Functional role of pectin in the bakery technology

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Abstract. Current problems of the quality of wheat flour bread were analyzed. Here we studied whether apple pectin can be used in production of bakery goods. The significance of such properties of pectin as solubility, swelling, viscosity, susceptibility to acid and enzymatic hydrolysis for technological process were determined. Pectin radioresistance and detoxifying properties are equally important. Results of investigation of the apple pectin effect on dough fermentation process and quality and sorption properties of wheat bread are presented. Experimental substantiation of the most rational way of introducing pectin into dough is provided. The effect of pectic substances on the process of acid accumulation during dough fermentation is confirmed. Investigations were performed using methods of testing baking quality. We confirmed that addition of apple pectin leads to intensification of biotechnological processes and provides high quality and sorption properties of finished products.

1. Introduction
Growing interest in healthy foods is the main trend in the modern society. Modified living conditions and environmental degradation dictate the nearly worldwide growing demand for high-quality and safe food. Improved food qualities include not only its nutritional value, physical accessibility and affordability, but also its functional focus on the prevention of socially significant diseases, detoxification properties, and protection from negative environmental impact [1, 2].

In this regard, preference for mass-market and daily demand goods including bakery products as one of the most important representatives of this class of goods is obvious.

Most researchers refer these products to staple food, and therefore, the modern man's diet can be enriched with all necessary nutrients with regulatory and immunomodulatory properties added with these products.

However, recently, there has been a lack of conformity of the quality of bakery products, especially wheat flour products, to the respective standards. This is manifested in deviations from organoleptic properties, reduced content of essential substances and their decreased bioavailability, reduced stability of physicochemical and microbiological indicators of finished products, and a growing distrust in their safety [3].

The main reasons of this include, as a rule, deterioration and significant fluctuations in processing properties of raw materials, first of all, flour. According to Russian experts, over 69% of the total production of wheat flour falls on flour with reduced gluten content (mainly low or short-gluten flour)
which has a high autolytic activity and a low gassing power. This determines the need for use of flour
improving agents, usually of chemical nature, to bake bread of a consistently good quality [4].

According to WHO experts, presence of synthetic food additives in food products, led to an increasing
incidence of allergic diseases. According to the World Allergy Organization, incidence of allergies in
some countries, including Russia, already accounts for up to 40%.

In this regard, there is a steady trend to search for natural agents improving bakery properties of flour,
and process solutions aimed at obtaining high-quality products with a high sorption capacity [5].

The attention of bakers is focused on pectin, which, due to the set of its properties, can be used as an
oxidizing effect enhancer during dough making process, as well as a structure-forming agent and sorbent
for improving the quality of finished products and positioning pastry as a functional product.

The main property of pectic substances determining their physiological significance is their ability to
bind toxins formed in the body or introduced with food [6].

Complexing ability of pectic substances depends on the degree of etherification of their carboxyl
groups with methanol, which directly affects the ability of pectin to bind lead, strontium, cadmium,
chromium and calcium ions [7].

Pectin complex formation is influenced by medium pH value. When pH grows, the degree of pectin
complex formation increases. The degree of pectin binding depends on its type. With regard to their metal
ion binding efficiency, pectin’s can be arranged in the following order (from lowest to highest affinity):
sugar beet, apple and citrus pectin’s [8].

Nowadays, inclusion in human diets of foods enriched with pectic substances is becoming a necessity
as such products enhance the body's resistance to adverse environmental impacts. The recommended daily
intake of pectin is 4 - 15 g [9–11].

Some researchers studied the use of pectin and pectin products in the bakery and pastry production
processes. It was established that addition of pectin activates fermentation and accelerates biochemical
and microbiological processes in the dough. It was also noted that pectin affects gluten springiness [12].

Therefore, 0.1-0.5% w/w of gluten added to flour during dough making, improved such indicators of
bread quality as volumetric yield, porosity, compressibility of crumbs and foam resistance. Further
increase in the amount of added pectin led to deterioration in bread quality. Specific volume of bread
decreased, the crumb became dense and poorly aerated [13–15].

At present, data on the method of pectin addition during dough making, its optimal dosages in
formulations and dough preparation methods are controversial. Such inconsistency substantiates the need
to investigate the possibility of regulating the intensity and orientation of microbiological, biochemical,
and colloid processes occurring at all stages of manufacture of bakery products with pectin and
optimization of the production process.

This determined the objective of our study: to investigate the effect of a technique used for adding
apple pectin on properties of dough and quality and sorption properties of wheat bread.

2. Materials and methods
Experiments were carried out in laboratories of the Department for Technology of Storage and Processing
of Agricultural Production of Kuban State Agrarian University (Russia).

We investigated first grade bakery wheat flour, apple pectin Unipectin XPP 240 with a molecular
weight of 26000 Da and esterification degree of 66%, yeast dough and control samples of bakery
products.

Dough with moisture content of 45% was prepared via straight dough procedure, then sent to a
thermostat for fermentation at 30°C for 180 min. During fermentation, two punchings of dough were
performed at 60 and 120 minutes. Fermented dough was formed and placed for final proofing into a
proofing oven at 40 ± 1°C and 80-85% relative humidity for 35-40 min. The products were baked in an electric laboratory oven at 220–230°C with increased humidity for 30–32 min.

Samples of dough and finished products were investigated using standard test methods. Bread sorption capacity was analyzed using a technique developed in Kuban State Agrarian University to more accurately determine the content of bound lead ions (Pb²⁺) in pectin-containing bread, and to calculate the value of bread sorption capacity. This was done to evaluate whether the bakery products satisfy the requirements for their health-promoting applications.

The experiments were performed in triplicate, and statistical analysis of the results was performed using a standard Microsoft Office software package.

At first, to establish an optimal method for introducing pectin substances into dough, gassing power of samples from the following experimental groups was determined:

1 – control (dough sample without pectin added);
2 – dough sample with 0.2 % apple pectin added to flour mass after presoaking in water at 1:25 ratio at 30–40°C for 30 minutes;
3 – dough sample with 0.2 % dry apple pectin added to flour mass;
4 – dough sample with 0.2 % apple pectin added to flour mass after presoaking in 1 % saline solution for 30 minutes;
5 – dough sample with 0.2 % apple pectin pre-mixed with salt at 1:3 ratio and then dissolved in water;
6 – dough sample with 0.2 % apple pectin added to flour mass with yeast activation with a 5 % sugar solution.

The pectin dose of 0.2% added to flour mass was based on previous study results and published data.

3. Results

Gassing power is the main parameter which determines the production process flow, fermentation intensity, accumulation of fermentation products and formation of substances responsible for bread taste and aroma. Estimation of this value is also necessary for development of bakery product formulation with sugar-free dough. Gassing power of different dough groups is shown in Figure 1.

![Figure 1. Effect of the method for pectin introduction on flour gassing power](image)

The test results showed that the highest gassing power was observed when pectin was mixed with salt and further dissolved in water, with the second-high value in the group with pectin pre-activation in a 5% sugar solution.

An equally important technological factor responsible for the bread quality is a process of acid accumulation, since the resulting acids can affect structural and mechanical properties of the dough,
causing partial acid hydrolysis of wheat flour polymeric proteins. Changes in titrable acidity during dough fermentation are shown in Figure 2.

Figure 2. Effect of the method for pectin introduction on titrable acidity of dough.

These data demonstrate that the acid accumulation is more productive when yeast is activated with a 5% sugar solution compared to the control. This can be explained by enrichment of medium for yeast growth leading to intensification of the fermentation process.

To evaluate the effect of the method for introducing pectic substances following different preparation protocols and for introducing low-methoxyl apple pectin during dough mixing, the bread quality was assessed 16 hours after baking. The results of assessment of the experimental bread sample quality are shown in Table 1.

Table 1. Physiochemical parameters of different bread samples (n=3, p≤0.95)

| Quality parameter            | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 |
|------------------------------|---------|---------|---------|---------|---------|---------|
| Specific volume, cm³/100 g   | 265±3.5 | 286±5.2 | 283±4.3 | 276±5.1 | 289±2.9 | 284±4.8 |
| Shape retention, (H/D)       | 0.41±0.02 | 0.49±0.05 | 0.46±0.03 | 0.43±0.01 | 0.50±0.05 | 0.47±0.04 |
| Moisture content, %          | 43.6±0.11 | 43.9±0.07 | 43.8±0.04 | 43.7±0.03 | 43.9±0.05 | 43.8±0.08 |
| Porosity, %                  | 67±1.1 | 72±1.3 | 70±0.9 | 68±0.8 | 73±1.0 | 71±1.2 |
| Acidity, degrees             | 2.3±0.08 | 2.8±0.05 | 2.7±0.02 | 2.6±0.03 | 2.9±0.06 | 2.8±0.07 |

The results obtained confirmed a positive effect of pectic substances on bread quality parameters. Specific volume, porosity and shape retention of bread in all experimental groups were significantly higher than in the control. However, the best results were observed in bread with dry pectin mixed with salt and after yeast activation in pectin-sugar solution.

It should be noted that addition of pectic substances extends shelf-life and improves freshness of products, as confirmed by the data in Figure 3.

It can be due to pectic substances competing with starch in the process of water absorption thereby reducing starch hydration, as well as due to the fact that during baking pectin’s are able to release again and desorb moisture, causing moisturizing of bread and additional gelatinization of starch present in it.
To determine the optimal method for preparing dough with apple pectin, we tested addition of 0.2% dry apple pectin to dough prepared using a straight-dough method, sponge-dough method, accelerated “cold” technology and a prefabricated cooled yeast mix method. Pectin was added directly to dough in the form of a water-salt-pectin solution, which was prepared by dissolving pectin premixed with salt in water. The data obtained are presented in Table 2.

Table 2. Comparative evaluation of the quality of bread made with apple pectin, depending on the dough preparation method

| Parameters                                      | Dough preparation method |          |          |          |
|-------------------------------------------------|--------------------------|----------|----------|----------|
|                                                  | Straight-dough           | Sponge-dough | Accelerated “cold” technology | Prefabricated cooled yeast mix |
| Specific volume, cm³/100g                        | 325                      | 311      | 384      | 400      |
| Moisture content, %                              | 43.3                     | 42.9     | 42.9     | 43.2     |
| Porosity, %                                      | 78                       | 79       | 79       | 81       |
| Acidity, degrees                                 | 2.2                      | 2.1      | 2.3      | 2.6      |
| Structural and mechanical properties, automatic penetrometer (AP-4/2) device units |          |          |          |          |
| $\Delta H$ total                                 | 86                       | 71       | 87       | 95       |
| $\Delta H$ formability                          | 56                       | 41       | 57       | 67       |
| $\Delta H$ springiness                          | 30                       | 30       | 30       | 28       |
| After 36 h storage:                              |                          |          |          |          |
| $\Delta H$ total                                 |                          | 56       | 50       | 55       | 61       |
| $\Delta H$ formability                          |                          | 32       | 27       | 32       | 38       |
| $\Delta H$ springiness                          |                          | 24       | 23       | 23       | 23       |
Baking test results showed that optimal technology for production of bread with pectin is the use of a prefabricated cooled yeast mix. This method provided the best porosity in comparison with other dough preparation methods, which positively affected structural and mechanical properties of bread crumb.

To determine the functional focus of the bread, its sorption capacity was evaluated (Figure 4).

![Figure 4. Bread sorption capacity, mg Pb²⁺/g sorbent.](image)

The results of experiments show that addition of pectin leads to almost 3-fold increase in the sorption capacity of bread.

4. Conclusion

The results of our study suggest that introduction of apple pectin in the wheat flour bread making technology provides regulation of biotechnological processes and leads to an improved quality of finished products. Bread quality improvement observed after addition of pectin is the result of activation of fermentation and acid accumulation processes. Acceleration of acid accumulation is associated with a possible disaggregation of pectin polymers and subsequent formation of monosaccharides. The bread crust acquires a golden-brown color, and the crumb has a thin-walled, with high porosity. It was further found that the best results could be achieved when dry pectin was pre-mixed with salt and when yeast was pre-activated in a pectin-sugar solution.

The functional focus of products with added pectin is determined by its sorption capacity, which is the most important property of pectic substances resulting from the interaction of pectin molecules with ions of heavy and radioactive metals.

We suggest that the developed technology can be used to extend the range and volumes of production of functional mass-market and daily demand goods.

5. Acknowledgements

The work was carried out within the framework of scientific and technical cooperation on the implementation of the state subprogram “Production, processing of agricultural products, raw materials and food”.

References

[1] Dewettinck K, Dewettinck F, Kühne B, Van de Walle D, Courtens T M and Gellynck X 2008 Journal of Cereal Science 48 243–257
[2] Encyclopedia of food safety 2014 ed Y Motarjemi (New Y ork: Academic Press)
[3] International Food Safety handbook. Science, International Regulation, and Control 1999 eds K Heijden, M Fishbein and S Miller (New Y ork: Marcel Dekker)
[4] Korotkaya E V and Korotkiy I A 2013 Foods and Raw Materials 1(2) 9–14
[5] Handbook of hydrocolloids 2001 ed G O Phillips and P A Williams (Cambridge: Woodhead Publishing Limited)

[6] Pectin. Chemical properties, uses and health benefits 2014 ed P Bush (New York: Nova Science Publishers, Inc)

[7] Degtyarev L S, Kupchik M P, Donchenko L V and Bogdanova O V 2002 Proceedings of higher educational institutions. Food Technology [in Russian – Izvestiya vysshikh uchebnikh zavedeniy. Pischevaya tekhnologiya] 4 15

[8] Food Stabilisers, Thickeners and Gelling Agents 2010 (Oxford: Imeson)

[9] EU 432/2012 Commission Regulation 2012 Official Journal of European Union p 40

[10] Flander L et al 2007 Food Science and Technology 40(5) 860–870

[11] Azimova S T, Kizatova M Z, Akhmetova S O, Donchenko L V and Admayeva A M 2017 Journal of Security and Sustainability Issues 6(4) 719–728

[12] Renard C M, Voragen G J, Thibault J F and Pilnik W 1991 Carbohydrate Polymers 1(2) 137–154

[13] Su X, Wu F and Zhang Y 2019 Food Chemistry 278 267–275

[14] Advances in pectin and pectinase research 2003 eds F Voragen, H Schols and R Visser (Dordrecht: Kluwer Academic Publisher)

[15] Donchenko L V and Firsov G G 2007 Pectin: basic properties, production and application (Moscow: Delhi print)