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Investigations on the quality of diploid and tetraploid rye in breadmaking

by

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INVESTIGATIONS ON THE QUALITY OF DIPLOID AND TETRAPLOID RYE FOR BREADMAKING[1]

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ABSTRACT

The baking quality of eight varieties of diploid rye grown at six locations in the Netherlands in 1948 was correlated with maltose value and amylase activity (both negatively), with maximum viscosity in the amylograph (positively), and with other properties associated with sprouting. Large interfield differences were found, whereas varietal differences were small.

Tetraploid rye was higher in protein content, lower in alpha-amylase activity, and superior in baking quality to diploid rye from different fields. The data indicate that tetraploid rye may be the more resistant to sprouting.

In western Europe the main objective in rye breeding is to improve yield, and such factors as disease resistance, winter hardiness, resistance to sprouting, and strength of straw are of direct importance. However, very little attention is given to baking quality of the grain in spite of the fact that in Scandinavia and in many districts of Germany the larger part of the rye crop is used for human consumption. Rye bread is eaten widely in the southern and eastern provinces of the Netherlands and the question of baking quality cannot be ignored.

The proper consideration of quality in a rye breeding program requires an adequate knowledge of the structural features and of the chemical and technological properties of the rye kernel which have an influence on baking quality. Although there is only limited knowledge in this field, important contributions have been made by investigators in western Europe during the past few decades. The extensive experiments of the Norwegian investigator, Schulerud (13), led him to stress the significance of starch and the starch-splitting enzymes; in the manufacture of rye bread, a correct balance between degree of gelatinization and amylolysis is essential for the formation of an elastic, porous, and uniform bread crumb. German investigations (8, 11, 12) with the Brabender Amylograph (2) have led to similar conclusions.

Aust and Ossent (1) ascertained that German varieties with a high protein content tended to exhibit a medium to low maltose-forming capacity, a property which served as a measure of the resistance of the grain to sprouting.

Pelshenke (10) and, later, Hintzer (4) studied several varieties grown in various districts and concluded that the degradation of starch

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during baking is predominantly influenced by conditions of growth, although there were indications that alpha-amylase activity also is a genetic factor.

In recent years, there has been considerable interest in tetraploid rye (3, 8, 14), but very limited information on its value for breadmaking is available. Kernels of tetraploid and diploid rye are illustrated in Fig. 1. The studies of Ljung (7) and of Müntzing (8) have shown that the tetraploid strains were higher in protein, ash, and crude fiber than the diploid strains and yielded bread of better volume, texture, and crumb color.

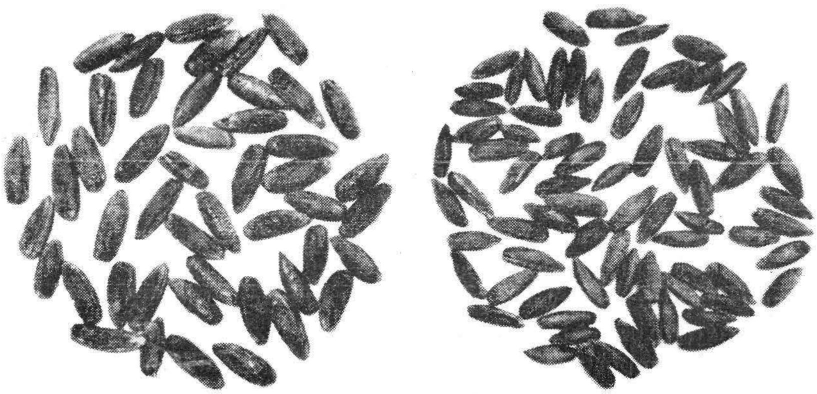

Fig. 1. Photographs of kernels of tetraploid (left) and diploid rye (right) showing the much larger size of the former.

The present studies were undertaken to secure additional information on the effect of variety and environment on the quality of diploid rye for breadmaking and to determine the relative quality of diploid and tetraploid rye grown in the Netherlands.

Materials and Methods

Two series of samples were employed. The first comprised 48 samples of diploid rye representing eight varieties (four Dutch, two German, one Belgian, and one Swedish), each grown in six districts in 1948. The second series consisted of 21 samples of tetraploid rye and nine samples of diploid rye grown in the crop years 1948 to 1951 inclusive. Strictly comparable diploid and tetraploid samples could not be obtained because they must be grown in different fields to prevent cross-pollination.

The investigation of these samples included determinations of hectoliter weight, 1000-kernel weight, protein content, alpha-amylase, maltose figure, amylogram properties, and the conduction of baking tests. With the exception of the first two properties, the investigations were carried out on fairly white flour (ash content, approximately 0.7%, dry matter basis) obtained by Bühler milling.

Hectoliter weight (kg. per hectoliter) and 1000-kernel weight (in g.) were determined in the usual way and the protein content was determined according to a modification of the Kjeldahl procedure, using a conversion factor of 5.83.

The alpha-amylase content was determined according to Hoskam (6). This method involves measurement of the decrease in color intensity with iodine when an aqueous extract of the flour or meal acts upon beta-limit dextrin solution at pH 5.3 and 30°C.

The maltose figure was determined according to the Rumsey procedure as modified by van der Lee (9), which involves the autolysis of the flour suspension for 60 min. at 27°C. The results are expressed as g. of maltose per 100 g. flour or meal. The corrected maltose figure is obtained by subtracting the reducing sugars (as maltose) originally present in the sample.

The amylogram, made by the Brabender Amylograph, represents the course of the viscosity of a suspension of 60 g. flour in 450 g. water upon heating to about 95°C., the temperature being raised at a rate of 1.5°C. per minute. From the amylograms, the following data were derived: 1) the maximum viscosity, expressed in Brabender units (B.U.); 2) the temperature (°C.) at which maximum viscosity is reached; and 3) the percentage decrease of the viscosity 5 minutes after the maximum.

Baking tests were carried out with rye flour and with rye meal. With the flour, a white pan bread was baked, which is normally not made in the Netherlands, but which in Denmark, Norway, and various districts in Germany is a popular food. This type of baking test is very attractive, since differences in quality are more clearly revealed by the better-developed shape and texture than in the case of brown rye bread, thus making a more precise evaluation possible. In the southern provinces of the Netherlands, rye meal is finely milled; in the eastern provinces, a more coarsely milled rye meal is made. Both are used for the preparation of a brown rye bread. In our experiments, the finely milled meal was baked to a brown hearth bread.

The formula for the baking test with rye flour was as follows: 100 parts (by weight) of flour, 2 parts of yeast, 2 parts of salt, and 61 parts of water were mixed for 5 minutes, followed by a first fermentation of 15 minutes (dough temperature 26° to 27°C.). The dough was divided into pieces for loaves of 600 g. and molded for pan bread. After a proof of 45 minutes, the loaves were baked for about 45 minutes at about 220°C.

In the baking test with rye meal, the following formula and procedure were used: 100 parts (by weight) of meal, 1 part of yeast, 1 part of salt, and 48 parts of water were mixed for 10 minutes, followed by a fermentation of 50 minutes (dough temperature 26° to 27°C.). The dough was divided into pieces for loaves of 650 g. and molded for oven plate loaves. After a proof of 45 minutes, the loaves were baked for 120 minutes at a temperature decreasing from about 210° to about 150°C.

The loaves were judged one day after being baked. Attention was paid to volume, shapeliness, color, and bloom of the crust and color and texture of the crumb. Great differences were especially noticeable in the degree of stickiness of the crumb. This quality was judged in two ways: viz., by external examination and by measurements. The external examination was expressed as a score number (higher according to the better quality of the bread, thus less sticky). The measurements were carried out with a compressimeter (panimeter) (5). A cylinder cut out of the bread is compressed by this instrument with gradually increasing stress; then the pressure is released and observation is made as to what percentage of the original height the bread cylinder recovers. This percentage, called "panimeter value," is a measure of crumb elasticity or lack of stickiness.

The percentage of soluble substance in the bread crumb was determined by extracting a certain amount of finely crumbled bread with water. After filtration the extract was evaporated on a water bath and dried to constant weight at 105°C. The results are expressed on a dry matter basis.

Results

Series I. Diploid Varieties, 1948 Crop. The mean analytical data for all diploid varieties grown at each of the six stations are recorded in Table I; the corresponding mean values for the eight individual varieties over all stations are given in Table II.

The station means show that the conditions under which the rye was grown had a great influence on baking quality and the various measures of amylase activity. These differences are to be attributed to the degree of sprouting, which has an important bearing on the level

TABLE I

ANALYTICAL DATA FOR DIPLOID RYE SAMPLES, 1948 HARVEST
FIELD MEANS FOR SIX VARIETIES

Properties	Experiment Field						
	E	C	A	B	D	F	Range[a]
Protein content (d. m. basis), %	7.9	7.0	7.7	6.9	8.5	8.2	1.6
Alpha-amylase activity, Hoskam units	0.85	1.10	1.70	2.40	3.81	9.34	8.49
Maltose figure (corrected), g maltose/100 g flour	0.75	0.89	0.99	0.92	1.38	1.24	0.63
Maximum viscosity, B.U.	673.00	647.00	528.00	506.00	414.00	365.00	308.00
Temperature at maximum viscosity, °C.	65.3	63.4	62.0	60.7	59.7	58.4	6.9
Viscosity decrease from maximum, %	34.5	36.1	49.3	60.0	57.0	67.9	33.4
Panimeter value (white bread)	78.0	75.0	74.0	67.0	62.0	53.0	25.0
Soluble substance (white bread, d. m. basis), %	23.6	23.8	27.8	31.0	33.4	41.8	18.2
Stickiness score (white bread)	3.63	3.31	3.06	1.88	1.31	0.50	3.13
Stickiness score (brown bread)	2.25	2.25	2.13	1.88	1.63	0.50	1.75

[a] Difference between maximum and minimum values.

of alpha-amylase activity. The samples from field F, which had the highest amylase activity, showed sprouts on visual examination; although sprouts were not clearly detected in the samples from the other fields, the analytical data show rather marked differences.

The varietal means over all stations show only minor differences; the only properties which differed significantly were the maltose figure and the degree of elasticity of white bread as determined with the panimeter.'

Simple correlations of alpha-amylase activity and of panimeter value with the various properties were obtained for varieties, stations, and the interaction (stations × varieties) by means of covariance analyses. These coefficients, recorded in Table III, show that those properties which depend upon the action of alpha-amylase on the starch are highly correlated.

Series II. Diploid and Tetraploid Ryes. The most important results of the comparative studies on the samples of diploid and tetraploid ryes are summarized in Fig. 2. With the exception of weight per 1000 kernels and protein content, the various analytical values are, in general, lower for the tetraploid than for the diploid samples. With tetraploid rye, the maximum viscosity, obtained by the amylograph test, is somewhat lower than would be expected from the maltose figure and the viscosity decrease from the maximum; this discrepancy

TABLE II

ANALYTICAL DATA FOR DIPLOID RYE SAMPLES, 1948 HARVEST
VARIETAL MEANS FOR EIGHT FIELDS

Properties	Varieties								
	I	II	III	IV	V	VI	VII	VIII	Range[a]
Protein content (d.m. basis), %	8.3	7.4	7.8	7.8	7.8	7.4	7.6	7.5	0.9
Alpha-amylase activity, Hoskam units	3.10	1.87	2.40	1.74	2.52	2.09	2.35	2.35	1.36
Maltose figure (corrected), g maltose/100 g flour	1.12	0.79	1.07	0.96	1.11	1.12	1.03	1.04	0.33
Maximum viscosity, B.U.	453.00	562.00	566.00	502.00	459.00	573.00	533.00	531.00	120.00
Temperature at maximum viscosity, °C.	59.8	62.8	60.6	61.8	61.0	62.6	61.9	62.1	3.0
Viscosity decrease from maximum, %	60.8	50.2	42.2	48.5	54.2	52.5	48.3	49.7	8.6
Panimeter value (white bread)	63.0	73.0	72.0	73.0	64.0	70.0	67.0	71.0	10.0
Soluble substance (white bread, d.m. basis), %	33.8	27.6	30.7	29.0	32.7	30.8	29.5	27.9	6.2
Stickiness score (white bread)	2.00	2.92	2.33	2.33	2.17	2.00	2.08	2.42	0.92
Stickiness score (brown bread)	1.50	2.00	1.83	1.50	2.00	1.83	1.67	1.83	0.50

[a] Difference between maximum and minimum values.

TABLE III

SIMPLE CORRELATION COEFFICIENTS BETWEEN SELECTED VARIABLES FOR FIELDS, VARIETIES, AND INTERACTION

Property	Correlations with Alpha-Amylase[a]			Correlations with White Bread Panimeter Value[a]		
	Between Fields	Between Varieties	Interaction	Between Fields	Between Varieties	Interaction
Protein content (d. m. basis), %	+0.47	+0.68	+0.26	−0.43	−0.62	−0.24
Alpha-amylase activity, Hoskam units	....	....	....	−0.98**	−0.83**	−0.59**
Maltose figure (corrected), g maltose/10 g flour	+0.83*	+0.68	+0.70**	−0.84**	−0.62	−0.41*
Maximum viscosity, B.U.	−0.97**	−0.53	+0.73**	+0.95**	+0.72*	+0.50**
Temperature at maximum viscosity, °C.	−0.96**	−0.80*	−0.63**	+0.96**	+0.62	+0.43**
Viscosity decrease from maximum, %	+0.94**	+0.51	+0.60**	−0.93**	−0.71*	−0.45**
Panimeter value (white bread)	−0.98**	−0.83*	−0.59**	....	....	....
Soluble substance (white bread, d. m. basis), %	+0.99**	+0.76	+0.83**	−0.97**	−0.84**	−0.50**
Stickiness score (white bread)	−0.98**	−0.56	−0.68**	+1.00**	+0.63	+0.61**
Stickiness score (brown bread)	−0.95**	−0.15	−0.36*	+0.92**	+0.07	+0.40*

[a] In fact, the logarithms of these properties were involved in the calculations, because they showed more rectilinear correlations with the other properties.
** Highly significant; value exceeds 1% point.
* Significant; value exceeds 5% point.

may be associated with the higher protein content and correspondingly lower starch content of the tetraploid rye.

Baking tests were also conducted on this series of samples and the breadmaking value of the tetraploid samples was superior to that of the diploid varieties. This finding is in line with the lower alpha-amylase activity of the tetraploid varieties. The photographs in Fig. 3 show that tetraploid rye gives very good bread, and show also the marked effect of extensive sprouting on the breadmaking value of diploid rye. In this loaf from the diploid sample, it would appear that a normal crumb structure was present originally, but collapsed after the crust formed as a result of the marked acceleration in alpha-amylase activity when the temperature increased during baking.

Discussion

The baking quality of rye in the humid climate of the Netherlands depends primarily on the extent of sprouting which results in an increase in alpha-amylase activity. This activity manifests itself in many ways and can be measured by direct as well as indirect methods with sufficient accuracy to provide satisfactory indexes of the relative breadmaking value of the various samples. This is established by the

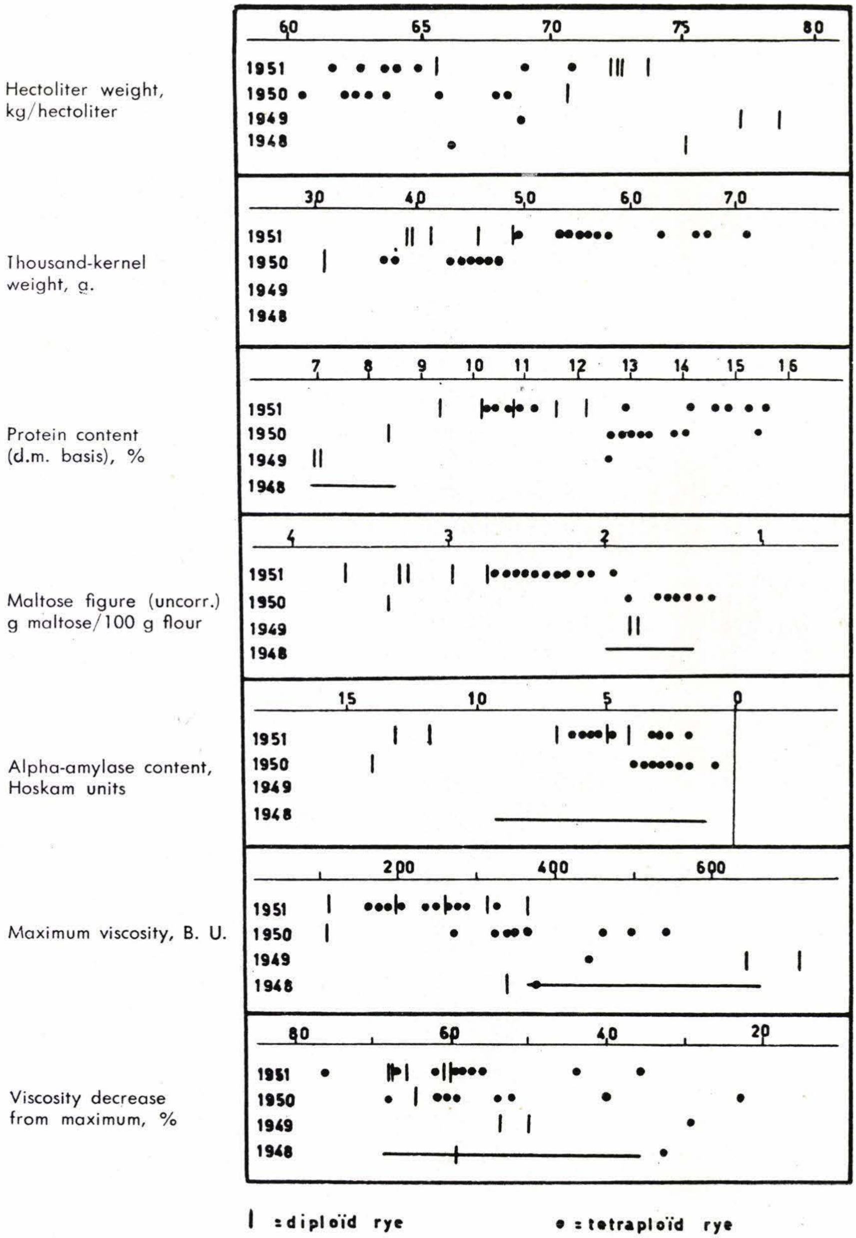

Fig. 2. Comparison of several properties of diploid and tetraploid rye. The horizontal lines indicate the regions of the values of Table I. The units for each property are arranged from left to right in order of their beneficial effects in relation to breadmaking.

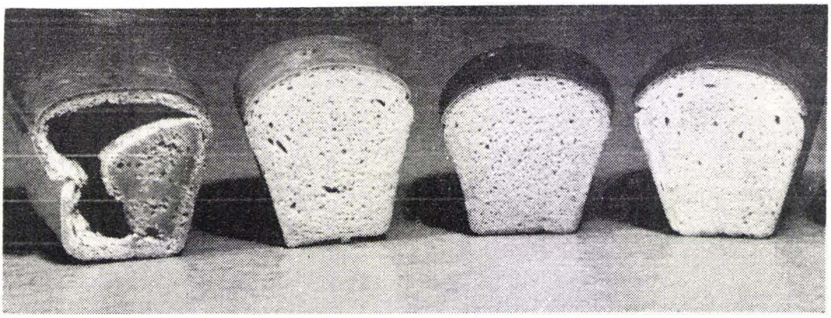

Fig. 3. Loaves of white bread made from rye flour from the 1950 crop. The loaf on the left, which shows extensive starch degradation, was made from diploid rye; the others are from tetraploid rye.

high correlation coefficients which were obtained between these measures and bread quality.

In comparison with environment, variety had relatively little influence on rye quality. This is to be expected because of the great importance of alpha-amylase activity which is increased by humid conditions. While no distinct varietal differences in alpha-amylase activity occurred, some variations in maltose figure and stickiness were noted; this may, perhaps, be due to differences in starch-susceptibility.

In the investigation of the tetraploid rye from various harvests in comparison with diploid rye, the most significant observation was that none of the samples of tetraploid rye showed high amylase activity, whereas several of the diploid samples did so. Although the number of samples was limited and those representing diploid and tetraploid rye did not come from the same field, these observations suggest that tetraploid rye is the more resistant to sprouting. This may be associated with the higher protein content, the larger size of the kernel and consequent increased endosperm content, or to a greater straw strength of the vigorous tetraploid plant, which permits less lodging. Further investigations will be necessary to determine the basic reasons for the differences between the tetraploid and diploid varieties.

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