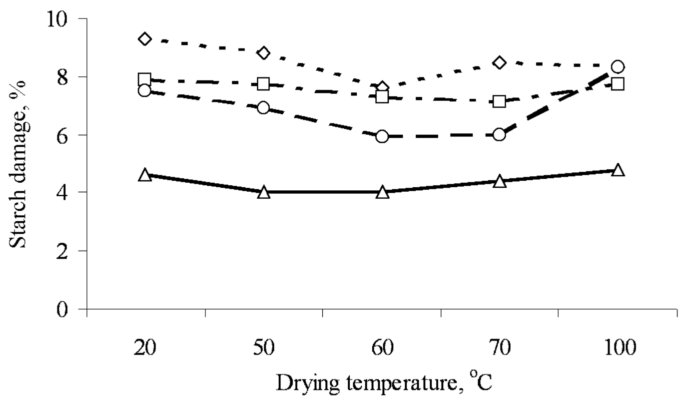

Fig. 4. Changes of starch damage with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

The enzyme levels in the mature, sound wheat grain are relatively low. Amylases and proteases have the highest influence on the technological properties. Increased enzyme activity, particularly of α-amylase is the main limiting quality factor in processing flour into bread and other baked goods. Degrading effects of enzymatic activities lower the water binding capacity in dough and thus decrease viscosity in dough and bread crumb. Enzyme activity in the wheat kernel depended on enzyme concentration, temperature and duration of heat treatment.

Sound cereals have low levels of α-amylase. However, upon germination, the level of α-amylase is increased by many times. This makes α-amylase activity a sensitive measure to detect sprouting of cereal grains. Because of its rapid effect on viscosity of flour-water suspension, measuring of relative viscosity has been widely used to control enzyme activity (Falling Number method). The samples had a low α-amylase activity (by all samples the Falling Number was higher than 300 s). Investigation results showed that all untreated samples had a low value of α-amylase (Fig. 5). α-Amylase activity decreased at temperatures above 70 °C. WEIPERT (1970) reported that the α-amylase activity and maltose content decreased at temperature above 60 °C for various rye samples. Changes of Falling Number at higher drying temperature of wheat kernel reflected changes of physico-chemical characteristics of starch components (KULP & LORENZ 1981). Viscosity of gelatinized starch increased at the drying temperature up to 70 °C in all samples.

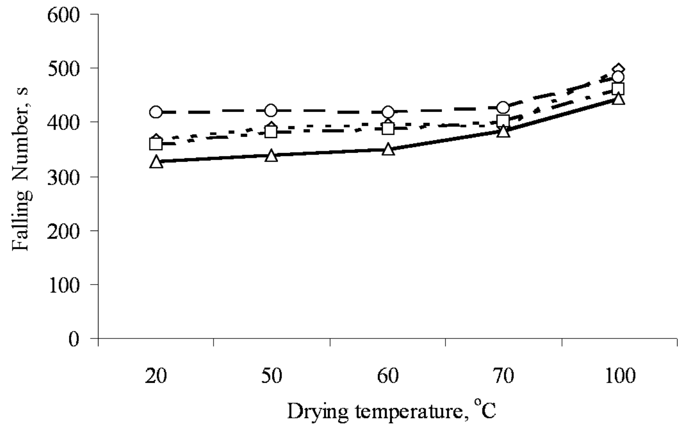

Fig. 5. Changes of Falling Number with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

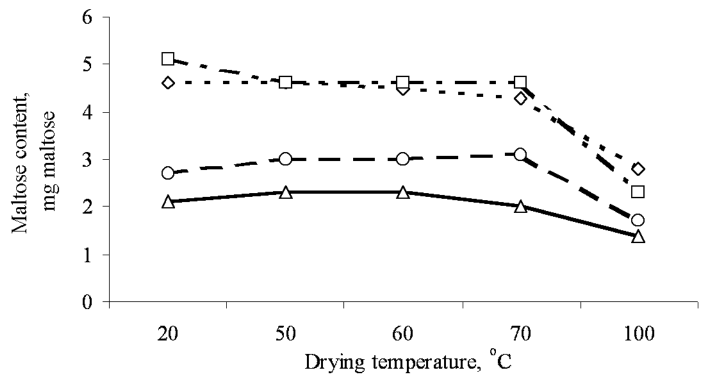

Fig. 6. Changes of maltose content with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

The β-amylase activity, as expressed by the maltose quantity, is shown in the Fig. 6. It was found that the β-amylase activity was reduced after drying at 70 °C.

The optimal temperature for the proteolytic enzyme activity in wheat is 50 °C. At temperatures higher than 50 °C enzyme activity decreased, while at 100 °C the activity completely stopped (Fig. 7).

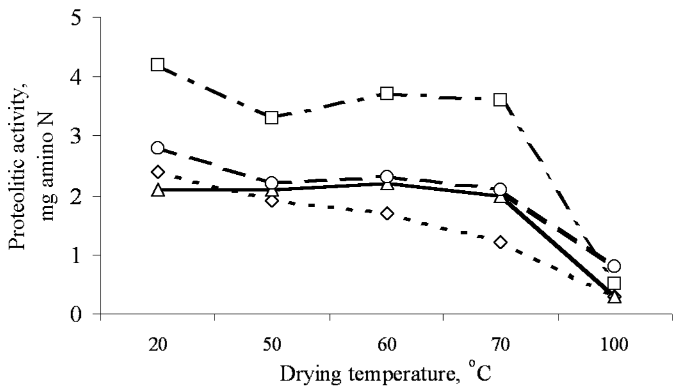

Fig. 7. Changes of proteolitic enzyme activity with drying temperatures. ◊: Sample 1; □: sample 2; Δ: sample 3; O: sample 4

3. Conclusions

To preserve biologically undamaged grain, the drying temperature of wheat should not exceed 50 °C.

The highest differences caused by the thermal wheat treatment were obtained for the sedimentation value and the starch damage. The changes of starch damage percentage are reflected in the higher starch susceptibility to enzymatic disintegration.

The wheat grain drying process at a temperature of 70 °C improves wheat quality with regard to the increased capacity of gluten swelling.

Proteolytic and amylolytic enzyme activities of the wheat grain decrease at a drying temperature higher than 70 °C.

More significant deterioration of wheat quality appeared at a drying temperature higher than 70 °C.

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