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Hydrothermal treatment of sprout-damaged grain

II. Effects on the technological quality of rye

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Abstract. Sprout-damaged rye with the falling number of 87 was heat-treated by immersing the grain in water having temperatures of 80, 90 and 100° C. The treatment lasted at the most 60 sec and was followed by an immediate chilling process. The aim of the treatment was to suppress the excess of α-amylase activity in the outer layers of the kernels. The changes in the quality of the rye were determined by the falling number test, amylograph test and baking tests in which yeast and no acid was added. All the performed treatments affected the results of the quality determinations. Treatment at 80, 90 and 100° C lasting 30 sec raised the falling number values to 102, 117 and 155, respectively.

After treatment for 60 sec the values were 101, 142 and 223. In the amylograms the peak viscosity increased markedly. Processing at 100 and 90° C for more than 20 sec resulted in an increase of the peak viscosity beyond 1000 B.U. The peak temperature of all the samples was rather low and some decrease in the peak temperature was indicated at the processing temperatures of 80 and 90° C. The loaf volumes of loaf made from the treated samples were all lower than the volume of the loaf from the untreated sample. The samples treated for 30 and 60 sec at 100° C gave lowest volumes. Stickiness of the doughs was diminished by the more severe processing conditions, as also were dampness and elasticity of the crumb. All loaves except the ones made of grain heated at 100° C for 30 and 60 sec had a rather large cavity beneath the crust. The samples processed at 90 and 100° C for 30 and 60 sec gave a lighter brown crust colour than the rest of the samples.

Introduction

Sprouting in the ear is a common crop deterioration of rye produced in areas with rather wet climatic conditions at harvest. During sprouting the level of α-amylase activity increases logarithmically (OLERED 1963, DRONZEK et al. 1972, ALBERTSSON 1976), the rate of increase being particularly rapid in the case of rye (LEE and UNRAY 1969).

Amylases are the most important group of enzymes in rye flour relative to its baking quality. Starch plays a major role in the crumb texture of baked rye bread. So a deficiency of starch or a poor starch quality can have a major effect on the crumb characteristics (DREW and SEIBEL 1976).

In rye, α-amylase activity in the endosperm increases slightly from 18 days after anthesis and constitutes at maturity the major contribution to the final activity of the grain. But the total levels encountered in the absence of pregermination are extremely low compared with those liberated by the aleurone cells upon germination (SIMMONDS and CAMPBELL 1976). DREWS and SEIBEL (1976) stated that the subleurone layer of sprouted grain has particularly high α-amylase activity.

Also the enzymatic activity of proteases and pentosanases in rye increase on germination. In addition to the α-amylase activity, these activities contribute to changes in the technologically important viscous properties of rye doughs (ALBERTSSON 1976, DREWS and SEIBEL 1976). Especially the pentosanase activity is highly important since the pentosans of rye have the same influence on the baking properties of rye as proteins have in the case of wheat (DREWS 1971). It has also been shown that pentosans protect starch against amylolytic attack. If the pentosans that surround the starch granules are degraded, the same degree of amylolytic activity will have a much greater effect on starch hydrolysis than it has in the absence of degradation (DREWS and SEIBEL 1976). Thus the level of enzymatic activity greatly influences the technological value of rye.

The level of enzymatic activity can be reduced by heat. According to REED and THORN (1971) the optimum temperatures for α- and β-amylases of rye are 54—63° C and 48—51° C, respectively. In experiments simulating baking conditions WALDEN (1955) demonstrated destruction of 90 % of the wheat α- and β-amylase activities at about 85 and 75° C, respectively. Rye α-amylase appeared to be slightly more heat-sensitive than wheat α-amylase in experiments using ungerminated enzyme preparations (GREENWOOD and MILNE 1968). On the other hand, rye starch is gelatinized at a lower temperature than wheat starch (ALBERTSSON 1976), so amylolytic starch degradation at baking commences at an earlier stage in rye than in wheat.

Because of the high levels of α-amylase activity especially in the subaleurone layer of sprouted grain (DREWS and SEIBEL 1976) it is theoretically possible to suppress excess activity by heat restricted to these outer layers of the kernel. SCHÄFER and ALTROGGE (1960) and STRÖM and QUIST (1963) have reported studies based on these assumptions. In both investigations steam was used as the source of heat for the processing improved the baking quality of sprouted grain. STRÖM and QUIST (1963) examined their findings also on an industrial scale with success. Unfortunately the information given of the processing conditions is scanty. EDER and STADLMAIR (1970) tried warm conditioning lasting 2 hours in order to improve the baking quality of sprout-damaged rye but failed in these efforts.

This study deals with efforts to improve the technological quality of sprout-damaged rye by suppressing excess anzymatic activity by heat. The aim of the momentary heat treatment was to restrict the heat to the outer layers of the kernels so that the starch and the swelling substances which fundamentally contribute to the baking quality of rye should not be detrimentally affected during the processing.

Materials and Methods

The material of the experiments was a rye lot received from a grain silo of the State Granary. The cleaned rye had a moisture content of 13.8 %, the falling number value of 87 and crude protein content of 13.1 % (d.b.).

The heat treatments were performed at 80, 90 and 100° C for 10 sec periods up to 60 sec as described in Part I of this investigation dealing with wheat (Westermarck-Rosendahl and Salovaara 1978).

The whole grain was milled to rye meal on a hammer mill of Finnish manufacture (O-IPL, Koneteollisuus).

The falling numbers were determined according to the standard method (Anon. 1971). For amylograms 80 g (14 % m.c.) of rye meal was suspended by stirring in 450 ml of distilled water and poured into the Brabender Viscograph bowl. The thermostat drive was set at a starting temperature of 25° C and a rise of 1.5° C per minute to 95° C.

The rye baking formula included 15 g of pressed yeast, 15 g of NaCl, 425 ml of water and 500 g of rye meal calculated on a 15 % moisture basis. The doughs was mixed for 1 min in a Kenwood-household mixer, fermented for 60 min and proofed as a single dough piece for 30 min at 32° C and at a rH of 75—80 %. Baking was performed at 230° C for one hour. The loaves were evaluated about 20 hours after baking.

Results

Falling number test

The falling number values of the heat-treated sample are shown in Fig. 1. The hydrothermal treatment caused an increase in the falling number of every sample. The higher the temperature, the faster was the increase. After processing for 20 sec at 80° C the falling number increased to 12—15 units over the initial value of 87. It maintained this level throughout the experiment. At the temperatures of 80, 90 and 100° C the initial falling number rose to 102, 117 and 155, respectively, when treated for 30 sec. Heat-treating at 90° C

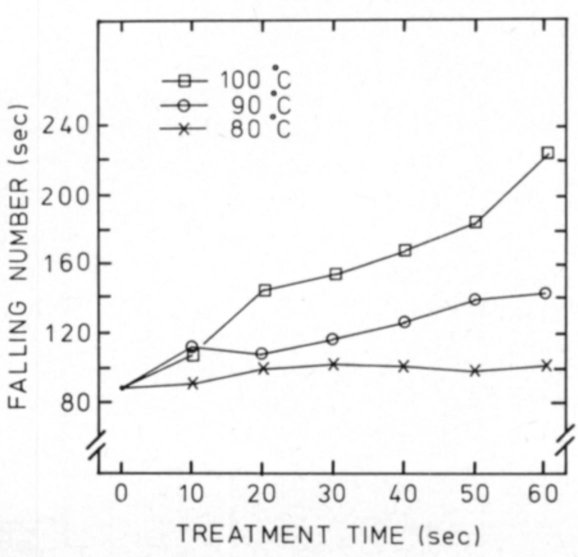

Fig. 1. Influence of hydrothermal treatment at three temperatures on the falling number value of sprout-damaged rye with the initial value of 87.

for 60 sec raised the falling number value as much as the treatment for 20 sec at 100° C, namely by 55 units. At 100° C the treatment for 60 sec raised the value with about 40 units higher than treatment for 50 sec.

Amylograph test

The value interpreted from the amylograms are shown in Table 1. Hydrothermal treatment at 90° C for more than 20 sec and at 100° C for all durations tested increased the peak viscosity beyond 1000 B.U. At 100° C the 1000 B.U. level was passed at 10 sec and the 2000 B.U. level at 30 sec. Already at 80° C the peak viscosity was markedly increased. The peak viscosity of the rye sample treated at 80° C for 40 sec was 820 B.U., and the sample treated at 90° C for 10 sec reached a slightly higher peak viscosity.

During the experiments performed at 80 and 90° C the peak temperatures of the amylograms decreased some degrees at the longer processing times, but at 100° C there was a slight increase of this value. The initial viscosities of all the samples were quite high at the beginning of the determinations.

The diastatic value increased in all the treated samples as compared with the initial value. The level of about 135 was reached already in the shortest processings at 90 and 100° C. At 80° C the same value was attained by the sample treated for 60 sec.

Table 1. Amylograph data of hydrothermally treated sprout-damaged rye.

Processing conditions (sec/° C)	Initial viscosity at 25°C (B.U.)	Peak temperature (° C)	Peak viscosity (B.U.)	Decrease in consistency[a] (B.U.)	Diastatic value[a]	Falling number (sec)
0/0[b]	100	60.0	350	320	109	87
10/80	60	60.0	550	470	117	90
20/80	110	60.0	650	560	116	99
30/80	100	59.0	760	610	125	102
40/80	120	59.0	820	670	122	100
50/80	100	56.5	805	655	130	99
60/80	220	58.5	980	730	134	101
10/90	180	59.0	825	615	134	112
20/90	180	58.5	960	710	135	105
30/90	170	58.5	1 200	880	136	117
40/90	180	58.0	1 390	970	143	126
50/90	210	56.5	1 680	1 200	140	140
60/90	220	57.0	1 810	1 290	140	142
10/100	150	59.0	1 180	860	137	109
20/100	130	59.0	1 290	970	133	142
30/100	180	59.0	2 340	1 760	133	155
40/100	130	60.0	2 200	1 550	142	168
50/100	120	60.0	2 100	1 430	147	184
60/100	180	60.0	2 390	1 650	145	223

a According to STEPHAN and EXNER (1971).

b Non-treated sample.

Baking tests

The baking characteristics of the rye samples heat-treated for 30 and 60 sec at 80 and for 10, 30 and 60 sec at 90 and 100° C are shown in Table 2.

Table 2. Baking characteristics of heat-treated sprout-damaged rye samples.

Processing conditions (sec/° C)	Loaf[a] volume (ml)	Weight loss at baking (%)	Loaf height/diameter After final proof (cm/cm)	Loaf height/diameter After baking (cm/cm)	Specific volume ml/g	Dough property
0/0[b]	1 175	25.5	0.15	0.16	1.76	Sticky
30/80	975	23.2	0.25	0.27	1.38	Sticky at dough making improved after fermentation
60/80	1 105	22.2	0.28	0.28	1.55	»
10/90	940	22.4	0.28	0.28	1.32	»
30/90	1 045	22.0	0.28	0.32	1.46	»
60/90	1 090	19.6	0.35	0.41	1.47	»
10/100	1 005	21.4	0.30	0.34	1.40	»
30/100	910	19.4	0.38	0.41	1.22	Not sticky, easy to handle
60/100	925	18.9	0.35	0.36	1.23	»

a The loaves contained 500 g of rye meal (m.c. 15 %).
b Non-treated sample.

The dough prepared of the untreated rye was sticky and difficult to form. The loaves spread out both at proofing and at baking, as is seen from the low value of 0.16 for the ratio between height and diameter. The crust of the loaves was thick and the crumb was dense, damp and of low elasticity. On cutting the crumb stuck to the knife. The porosity of the crumb was uneven. Under the crust there was a cavity around the loaf. The untreated rye gave the highest loaf volume and specific volume of the examined samples.

After the hydrothermal treatment some technological changes became apparent. Treatment at 80° C for 30 and 60 sec made the dough less sticky and easier to mold after fermentation. The loaves did not spread out as much as the non-treated sample, as is seen from the higher values for the ratio between height and diameter. On cutting the crumb adhered to the knife and the pores disrupted, The crumb was especially damp aftre the 30 sec treatment, but after 60 sec the damp area situated only in the centre of the loaves. Beneath the whole crust there was a cavity in all the loaves made of rye treated at 80° C.

Processing of the rye at 90° C did not diminish the stickiness of the dough at mixing but after fermentation the doughs were easier to mold. The loaf volumes were largest after the longest processing time but did not reach the volume of the untreated sample. After all the treatments the cavity under the crust was large, but after the longer precessing times the dampness of the crumb decreased. The dampness was restricted to the loaf centre when the rye had been treated for 30 sec, and only one of the parallel loaves made of rye treated for 60 sec showed a small damp area. The height of all the breads in this series was higher than that of the control loaves. All the loaves were of even porosity. The pores in the cut surface did not become compressed although some crumb still adhered to the knife when the grain had been processed for 30 sec. The 60 sec processing improved the elasticity of the crumb. The crust colour of loaves made of rye processed for 30 or 60 sec was a lighter brown than that of loaves of more moderately processed grain.

Heat treatment of the rye in boiling water for 30 or 60 sec eliminated the stickiness of the doughs already before fermentation. The bread volumes were quite low, as also were the specific volumes of the breads. The porosity was even in all the loaves of rye processed at 100° C, and at 10 sec the elasticity of the crumb was better than in the untreated sample. After 60 sec treatment the crumb elasticity was so good that a dent pressed with the finger was entirely restored. The cavity beneath the crust was formed during baking specifically in the loaves made of grain treated for 10 sec. These loaves also were a darker brown than the ones made of rye treated for 30 and 60 sec.

Discussion

All the heat treatments performed affected the viscous properties and so also the water-binding capacity of the rye meal. Such changes during hydrothermal processing are also reported in the literature (Altrogge and Schäfer 1960, Ström and Quist 1963, Eder and Stadlmair 1970). These changes are most clearly evident from the marked increases in the peak viscosities interpreted from the amylograms, as a consequence of stronger processing conditions.

The changes in viscosity of the heat-treated rye samples indicate suppression of α-amylase activity measured by the falling number and amylograph tests. But in the case of rye there has evidently occurred also suppression of enzymes that degrade other swelling substances and this contributes to the increased viscosity. Ström and Quist (1963) used the autolytic Molin method for estimating the α-activity in heat-treated rye lots and found the activities diminished compared with untreated samples. Schäfer and Altrogge (1960) used the maltose value with the same result. Eder and Stadlmair (1970) showed increasing maltose values at warm conditioning up to 75° C, but at 80° C the value dropped abruptly. These results are in agreement with the reported inactivation temperatures of α-amylase (Walden 1955, Jong 1967, Stephan 1976).

During the heat treatments at 80° C the peak viscosity showed a maximum increase of 630 B.U. although the falling number values increased by only about 15 units. The increases in the falling number values were more pronounced during processings at 90 and especially at 100° C. During momentary treatment with superheated steam Ström and Quist (1963) found changes in the falling number values which agree with the results of the present experiments in which the rye was immersed in boiling water. In the latter the falling number value exceeded 115 units at processing temperatures of 90 and 100° C for 30 and 20 sec, respectively. The value of 150 units was passed only at 100° C during processing lasting more than 20 sec. For Finnish industrial uses these two falling numbers are the minimum levels permissible for rye utilized in non-sour bread and crispbread production, respectively (ANON. 1975).

The maximum viscosity of the amylograms increased by 60–85 B.U. during steam conditioning of rye containing 4.8 % sprouted kernels (SCHÄFER and ALTROGGE 1960). Their experiments, however, were performed at essentially lower grain temperatures (54 and 63° C) and were of shorter duration than those in the present study. In spite of much longer processing times (2 h) during warm conditioning at 80° C performed by EDER and STADLMAIR (1970) the peak viscosity in their amylograms did not reach the high level found in the present experiments. But treatment at 85° C raised the viscosity markedly and at 90° C it exceeded the recording scale of 1000 B.U. This limit was passed in our experiment at 90° C and 30 sec as well as by all the samples processed at 100° C. Such high viscosity values are not recommendable for breadmaking (ROHRLICH and BRÜCKNER 1967).

According to STEPHAN (1976) a low peak temperature indicates high levels of enzymatic activity. This statement was found to be correct as far as the untreated sample was concerned, but the treatments at 80° and 90° C caused no increase but rather a decrease in the peak temperature. Some increasing tendency was shown after processing at 100° C.

As is seen from the diastatic value (STEPHAN and EXNER 1971) evaluated according to STEPHAN (1976), dampness of the bread crumb is decreased by heat treatments. The optimum range of the diastatic value 120–130 was exceeded when the processing temperatures of 90 and 100° C were applied. Also the swelling properties of the flour constituents at the dough stage increased, as illustrated by the rising viscosity values at 25° C.

The baking formula chosen included rye meal, yeast, salt and water and thus was not the optimal fromula for meal containing high or very low levels of starch degrading enzymes.

The cited two investigator teams (SCHÄFER and ALTROGGE 1960, STRÖM and QUIST 1963) who used steam as the source of heat at conditioning the grain do not present the methods of baking. EDER and STADLMAIR (1970) included 10 % wheat flour in the baking formula.

The first improving effects on the dough were observed after the fermentation stage as they were easier to handle and form. This occurred already at 80° C when the grain was processed for 30 sec. The dough stickiness was eliminated when processed at 100° C for 30 sec.

The bread volumes from all the heated samples, as also those in the cited experiments (SCHÄFER and ALTROGGE 1960, EDER and STADLMAIR 1970) were smaller than the volumes from the untreated sample. Information on the loaf volumes is not included in the research report of STRÖM and QUIST (1963).

The crumb characteristics, especially dampness, stickiness, prosity and elasticity, were improved in the samples treated at 90° C for 30 sec and longer and at 100° C. The crumb elasticity was really good when the rye had been immersed in boiling water for 60 sec. The large cavity under the crust of breads from some heat-treated samples was not present in the loaves made of grain treated in boiling water for 30 and 60 sec. Similar improvements were described also by Ström and Quist (1963) even with rye containing 11.1 % sprouted kernels. But Schäfer and Altrogge (1960) found rye lots containing 12.8 % sprouted kernels too damaged to be improved by the processing conditions used by them. Eder and Stadlmair (1970) found no improvement in the bake-ability of sprouted rye after warm conditioning; this they considered to depend on protein denaturation and starch damages during the processing. The authors emphasized the light colour of the loaf crust which also was observed in our baking tests with the samples exposed to severe processing. This is evidently explained by the suppressed maltose producing ability of β-amylase.

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SELOSTUS

Idäntävaurioituneen viljan hydroterminen käsittely. II. Vaikutukset rukiin teknologiseen laatuun.

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Idäntävaurioitunutta ruista, jonka sakoluku oli 87 lämpökäsiteltiin upottamalla viljaa 80, 90 ja 100° C veteen. Käsittely kesti pisimmillään 60 sek ja sitä seurasi välittömästi jäähdytys kylmään veteen upottamalla. Käsittelyn tarkoituksena oli vähentää liiallista α-amylaasiaktiivisuutta jyvien ulkokerroksissa. Muutokset rukiin laadussa todettiin sakoluvun määrityksellä, amylografilla ja leivontakokeilla, joissa käytettiin hiivaa mutta ei happolisäystä. Kaikilla suoritetuilla lämpökäsittelyillä oli vaikutuksia näillä menetelmillä saatuihin tuloksiin. 30 sek kestävä käsittely 80, 90 ja 100° C:ssa kohotti sakolukua arvoihin 102, 117 ja 155. Vastaavat sakolukuarvot 60 sekunnin käsittelyn jälkeen olivat 101, 142 ja 223. Amylogrammin piikin korkeus kasvoi huomattavasti. Yli 20 sekunnin käsittely 100 ja 90° C:ssa aiheutti maksimiviskositeetin nousun yli 1 000 B.U.:n. Viskositeetin maksimissa mitattu lämpötila oli kaikilla näytteillä melko alhainen ja siinä ilmeni hiukan laskua 80 ja 90° C:n käsittelylämpötiloissa. Kaikkien lämpökäsitellyistä ruiseristä valmistettujen leipien tilavuudet olivat pienemmät kuin käsittelemättömästä erästä valmistetulla leivällä oli. Pienimmät leipien tilavuudet saatiin näytteillä, joita oli käsitelty 30 ja 60 sek 100° C:ssa. Taikinoiden tarttuvuus väheni sen mukaan mitä ankarampi lämpökäsittely oli, ja samoin vähenivät leivän sisustan kosteus ja elastisuus. Kaikissa leivissä oli melko suuri onkalo kuoren alapuolella lukuun ottamatta niitä leipiä, jotka oli tehty 30 ja 60 sek 100° C:ssa käsitellystä rukiista. Eristä, jotka oli käsitelty 30 ja 60 sek 90 ja 100° C:ssa saatiin kuoren värin suhteen vaaleamman ruskeita leipiä kuin muista.