A C T A   A L I M E N T A R I A   P O L O N I C A
Vol. XIV (XXXVIII), No. 3-4   1988

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EFFECT OF PHYSICOCHEMICAL PROPERTIES OF TRITICALE STARCH ON SELECTED INDICES OF BREAD QUALITY

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Key words: triticale starch, physicochemical characteristics, bread volume

Starches ware isolated from 28 Polish triticale lines by the laboratory method, and their fundamental physicochemical properties determined. Next, pup loaves were baced in the starch — gluten system (by the direct method) and the volume of the loaves was measured. The results were subjected to statistical analysis which showed a positive correlation between bread volume and viscosity of starch pastes.

INTRODUCTION

Till recently, baking properties were being attributed to gluten alone. However, Jongh [6] obtained breads with good texture and volume, replacing gluten with glycerin monostearate. Similar results were obtained by Rotsch (after [6]) who baked bread only from starch and viscous carbohydrates substances such as sodium alginate, pasted potato starch or maize starch. According to these authors it is starch rather than gluten that is the essential substance in baking.

Many authors investigated the function of starch during baking, without fully clarifying the issue. Alsberg [1] found that differrences in physicochemical properties of starches in various flours affect the starches' baking properties. It is belived that the following physicochemical properties of starches significantly affect their baking properties: density of starch granule [2], amylose-to-amylopectin ratio [4], total area of starch granule [13], capacity of adhesion to gluten and degree of granule damage [11].

So far, the effect of starch granule size and of starch pasting temperature on the baking properties of starch has not been elucidated [4, 12].

A literature survey reveals that not all of the important properties of starch were studied in connection with bread quality. Accordingly, we decided to investigate the effect on selected bread quality indices of the following starch properties: pasting characteristic, water binding, solubility in water, granule size, amylose content, and content of non-carbohydrate components of starch granule.

All these starch properties were studied previously in a large collection of 53 starches from Polish triticale lines [3-7, 12, 13]. With such detailed data on cereal starch in hand, it seemed worthwile to additionally study the effect of this starch on bread quality. To this end, model bread loaves were baked using one kind of gluten and triticale starches with various properties.

MATERIAL AND METHODS

The investigated starches were isolated by the laboratory method [3] from 28 Polish triticale lines, part of the voluminous research material described in [3-7, 12, 13]. The genetic origin and places of breeding of the lines are given in [3]. The following were determined in the studied starches:

1. Amylose content by photometric titration [10].
2. Protein content by Kjeldahl's method [10].
3. Fat content by Soxhlets method [10].
4. Phosphorus content by Marsh's method [7] after previous mineralization with concentrated nitric and sulfuric acids.
5. Per cent content of the various starch granules fractions with a Sartorius sedimentation balance in anhydrous ethyl alcohol.
6. Pasting characteristic of 7.4% water starch pastes in a Rheotest 2 rotational viscosimeter according to a basic program [3].
7. Flow curves of 7.2%water starch pastes in a Rheotest 2 rotational viscosimeter [3] at 50°C; the curves were used to calculate constants of the Ostwald-de Waele power model.
8. Water binding capacity and solubility in water at 60°C, by modified Leach's method [10].
9. Temperatures of pasting beginning and end by the microscopic method according to [10].

The analysed starches were used to prepare doughs, always with the same vital wheat gluten obtained from the Bundesforschungstalt for Getreide-und Kartoffelverarbeitung in Detmold, FRG (courtesy of professor W. Kemf). The gluten displayed the following features: dry substance — 93.2%, protein (N × 5.7) — 83%. starch — 6.7%.

In standard breads, the triticale starch was replaced with commercial wheat starch, produced in the FRG in 1983.

The breads were baked by the direct method. The dough was made of 40 g starch dry mass, 10 g gluten, 4 g sugar, 1.5 g salt, 0.5 g yeast and 35 cm^3 of water (at 30°C). Dough yield was 170. The dough was prepared as follows: all components were mixed together for five minutes, the first fermentation lasted 60 min and was followed by punch and a 30-min second fermentation; the final fermentation of 40 g portions of dough lasted 30 min, and baking (at 230°C) took 20 min. The loaves were weighed after removal from the oven and after cooling, and the results were used to calculate baking loss and total baking loss as well as bread yield. Also measured was the volume of the loaves in loose material. Crust colour and crumb elasticity were determined organoleptically, using bread quality scering system according to the standard [9].

RESULTS AND DISCUSSION

The triticale starches used in this investigation came from a larger collection of starches of this cereal. The criterion for their selection was considerable differentiation of all the analysed physicochemical properties. The analyses results are collected in Table 1 which gives the range of variability of these properties. Five of the starches used in our experiments had greatly reduced paste viscosity, namely maximum viscosity of 27-66 mPa·s, viscosity at 50°C amounting to 57-94 mPa·s, and intrinsic viscosity of 0.88-1.1 g/100 cm^{3-1}. The numbers of these starch samples are given in Table 3.

Table 1. Physicochemical properties of 28 triticale starches

Property	Range of mean determinations
Amylose content (%)	15.4-29.7
Protein content (%)	0.18-0.30
Eat content (%)	0.20-0.45
Phosphorus content (mg %)	32.5-50.5
Starch granule size (μm)	2-46
Content of various granule size fractions (%):	
≥31.1 μm	6-20
21.9-30.9 μm	18-45
13.8-21.8 μm	26-28
<13.8 μm	12-28
Pasting characteristic:	
pasting temperature (°C)	83-92
maximum viscosity (mPa·s)	27-474
temperature at maximum viscosity (°C)	91-94
viscosity at 96°C (mPa·s)	12-217
viscosity after 20 min at 96°C (mPa·s)	6-338
viscosity at 50°C (mPa·s)	57-930
Flow curves:	
"n" constant	0.44-1.0
"K" constant (mPa·s^n)	33-7966
Intrinsic viscosity (g/100 $cm^3)^{-1}$	0.88-1.1
Degree of water binding at 60°C (%)	4.99-6.75
Solubility in water at 60°C (g/l g dry mass of starch)	2.44-16.44
Pasting temperatures (°C):	
beginning of pasting (t_p)	50.5-53.0
end of pasting (t_k)	54.0-58.0
pasting temperature range (t_k-t_p)	2.5-6.0

Table 2. Baking indices and selected qualitative features of experimental breads

Property	Loaves baked with triticale starch (variability range)	Standard loaves baked with wheat starch
Loaf volume (cm^3)	40.0-82.5	60.0
Crumb elasticity	excellent to satisfactory	satisfactory
Crust colour	specific, slightly lighter or darker, very light	slightly darker or lighter
Baking loss (%)	13.0-19.0	17.5
Total baking losses (%)	16.0-21.0	19.0
Bread yield (%)	134-142	138

Table 3. Comparison of paste viscosity, loaf volume and selected parameters of baking, of starch with lowest viscosity with starches from the remaining triticale samples and with standard wheat starch

Sample	Viscosity at 96°C (mPa·s)	Viscosity at 50°C (mPa·s)	Loaf volume (cm^3)	Baking loss (%)	Total baking losses (%)	Bread yield (%)
No. 22	24	94	49	14.3	16.3	142.4
No. 30	39	124	40	16.3	18.0	139.4
No. 33	12	57	40	15.0	18.0	139.4
No. 43	12	60	50	13.0	16.3	142.4
No. 44	21	69	46	16.8	18.8	138.1
Mean	22	81	45	15.1	17.5	140.3
Mean for remaining samples	97	648	61.6	17.3	19.8	136.4
Wheat starch	233	355	60	17.5	19.0	138.0

The pasting characteristic of the standard wheat starch was determined. The viscosity of paste of this starch in the various points of the pasting characteristic was as follows: maximum viscosity — 245 mPa·s, viscosity at 90°C — 233 mPa·s viscosity after 20 min, at 96°C — 211 mPa·s, viscosity after cooling to 50°C — 355 mPa·s.

Results of quality checks of the obtained bread loaves are presented in Table 2 and in Photo 1. As can be seen, breads baked with starches selected according to the mentionad criteria differed as to volume, shape, crust colour, crumb elasticity, baking loss, total baking loss and yeald.

Loaves baked with starches of low-viscosity pastes had the lowest volume, baking loss, total baking losses, and the highest yield (Table 3). They were also marked by very light crust, poorly elastic crumb (graded as barely satisfactory) and untypical round shape, different from the shape of the rectangular mould in which they were baked (Photo 2). It seems that this considerable difference, both

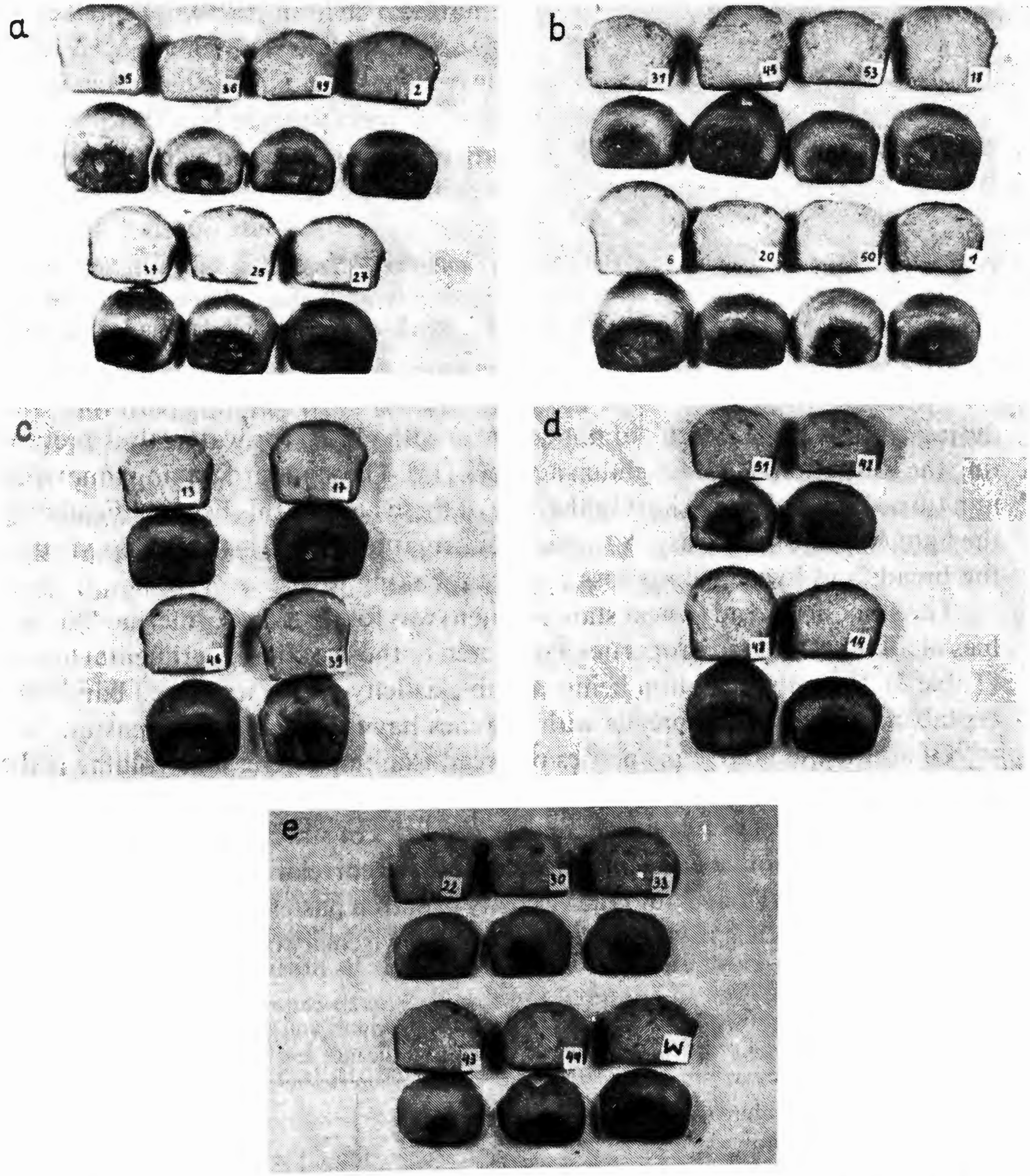

Photo 1. Outward appearance of experimental breads. Loaves baked with triticale starch with the following paste viscosities at maximum: a — 402-474 mPa.s, b — 302-344 mPa.s, c — 287-299 mPa.s, d — 139-199 mPa.s, e — 27-66 mPa.s; "w" standard bread baked with wheat starch (paste viscosity at maximum — 245 mPa.s)

as regards bread quality and baking indices, is due to an earlier hydrolysis of the starches [8] with the consequent poorer binding of water which was always added in the same amount to obtain the dough yield of 170. The result of this was that the dough made with these starches was of a loose consistence caused by an excess of unbound water. This amount of water apparently did not favour the formation of a suitable dough structure during fermentation and its preservation

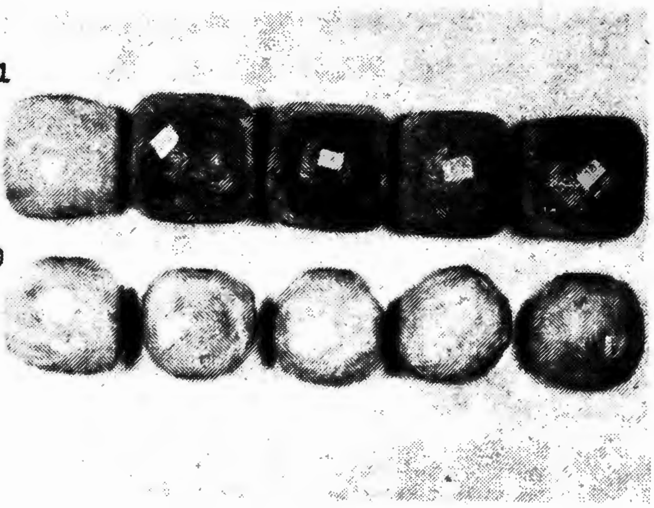

Photo 2. Top view of selected loaves; a — typically shaped loaves, b — round loaves baked with starch hauing low-viscosity pastes

during baking, since starch did not compete with gluten for water, thus preventing the formation of a rigid gluten network [11]. The standard baking time of 20 min turned out to be too short in the case of these breads, this being indicated by the light colour of the crust. A further confirmation of this is the higher yield of the bread, and lower baking loss and total baking loss.

The standard bread (wheat starch-gluten) was found to have intermediate values of all the estimated properties, compared to those of the experimental loaves (Table 2), the only exception being crumb elasticity which was rated barely acceptable, similarly as in breads with starches having low-viscosity pastes.

Of all the qualitative properties of bread examined here, loaf volume is the most definitive indicator of quality, and so statistical analysis was performed to determine the effect of physicochemical properties of starch on this feature. The obtained correlation coefficients showed positive correlation between the volume of experimental loaves and the viscosity of starch pastes (Table 4). Moreover, the starch features negatively correlated with the viscosity of starch pastes [8], the

Table 4. Coefficients of correlation between loaf volume and selected physicochemical properties of triticale starch (significance level $\alpha = 0.05$)

Pasting temperature (Rheotest 2)	r = −0.66
Intrinsic viscosity	r = +0.56
Solubility at 60°C	r = −0.54
Protein content	r = −0.54
"n" constant	r = −0.49
Viscosity at 96°C	r = +0.46
Viscosity at 50°C	r = +0.45
Per cent content of granules measuring 21.9-30.9 μm	r = +0.44

constant of Ostwald's and de Waele's power model "n" and solubility, also turned out to be negatively correlated with loaf volume.

The results of this research do not corroborate the findings of D'Appolonia et al. [2] who did not obtain any correlation between loaf volume and starch paste viscosity, despite the fact that they also baked their bread in the wheat starch-gluten system. However, in their research, these authors did not use starches with paste viscosity as diverse as in our experiments. Also, in our studies we used starch extracted from a different cereal species.

We also found positive correlation between loaf volume and starch granule size (expressed as per cent content of granules measuring 21.9-30.9 μm), and negative correlation between loaf volume and pasting temperature determined in a Rheotest 2 viscometer.

As regards the non-carbohydrates components of starch, only protein content was found to be negatively correlated with loaf volume.

It seems that we managed to ascertain these correlations because we used starches of only one cereal species (triticale) in our experiments, unlike other authors who used starches from several species [4, 12].

In all, the reported results confirm the significant effect of starch properties on the quality of bread. Starch paste viscosity was found to clearly affect not only loaf volume, but also loaf shape and elasticity of the crumb, something never reported previously by other authors. The results also indicate the dependences between starch granule size and pasting temperature and loaf volume.

CONCLUSIONS

1. Statistical analysis revealed positive correlation between bread loaf volume and triticale starch paste viscosity and starch granule size, and negative correlation between loaf volume and triticale starch pasting temperature and protein content in this starch.
2. The use of triticale starch having low-viscosity pastes in baking had an adverse effect not only on loaf volume, but also on loaf shape and crumb elasticity, in the examined condition of dough preparation and baking.
3. All triticale starches except those characterized by very low paste viscosities promoted satisfactory quality of the experimental breads, despite their widely varied physicochemical properties.

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Manuscript received: September, 1986
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WPŁYW FIZYKOCHEMICZNYCH WŁAŚCIWOŚCI SKROBI Z PSZENŻYTA NA WYBRANE WSKAŹNIKI JAKOŚCI CHLEBA

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Streszczenie

Skrobie wyizolowane metodą laboratoryjną z 28 polskich rodów pszenżyta przebadano pod względem ich właściwości fizykochemicznych. Używając tego samego glutenu i różnych próbek skrobi z pszenżyta wypiekano chlebki metodą bezpośrednią w systemie skrobia-gluten. Oznaczano: upiek, stratę wypiekową całkowitą, wydajność oraz barwę skórki i elastyczność miękiszu chlebków. Fizykochemiczne właściwości skrobi oraz objętość otrzymanych chlebków poddano analizie statystycznej. Wykazała ona korelacje pomiędzy objętością otrzymanych chlebków a: lepkością kleików w temp. 50°C (r = +0,45), wielkością ziarenek skrobiowych (% ziarenek o wielkości 21,9-30,9 um: r = +0,44), temperatura kleikowania (r = −0,66) oraz zawartością białka (r = −0,54). Wydaje się więc, że te właściwości fizykochemiczne skrobi w sposób istotny wpływały na objętość chlebków. Nie wykazano istotnej zależności pomiędzy objętością chlebków a: stopniem wiązania wody i rozpuszczalności skrobi pszenżytnej w wodzie, zawartością amylozy oraz zawartością tłuszczu i fosforu w skrobi z pszenżyta.