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# TECHNOLOGICAL AND SENSORY ASPECTS OF NEW RESISTANT STARCH PREPARATIONS USED IN BAKING PROCESS

Abstract

Among polysaccharides occurring in food products, only starch and glycogen are completely digested. Rich sources of resistant starch are starchy food products after hydrothermal treatments, being obtained with share of chemically-modified starch, or thermally-dehydrated foods. Bread is also a source of resistant starch. Because of high consumption of bread in our climatic zone, it was interesting to know how the addition of new preparations of resistant starch, being obtained from physically-modified wheat, potato, maize and tapioca starches, would affect the technological and sensory qualities of the final product and its level of RS.

Based on the results of experiment, in which wheat dough was prepared with 10% share of RS-preparations from different botanic origin, it could be observed that the water absorption of flour mixed with RS-preparations increased from 4 to 7%. The rheological properties of dough from commercial wheat flour of poor technological quality with the share of RS-preparations were slightly changed since the time of dough development was lengthened, consistency of dough was improved, and its structure stability was weakened during kneading. Farinographic quality number (FQN) decreased, as compared to control in the same degree irrespective of the type of investigated RS-preparation.

On a basis of the results of panel evaluation by profile method, in which 16 quality factors and total desirability in hedonic terms were considered, it was found that the wheat RS-preparation affected most favourably the taste and smell qualities. Tapioca and maize RS-preparations favoured less advantageous quality factors such as plain and floury.

The examination of rheological properties of bread crumb showed that hardness of fresh breads, 1h after baking, was higher for breads with RS-preparations compared to control bread. The instrumental measurements confirmed the expected decrease of elasticity and cohesiveness in fresh and 24- and 72h-stored breads. These results suggest lower staling of bread, particularly with wheat and potato RS-preparations.

The RS contents measurements as determined with involvement of salivary α-amylase during chewing, show the increasing tendency for all RS preparations.

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## Introduction

Starch is quantitatively the most important food carbohydrate and along with glycogen is the only digestible food polysaccharide. The way and rate of enzymatic hydrolysis of dietary starch depend to a considerable degree on starch interaction with other food components and conditions of technological process. Hydrolysis of starch is initiated by salivary amylase and is completed in the small intenstine. Thus, in starchy foods the proportion between starch in solution, partially degraded starch, and glucose gives the same glycemic and insulin responses as their equivalent amounts (Wahlqvist et al, 1978). However glycemic index of starchy food varies widely because of food properties that affect the availability of starch for enzymatic degradation (Björck et al, 1994). One of the richer sources of resistant starch are food products after hydrothermal treatment which were obtained with the share of chemically modified or retrograded starches. Resistant starch was first discovered as a starch fraction that was associated with the non-starch polysaccharides in dietary fibre. Most frequently it is retrograded amylose (Siljeström et al, 1989), which is one of many forms of physically resistant starch that pass through the small intestine (Englyst et al, 1992).

The extent the resistant starch is present in foods depend on botanical source of starch and number of factors, including the type of processing. The most important sources of dietary starch are cereal products. As Liljeberg et al. (1996) report, the estimated annual intake of bread in European countries ranges from 46 to 100 kg per person. Attempts to change the resistant starch (RS) intake in a mixed diet should thus focus on optimizing the RS content in rolls or bread. Higher resistant starch content in food, escapes digestion in small intestine, improves long-term glycaemic and lipid metabolism through the short-chain fatty acids produced during its fermentation (Muir et al., 1993). Resistant starch is particularly prone to generating butyric acid upon fermentation in colon (Scheppach et al., 1988) and might have a protective effects against colonic diseases.

The purpose of present study was to see if it is possible to increase the amount of resistant starch in wheat bread by including the RS-preparations from different botanic sources to dough before fermentation and to assess the technological and sensory effects.

## Material and methods

### *Material*

Basic material for baking experiment was commercial wheat flour with characteristics as shown in Table 1. Resistant starch preparations were obtained from commercial wheat (RSW), potato (RSP), maize (RSM) and tapioca (RST) starches produced by the physical processes acc. to Polish patent specification No. P.325981. The preparations were made of particles smaller than 200 μm. Chemical and functional characteristics of these RS-preparations is shown in Table 2.

Table 1

Chemical components and technological properties of commercial wheat flour

| **Wheat flour** | |
|---|---|
| **Chemical components:** | |
| Moisture [%] | 15.0 |
| Starch [%d.m.] | 84.2 |
| Proteins [% d.m.] | 12.1 |
| Ash [% d.m.] | 0.6 |
| **Quality and quantity of gluten proteins:** | |
| Sedimentation index | 32 |
| Amount of wet gluten [%] | 37.2 |
| Elasticity of gluten [degree] | 3 |
| Deliquescence of gluten [mm] | 22 |
| Moisture of wet gluten [%] | 33.8 |

Table 2

Granulation of commercial wheat flour

| Eyelet [μm] | Amount of flour [%] |
|---|---|
| >265 | 0.03 |
| >150 | 6.44 |
| >120 | 3.48 |
| >105 | 17.96 |
| >95 | 11.37 |
| <95 | 59.34 |
| sum | 98.62 |

## *Experiment*

One-phase baking experiment was carried out after 1h fermentation.

The control sample contained: 100g commercial wheat flour, 3g yeast, 1g salt and the addition of water that enabled to kneed the dough, after determining the flour water absorption from farinographic curves for the dough consistency at 350 B.U. The experimental samples were prepared on a basis of the same as above composition, using instead the wheat flour mixture of 90g wheat flour and 10g addition of resistant starch preparations from wheat (+RSW), potato (+RSP), maize (+RSM), and tapioca (+RST). Baking was carried out at 220°C for 30 min. The size of pieces was 250g.

***Methods***

Chemical composition was analysed by standard AOAC methods.

The *in vitro* resistant starch content was determined acc. to modified Berry method described by Champ (1992). The content of resistant starch in *in vivo* simulated conditions was determined acc. to Asp et al (1992) in modification by Granfeidt (1992) method.

**Functional properties:**

- water holding capacity (WHC) was determined for 5g d.m. of starch suspended in 75 $cm^3$ of distilled water at 20°C. Suspension was shaken for 1 h. Centrifugation was made at 2200 x g for 10min and the mass of water holding per 1g starch d.m. was determined.
- oil absorption was determined after mixing 0.5g d.m. of starch with 3 $cm^3$ sunflower oil for 1min at 200 rpm, standing 30 min at 20°C and centrifuging at 1700 x g for 30 min. The supernatant was discarded by turning the tube for 30min. The increase in weight per 1g starch d.m. was measured for oil absorption.

***Technological characteristics***: amount and quality of gluten proteins, including sedimentation test was determine acc. to Polish Standards No PN-77/A-74041 and PN-77/A-74019. It was measured water absorption of flour acc. to farinographic curves at 500B.U. and its technological value from farinographic curves acc. to AACC method, and farinographic quality number (FQN) acc. to ICC methods (Schogll, 1995; ICC Standard no. 155).

***Sensory analysis*** was carried out by an 11 member panel using profile sensory method – Quantitative Description Analysis (QDA). The panelists evaluated 16 quality factors: colour, taste, smell, texture and desirability in hedonic scale degree of liking. Computer program ANALSENS was used to prepare test, record individual scores, and make statistical analysis of results.

***Texture analysis***: texture properties of crumbs were measured using compression device of Instron 1011 (Juston, England). The samples, size 20 x 20 x 20 mm, were twice compressed to 70% strain at 10 mm/min crosshead speed. Hardness expressed as maximum force during first compression, $F_1$ [MPa], elasticity expressed as ratio of maximum forces determined in second and first compression, $F_2/F_1$ [-], cohesiveness expressed as ratio of energies determined in second and first compressions, $E_2/E_1$ [-], and gumminess characterized by expression, $F_1$ x ($E_2$ /$E_1$) [MPa], were calculated according to Mohan Rao and Skiner (1986). Four replications were made for each loaf.

## Results and discussion

Commercial wheat flour, the basic raw material in technological experiment, contained a standard amount of total protein, including a considerable amount of gluten, as wet gluten (Table 1). On a basis of sedimentation test, indicative of hydration properties of gluten fractions, gliadine and glutenin, it can be however said that the quality of proteins responsible for dough structure was poor. This would also indicate two other quality factors of hydrated and isolated gluten; elasticity of gluten and deliquescence of gluten. The quality of starch in wheat flour was indirectly determined by the analysis of flour granulation, according to which the particles below 100μm made over 70% of the mass (Table 2). Thus, the amount of particles with the granulation between 265μm to 100μm was too low, proving highly developed surface of particles in the flour and a possible mechanical damage of a certain amount of starch granules during milling.

The characteristics of resistant starch preparations showed that the greatest amount of resistant starch was present in potato starch preparation (~32%). The other preparations followed the order: wheat>maize>tapioca (Table 3). Analysing the functional properties for water holding capacity (WHC) of the examined RS-preparations it was found that all of them absorbed at least 3.5g water per 1g d.m. of sample. Slightly higher absorption of water showed tapioca and wheat RS-preparations. The affinity for oil was characteristically higher for potato starch preparation, and wheat starch preparation had the smallest oil absorption ability.

Such behaviour of RS-preparations against oil was determined by native structure of the starches, particularly B-type, inclusive fat-free potato starch and A-type wheat starch containing bound fat, mostly polar glyco-and phospholipids (Soral-Śmietana, 1992, Soral-Śmietana et al, 1997).

Table 3

Chemical and physico-chemical characteristics of investigated resistant starch preparations

| Components / Properties | Preparation from starches: | | | |
|---|---|---|---|---|
| | **Wheat (RSW)** | **Potato (RSP)** | **Maize (RSM)** | **Tapioca (RST)** |
| **Components:** | | | | |
| resistant starch [% d.m.]* | 28.4 | 31.8 | 22.5 | 18.9 |
| ash [% d.m.] | 0.3 | 0.5 | 0.3 | 0.3 |
| moisture [%] | 10.0 | 11.5 | 10.5 | 11.0 |
| **Properties:** | | | | |
| water holding capacity [g $H_2O$/g d.m. sample] | 3.8 | 3.6 | 3.5 | 3.9 |
| oil absorption [g oil/g d.m. sample] | 1.1 | 1.5 | 1.2 | 1.0 |

* measured modified Berry method described by Champ

Based on farinographic measurements of water absorption of wheat flour and experimental mixtures of wheat flour with the preparations containing starch resistant to amylases from different sources, it was observed that the incorporation of RS-preparations to dough required to increase the addition of water to obtain the farinograph curve of consistency 500 B.U. (Table 4). Inclusion of the RS-preparations obtained from cereal starch, potato starch and tapioca starch required to increase the addition of water by 5%, 4% and 7%, respectively, as compared to control flour.

Table 4

Technological values of wheat flour and mixed with resistant starch preparations to farinographic curves acc. to AACC method

| **Farinographic parameters from normal curve (500 B.U.)** | **Samples of dough** | | | | |
|---|---|---|---|---|---|
| | **Control** | **with RSW** | **with RSP** | **with RSM** | **with RST** |
| Water absorption [%] | 54.8 | 60.0 | 58.6 | 60.0 | 61.6 |
| Arrival time [min.] | 0.5 | 0.7 | 0.5 | 0.5 | 1.0 |
| Stability time [min.] | 4.8 | 3.2 | 3.5 | 3.0 | 2.8 |
| Resistance of dough to kneeding [min.] | 5.3 | 3.9 | 4.0 | 3.5 | 3.8 |
| Peak time [min.] | 1.5 | 1.6 | 1.5 | 1.5 | 1.8 |
| Time to breakdown [min.] | 6.9 | 4.8 | 5.0 | 5.0 | 5.0 |
| Tolerance index [B.U.] | 120.0 | 190.0 | 200.0 | 180.0 | 150.0 |
| Farinographic quality number [FQN] | 69.0 | 48.0 | 50.0 | 50.0 | 50.0 |

Table 5

The resistant starch contents in bread crumb

| **Bread crumb** | **Resistant starch content* [% d.m.]** |
|---|---|
| Control | 4.39 ± 0.47 |
| with RSW | 4.27 ± 2.17 |
| with RSP | 4.64 ± 1.49 |
| with RSM | 4.72 ± 1.45 |
| with RST | 4.75 ± 2.23 |

* measured acc. to Asp modified by Granfeidt method.

Analysis of farinographic curves (Table 4) showed that arrival time was lengthened the most when tapioca RS-preparation was used, whereas it lengthened slightly for wheat RS-preparation. The contribution of RS-preparations in the formation of wheat dough structure generally shortened the time of dough stability and resistance time to kneeding. Both these parameters were distincly different using RSM and RST. Although the time to breakdown was similar for all RS-preparations, it was shorter by about 2 min. than for control sample. The tolerance index had a bigger value for all mixtures than for control, but the smaller difference was for RST. Comparing new parameter acc. to ICC, fariographic quality number (FQN), is the lenght from the first addition of the water to the time at which the consistency has decreased 30 B.U. from the peak point, it could be observed a similar tendency as for the measurements of time to breakdown.

Based on characteristics of the farinographic curve it can be said that during dough formation the participation of the examined RS-preparations produced a competition for water with native structure-forming flour polymers proteins and starch. This is confirmed by the results in table 3 and table 4. Elongation of arrival time in the case of RST and RSW preparations suggests that higher affinity of both these preparations to water disturbed the hydration of gluten proteins and then the formation of spatial gluten network. This phenomenon caused the formation of a weaker quaternary structure, less resistant to mechanical action of mixers. It may be also supposed that competitive and diversified water affinity of all polymeric structures in the mixture allowed the interactions between wheat protein and RS-preparation to be occurred more quickly and decreased the possibility for an overtaking hydration and stabilization of protein within the structure of spatial network.

Additionally, the 10g share of RS-preparation relative to 90g of wheat flour causes a certain dilution of the proteins able to form gluten network of dough. It may be also supposed that included RS-preparation can be located due to water absorption and swelling in the gluten network on inert supporting-filling structures being caused by wheat starch – wheat protein – RS-preparation interactions.

Based on *in vivo* simulated determination of resistant starch content in experimental bread crumb it was observed a tendency that the average resistant starch content increased with the addition of all RS-preparations (Table 5), although the most labile enzymatic susceptibility (standard deviation value) of resistant starch had the bread crumb with RSW and RST preparations. The assumption then that wheat starch non-susceptible for amylases, formed upon reactions of colloids from the same botanic source, may be formed via physical forces or physico-chemical interactions, showing a considerable amylolytic lability. A similar behaviour of variable susceptibility was also observed in the case of RST-preparation, however, in this case the source of resistant starch was starch with a small amount of amylose. It is assumed that the co-formation of resistant starch within the fraction amylose/amylopectin of wheat flour and amylopectin of tapioca starch gives structures less resistant to hydrolytic action of amylases. The ability for the formation of resistant starch structures during production of this preparation also appeared the smallest (Table 3).

Profile sensory analysis performed for 16 factors of colour, smell, taste and hedonic sensations showed no statistically significant differences between the share of resistant starch preparations (Table 6, Fig. 1). Among the sensory factors analysed for bread samples with RS preparations, the following ones dominated, as compared to control bread: crumb color and elasticity, smell and taste of bread, and mastication. Unfavourable smells, like floury, yeasty or sour and tastes, i.e. sweet, salty and insipid reached the low level in profile analysis. Distinctly higher intensity of measurements were also noted for mastication of samples with RS-preparations. It also turns attention that on a basis of evaluation of desirability, the control bread was scored the least (Fig. 2). Therefore, it can be said that despite the effect of RS-preparations on the compactness of gluten protein structure, the barrier for gases generated during fermentation, the products of smaller volume but with better dispersion of gases in the crumb structure can be obtained.

Table 6

Results of sensory profiling of bread with share of RS-preparations

| Quality factors | Samples of bread (0-10 point) | | | | |
|---|---|---|---|---|---|
| | Control | with RSW | with RSP | with RSM | with RST |
| C. crumb | 5.95 | 5.06 | 6.47 | 6.07 | 6.43 |
| C. peel | 7.19 | 5.14 | 5.36 | 6.18 | 7.14 |
| Porosity | 6.02 | 5.54 | 4.42 | 3.93 | 5.51 |
| Size of pore | 5.46 | 3.84 | 5.14 | 4.52 | 6.30 |
| Elasticity | 6.20 | 8.12 | 6.09 | 7.35 | 6.68 |
| S. bread | 4.05 | 4.32 | 4.03 | 4.23 | 3.26 |
| S. roll | 4.00 | 3.54 | 3.95 | 3.80 | 4.33 |
| S. floury | 2.96 | 2.27 | 2.35 | 2.88 | 2.48 |
| S. yeasty | 1.77 | 1.89 | 2.14 | 1.58 | 1.66 |
| S. sour | 1.64 | 1.37 | 2.20 | 1.91 | 1.76 |
| T. bread | 3.12 | 4.15 | 4.90 | 4.18 | 3.98 |
| T. roll | 3.08 | 3.57 | 3.34 | 3.23 | 2.89 |
| T. sweet | 2.08 | 3.03 | 2.21 | 1.95 | 2.38 |
| T. salty | 1.00 | 0.96 | 1.35 | 0.97 | 0.81 |
| T. insipid | 2.57 | 1.25 | 1.05 | 1.23 | 2.10 |
| Mastication | 5.04 | 7.09 | 6.05 | 7.21 | 4.72 |

C – colour, S – smell, T – taste.

Instrumental measurements of texture of experimental bread crumbs included hardness, guminess, elasticity and cohesiveness, as determined after 1, 24 and 72h from the baking (Fig. 3A and 3B). The analysis of hardness after 1h from baking showed that all bread crumbs with

RS-preparations were harder than control crumb. This phenomenon intensified during 72h storage, except breads with RSW- and RSP-preparations. A decrease of guminess was observed during storage in all breads with RS-preparations. Fresh bread with RSW-preparation had the highest guminess that turned to be the lowest after 72h. Despite large differences in hardness, the values for crumb elasticity were within a narrow range. The changes of cohesiveness during 72h were smaller for experimental samples than control sample. The results for rheological properties of bread with RS-preparations, from wheat and potato starches allow to say that experimental breads remained fresh during 72h without the necessity for using improvers.

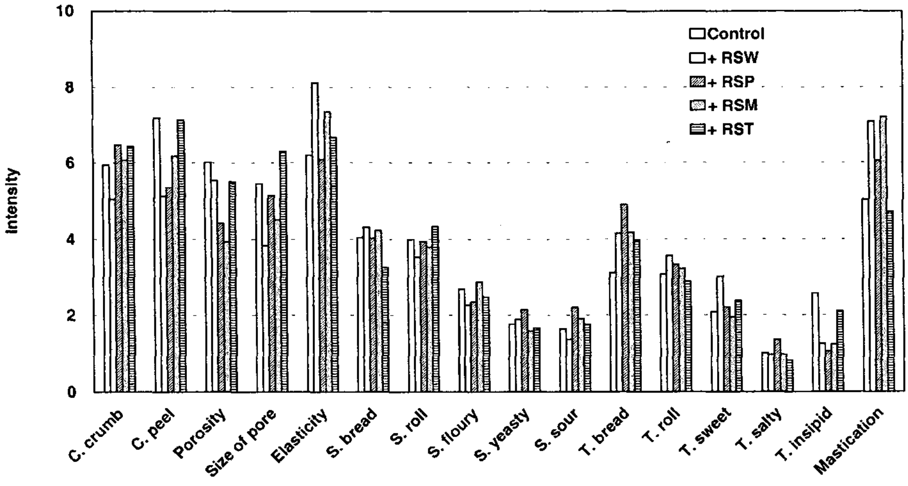


Fig. 1. Sensory profiling of bread with share of RS-preparations.

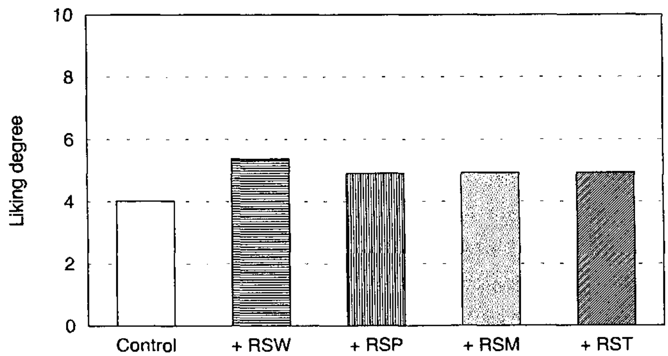


Fig. 2. Liking degree of bread with share of resistant starch preparations.

Gelatinization, which takes place in baking process, is the first step in many cases of starch utilization whereby native granular structure is partially or completelly disrupted. Swelling and solubility of starch granules is a function of temperature and indicate two levels of bonding forces within a granule structure. Donovan (1979) put forward the hypothesis that the gelation process is one of disorder being aided by the swelling action of water in the amorphous phase. In the literature, this process has been referred to as water-mediated, and as solvation or hydration-assisted melting. Donovan further described the gelatinization phase transition as the disordering of individual chains being separated from ordered regions with the possibility that crystallites might not be left for melting at a higher temperature. He also alluded to the unfolding and hydration of helices as result of their being separated from crystallities. Subsequently, this author as cited in a book (Alexander and Zobel, 1992) described the process as that in which crystallites were being „pulled apart as increased thermal energy and swelling pressures overcame the internal binding forces of the crystallites".

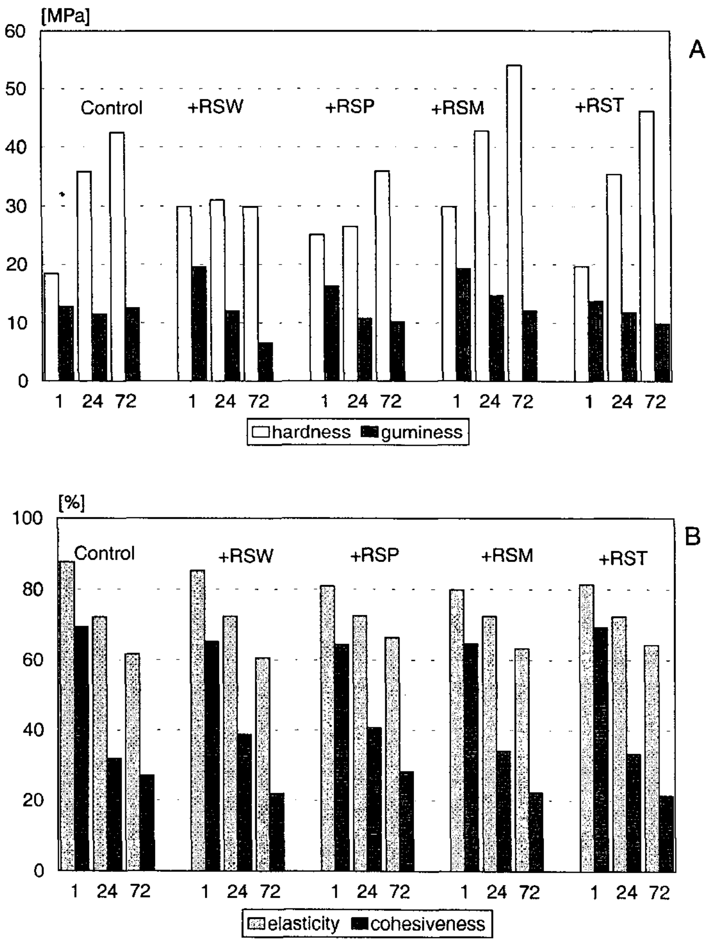


Fig. 3. Texture of bread crumbs 1-, 24- and 72 hours after baking;
A- Hardness and guminess measumements,
B- Elasticity and cohesiveness measurements.

## Conclusions

The results obtained for bakery product during dough formation, fermentation and baking indicate that, because of hydratation of native polymers, the inclusion of starch preparations containing a certain amount of resistant starch is possible via hydrophilic interactions.

By replacing of 10% wheat flour with RS-preparations from wheat, potato, maize and tapioca, there are tendencies for the RS content in product to increase from 5 to 7%, with a weaker effect being observed for a homogenous botanic source of wheat starch.

Hydrophilic-hydrophobic affinity of included RS-preparations gives the possibility, through swelling and gelatinization of starch, for active participation in post-baking redistribution of water between polymers, wheat starch – wheat proteins – RS-preparations, resulting in prolonged freshness, particularly in the case of preparations obtained from wheat and potato starches.

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## TECHNOLOGICZNE I SENSORYCZNE ASPEKTY ZASTOSOWANIA NOWYCH PREPARATÓW SKROBI OPORNEJ (RS) W PROCESIE WYPIEKU

S t r e s z c z e n i e

Skrobiowe produkty żywnościowe po procesach hydrotermicznych, mogą być znacznym źródłem skrobi opornej na działanie enzymów trawiennych ("resistant starch" – RS). Również chleb zawiera skrobię oporną. Ze względu na znaczące jego spożycie w naszej diecie, wydało się interesujące określenie jak wpłynie dodatek preparatów skrobi opornej, otrzymanych wg polskiego zastrzeżenia patentowego nr P.325981 ze skrobi pszennej, ziemniaczanej, kukurydzianej i tapiokowej, na jakość technologiczną i sensoryczną oraz na poziom RS w gotowym produkcie.

Wyniki doświadczenia, w którym zastosowano podczas tworzenia ciasta pszennego 10% udział preparatów skrobi opornej z różnych źródeł botanicznych wskazały wyraźne oddziaływanie na wodochłonność mąki, powodując jej zwiększenie podczas tworzenia ciasta od 4 do 7%. Cechy reologiczne ciasta otrzymanego z handlowej mąki pszennej o słabej jakości technologicznej z udziałem preparatów RS uległy zmianie. Wydłużył się nieznacznie czas rozwoju ciasta, poprawie uległa konsystencja tworzonego ciasta lecz osłabiła się trwałość jego struktury podczas miesienia. Farinograficzna liczba jakości (FQN) obniżała się w stosunku do próby kontrolnej w takim samym stopniu przy udziale wszystkich badanych preparatów skrobi opornej.

Na podstawie wyników panelowej oceny wykonanej metodą profilowania sensorycznego, w której brano pod uwagę 16 wyróżników jakościowych oraz ocenę pożądalności ogólnej w kategoriach hedonicznych stwierdzono, że najkorzystniej na wyróżniki smakowe i zapachowe wpłynął udział preparatu RS pszennej. Z kolei dodatek preparatów RS tapiokowej i kukurydzianej sprzyjał zaznaczeniu mniej korzystnych wyróżników, jak mdły czy mączny.

Badanie cech reologicznych miękiszu wskazało większą twardość miękiszu w porównaniu do próby kontrolnej, mierzoną po 1 godz. od wypieku. Natomiast w ciągu 72 godz. stwierdzono zmniejszenie elastyczności i kohezyjności. Stabilny poziom twardości miękiszu, przy zastosowaniu preparatów RS pszennej i ziemniaczanej podczas 72 godz., sugeruje minimalne objawy starzenia tego chleba.

Pomiary zawartości skrobi odpornej w symulowanych warunkach *in vivo* wykazały, w stosunku do próby kontrolnej, tendencję zwiększania zawartości RS w produkcie przy zastosowaniu badanych preparatów.