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Thermal Treatment Influence on the Quality of Rye Bread Packaged in Different Polymer Films

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Abstract**—**this study was carried out to investigate the changes in quality parameters of rye bread packaged in different polymer films during convection air-flow thermal treatment process. Whole loafs of bread were placed in polymer pouches, which were sealed in reduced pressure air ambiance, bread was thermally treated in at temperature +(130; 140; and 150) ± 5 ºC within 40min, as long as the core temperature of the samples have reached accordingly +80±1 ºC. For bread packaging pouches were used: anti-fog Mylar®OL12AF and thermo resistant combined polymer material. Main quality parameters was analysed using standard methods: temperature in bread core, bread crumb and crust firmness value, starch granules volume and microflora. In the current research it was proved, that polymer films significantly influence rye bread quality parameters changes during thermal treatment. Thermo resistant combined polymer material film could be recommendable for packaged rye bread pasteurization, for maximal bread quality parameter keeping.

Keywords**—**bread, thermal treatment, bread crumb, bread crust, starch granule's volume.

I. INTRODUCTION

BREAD has always been one of most popular daily consumed food products and is a common food in many countries [1]. Rye bread is a regular bread type. In particular dark whole grain rye bread is becoming more and more popular, due to its nutritional and sensory characteristics; it contains a lot of fibers and iron. However, the shelf life of most baked products is limited unless products are refrigerated or packed. Most bakery products are marketed fresh and are stored at ambient temperature. Unpreserved bread has a shelf of 3-4 days, at which point a visible mould becomes evident [2].

The most common forms of bakery products' deterioration are microbiological spoilage, staling and moisture loss [3], [4]. During baking viable moulds and bacteria are destroyed, nevertheless serious recontamination accrues during cooling and following packaging process [5], [6], [7]. Rye bread is generally sold as cut in few millimeters thick slices. There is a grate chance of contamination during cutting. The growth of moulds in bread determines oxygen inside of package and a water activity (a_w) of the product. Two main methods are considered to delay spoilage of bakery products: elimination of oxygen from the package headspace or use substances that inhibit mold growth [8].

Recently, in order to achieve a longer shelf life for bakery products, some new packaging technologies were investigated [9]. A more recent and increasingly popular, however not so new way of preserving foods is modified atmosphere packaging (MAP). The advantage of this method is combination of the inhibitory effects of low oxygen levels and elevated carbon dioxide levels on many deterioration processes in foods and is effective in preventing microbial spoilage. The MAP is used to maintain the product's initial quality for much longer periods and to extend the product's shelf life and retain appeal to consumers [10]. Some authors emphasize the importance of combining several barriers, such as MAP, a_w, and pH, whose have effects on mould growth in bakery products [11]. Evaluation of combined effect of MAP and refrigeration (7±1 °C) on shelf-life extension of ready-to-serve pizza shows the shelf life in air atmosphere 15 days, however, a significant shelf life increase of 45 days (300% increase) was achieved under modified atmospheres for baked pizza samples [12].

Active packaging could restrict microbial spoilage of bread and other bakery products. The use of natural antimicrobials to extend the shelf life of bakery products is one example of active packaging. The use of oxygen scavengers has the advantage over gas-packaging methods. Ethanol is an effective antifungal agent that can be used for food preservation purposes. Modifying the headspace atmosphere with ethanol vapor is an excellent way of preserving bakery products. Not only the growth of molds, yeasts, lactobacilli and other microbial contaminants will be retarded, but the rate of staling will also be reduced [13], [14]. Results found by Limbo et al (2007) [15] show that *Aspergillus niger* grows with high levels

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of carbon dioxide, even if oxygen was present at low concentration; moreover, the ethanol alone was not sufficient to inhibit mould growth. Microbial, sensory and textural protection requirement of sliced bread can be guaranteed when two or more preservative factors are involved [15]. Some of presented studies show that active packaging in combination with a high barrier packaging material can substantially extend the shelf life of sliced bread, especially when active substances are combined, for example ethanol emitter and oxygen scavenger [16]. Ethanol emitting sachets are relative expensive compared with other active packaging technologies; nevertheless, they represent a relatively small but growing area of the active packaging market [17].

After the packaging the rye bread could be pasteurized to cut of contamination. The pasteurization time at 80 ºC should be 15 minutes to guarantee a shelf life of several weeks up to few months. This time and temperature is for inner part of rye bread, so the actual heating takes a lot longer [18].

For the time being several bakeries take out the preservatives in their formulas, and pasteurize bread after it has been sliced and packaged, and create a product that is mold free for more than 90 days at ambient temperature. With preservatives, mold begins to form within 21 days. However pasteurization process cannot to stop staling. Bread staling is a process of chemical and physical changes including moisture redistribution, drying, starch retrogradation, increased firmness, as well as loss of aroma and flavors. Bread molding and staling results in the decrease of consumer acceptance for bakery products and also increase in economic losses. Baking destroys most moulds but surface recontamination can occur during packaging [19].

Microwave pasteurization is a gentle heat treatment usually at temperatures between 60 and 82 ºC, which has been applied to several foods, including bread. The main advantage of microwaves sterilization or pasteurization is the effective reduction in the time required for the heat to penetrate to the food centre [20].

In scientific literature found results of invention relates to packaged bread products thermal treatment technology, and its use for rye, wheat, wheat-rye and rye-wheat or other types of bread shelf-life prolonging on to two months. The technology include ready bread sample packaging applying partial vacuum into laminated polymer material with high barrier properties with or without EVOH layer, pasteurization of bread samples in rotary-convection or in other type ovens for 20 to 30 min at a temperature of +120 to +130 ºC without steam infusion, in order to eliminate spores of mould fungi and to keep bred freshness value [21].

Pasteurization is critical to minimize the growth of spoilage microorganisms during storage of thermally treated hermetically packed foods. The processing parameters, however, should be kept at a minimum in order to remain maximum quality. The pasteurization parameters must be defined individually for each product [22]. The advantage is due to the reduction of natural spoilage bacteria via pasteurizing and storage under refrigerated conditions that limit competitive bacterial growth. To develop effectiveness of in-package thermal treatment processes for rye bread packed in heat resistant polymer pouches, the rate of inactivation of target microorganisms (i.e. *L. monocytogenes*, *Salmonella, S. aureus*) at various processing temperatures must first be determined [23]. The microbial load and its changes during pasteurization are important information in establishing a standard that will ensure food safety [24].

This study was carried out to investigate the changes in quality parameters of rye bread packaged in different polymer films during convective air-flow thermal treatment process.

II. MATERIALS

The research was accomplished on the testing of non sliced traditional Latvian rye bread (0.65±0.10kg).

For bread packaging pouches made from two different polymer films were used: thermo resistant combined polymer material (density 40.0±0.5 µm) and Mylar® polyester OL (density 40.0±0.5 µm).

Mylar® polyester OL family range film by DuPont Teijin Films anti-fog Mylar®OL12AF, suitable for use in 'balanced pressure' autoclave for pasteurisation, was used for whole bread loaf packaging and pasteurization. Mylar®OL12AF is specifically designed to minimise 'fog' during freezing, chilling and cooking operations, it is dual oven able (conventional oven and microwave). Mylar®OL12AF withstand freezer temperatures down to -70 °C and food can be heated/cooked in this film at typical heating conditions of +220 °C for 30 minutes [25].

III. METHODS

A. Bread thermal treatment

The tested samples – whole loafs of bread were placed in polymer pouches (200mm x 390mm), which were hermetically sealed in reduced pressure air ambiance by chamber type machine MULTIVAC C350. Bread was thermally treated in rotary-convection air-flow oven SvebaDahlen S-400 at three temperature regimes in heating ambient: + (130; 140; and 150) ± 3 ºC. The thermal treatment time was within 40min, as long as the core temperature of the samples has reached accordingly +80 ± 1 ºC.

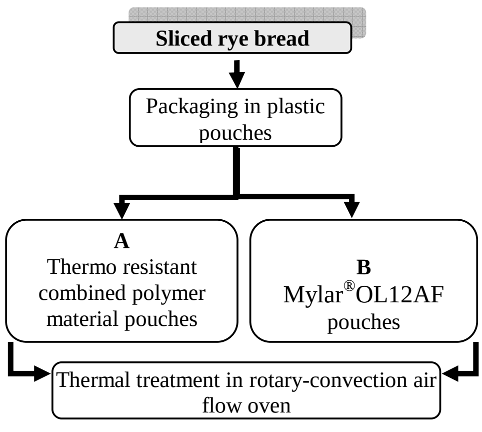

Fig. 1 In-pack thermal treatment scheme of rye bread

B. Structure of performed experiments

The temperature of samples in the core of bread loafs at the thermal treatment process in a convectional air flow oven was measured at each ten minute by thermometer *MULTI, Precision*, ambient temperature in the rotary-convection air-flow oven was kept constant accordingly that foreseen in experiment. In-pack thermal treatment (pasteurization) scheme of rye bread is shown in Fig.1.

C. Physical analysis

"TA.XT.plus Texture Analyser" was used for bread crust and crumb hardness determination.

Two penetration methods were applied for crust and crumb hardness analysing. Measuring probe SMS P/7R (7mm dia., 40mm long, supplied with the Texture Analyser) was used for bread crust with penetration distance 20mm mainly for determination of force for crust perforation, but measuring probe P/25 (25mm dia., cylinder aluminium, supplied with the Texture Analyser) was used for bread crumb (bread slice with thickness of 10mm) with penetration distance 4mm [26].

The system for both tests was equipped with a compression cell of 50kg and software Texture Exponent 32.

Hardness was measured as the maximum penetration force (N) reached during tissue breakage.

The measuring parameters for both tests were: pre-test speed 1 mm/s; test speed 1 mm/s; post test speed 10 mm/s. The measurement is triggered automatically at 0.05 N. The maximum force required for sample compression was calculated as an average of 10 measurements.

D. Microbiological and starch structure analysis

The volume of starch granules incorporated in ray bread samples was analysed under the triocular microscope *Axioskop 40*. The images of granules were taken by digital compact camera *Canon PowerShot A620* via 16X20 magnification of the microscope. Size and area of cells and starch granules was measured using software *Axiovision Le Rel 4.7*. The samples of analysed bread were cut and placed on a glass slide and coloured with Lugol's solution.

Bread samples for microbiological testing were prepared by dilution method in conformity with standard LVS EN ISO 6887-1:1999 and 6887-4:2044. TPC (total plate count) − determined in conformity with standard LVS EN ISO 4833:2003 A. TPC evaluated as decimal logarithm of colony forming units (CFU) per gram of a product (log10 CFU/g).

E. Mathematical data processing

Data are expressed as mean ± standard deviation; for the mathematical data processing p-value at 0.05 was used to determine the significant differences. Experiments were carried out in tenfold.

IV. Results and Discussion

The packed rye bread loafs were pasteurized mainly for microbiological safety. The temperature in bread loaf core could be about +80 ºC to guarantee a safe shelf life [18]. That is why pasteurization temperature in the core of loaf for non-advantageous microflora destroying could be recommendable from +75 to +82 ºC.

In the current experiments the increase of temperature in rye bread inner core was measured mainly to determine pasteurization effect (Table 1). It was observed – packaging materials substantially influence the temperature increase rate in the loaf inside from crust to core.

The pasteurization effect of bread samples packaged in thermo resistant combined polymer film pouches and heated at ambiance temperature +140 ± 3 ºC was reached within 40min, while in bread samples packaged in pouches made of Mylar®OL12AF film and treated at +140 ± 3 ºC – already within 30min (Table 1). Whereas maintaining the heating ambiance temperature +150 ± 3 ºC, the preferable core temperature could be gained in time less than 30 min – within 25 to 26 min in Mylar®OL12AF film packaging, while in thermo resistant combined polymer film – within 36 to 38 min. Consequently from this point of view the rye bread packaging for pasteurization in Mylar®OL12AF film appears to be accepted as better.

TABLE I
TEMPERATURE CHANGES OF RYE BREAD INNER PART WITHIN THERMAL TREATMENT

Treatment time, min	Treatment temperature, ºC					
	Polymer material pouches			Mylar® OL12AF pouches		
	130±5	140±5	150±5	130±5	140±5	150±5
0	20.5±1.0	20.5±1.0	20.5±1.0	20.5±1.0	20.5±1.0	20.5±1.0
10	23.5±1.0	25.0±1.0	35.4±1.0	36.4±1.0	37.2±1.0	41.5±1.0
20	31.6±1.0	49.8±1.0	54.1±1.0	46.5±1.0	52.3±1.0	52.0±1.0
30	47.0±1.0	57.3±1.0	64.8±1.0	64.2±1.0	80.2±1.0	83.2±1.0
40	67.2±1.0	81.8±1.0	82.1±1.0	74.2±1.0	82.7±1.0	87.9±1.0

Bread is one of the most important staple foods in the world and it can be spoiled by many kinds of moulds. However, the dominant spoilage flora varies with the type of bread and the storage temperature [27]. Therefore, the main idea of packed brad thermal treatment was to minimize the unwanted microflora (especial, as fungi) growth in product.

In the present experiment it was proved, that packaged rye bread treatment at elevated heating ambiance temperature could be recommendable for minimizing of the undesirable microflora (Fig. 2 and Fig. 3). The reduction of total plate count more intensively is going on when rye bread is packaged and thermally treated in thermo resistant combined polymer film pouches (Fig. 2.). Possibly, it could be explained with packaging material lower water permeability, as a result "conservatory" effect was reached especially when bread has been thermally treated at temperature +140 ± 3 and +150 ± 3 ºC.

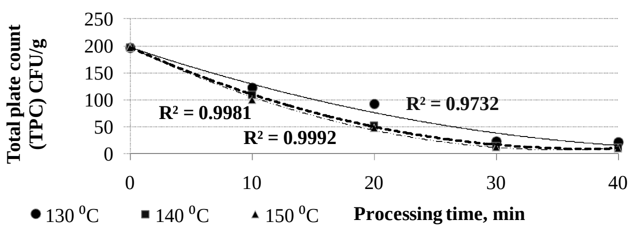

Fig. 2 Total plate count dynamics during thermal treatment process within bread packed in thermo resistant combined polymer film

The core temperature of bread loafs packed in Mylar®OL12AF film raised more quickly, the total plate count decreased not so intensively (Fig. 3). The lowest total microbial count 25 CFU g^{-1} at heating ambiance 140 ± 3 °C in thermo resistant combined polymer film packaging was gained within 30 min, while in Mylar®OL12AF film packaging – only within 40 min. It could be permissible that the water vapour permeability of Mylar®OL12AF film is higher, therefore the partial voter vapour pressure in pouch is lower as well and it influences the survival of microorganisms.

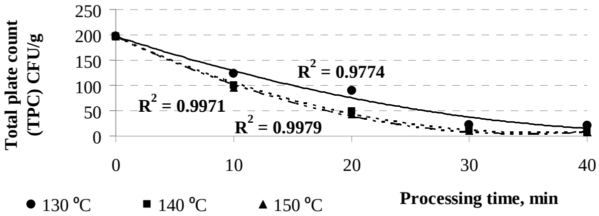

Fig. 3 Total plate count dynamics during thermal treatment process within bread packed in Mylar®OL12AF film

The main factor often involved during the shelf life of baked products is changes in the starch component. Starch retrogradation begins as soon as baking is complete and bread cooling has started. Amylose retrogradation is mostly complete by the time the product has cooled to room temperature. Amylopectin retrogradation requires more time than amylose retrogradation and as a result, is the primary factor [28]. Therefore, the volume changes of starch granules in rye bread core (Fig. 4, Fig. 5 and Fig. 6) during the thermal treatment process could be very important.

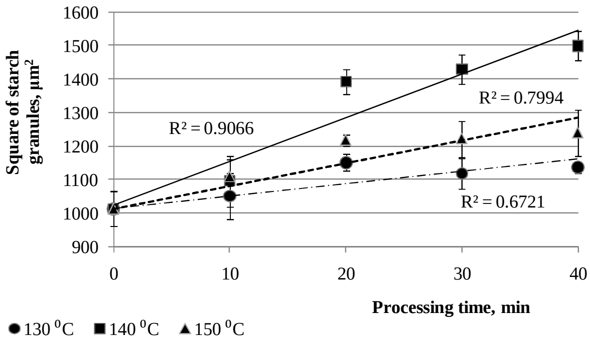

Fig. 4 Volume changes of starch granules n thermo resistant combined polymer film packed rye bread during thermal treatment process

In the present experiments it was established, that packaging materials significantly influence the volume of starch granule changes during thermal treatment time. Volume of starch granules in thermo resistant combined polymer film packed rye bread, during pasteurization at ambient temperature +140 ± 3 ºC in oven, increased from 1000 to 1500 µm (it is for 1.5 times) (Fig. 4), whilst in Mylar®OL12AF film packed bread the changes of starch granules were contrary to previously mentioned – their volume decreased from 1000 to 750 µm (it is for 1.33 times) (Fig. 5). During pasteurization time the moisture evaporates from bread flash, as a result water vapor accumulates in the head space of pouches and in flash pores as well, in this way due to low water vapor permeability of thermo resistant combined polymer film the partial voter vapours pressure increases, promoting the swelling of starch granules. However, the changes of starch granules volume of bread heated at +130 ± 3 and +150 ± 3 ºC are not so relevant. The evaporation rate of water at temperature +130 ± 3 ºC is not so intensive, however, temperature +150 ± 3 ºC is too high: water evaporation occurs intensively and starch granules are not managed to absorb it. It is important to admit, that heating temperature influences the starch modification as clusterisation: at temperature +70 ºC the 90% of starch could be modified [29].

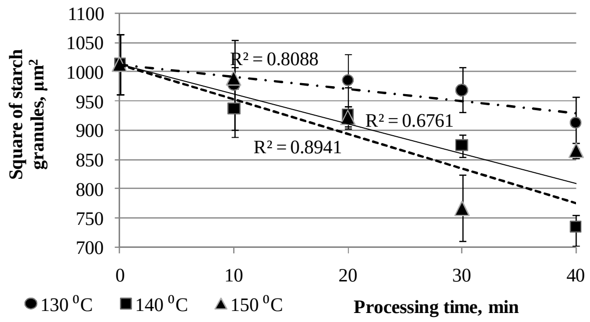

Fig. 5 Volume changes of starch granules in Mylar®OL12AF film packed rye bread during thermal treatment process

Within rye bread packaged in Mylar®OL12AF film with anti-fog layer and processed at several ambient temperature in oven the volume of starch granules decreased (Fig. 5 and Fig. 6), what mainly could be explained with moisture permeability of packaging material. Less starch volume changes were indicated, if bread was treated at temperature +130±5 ºC however the maximal pasteurisation effect at this processing temperature within treatment time 40 min was not reached (Table 1).

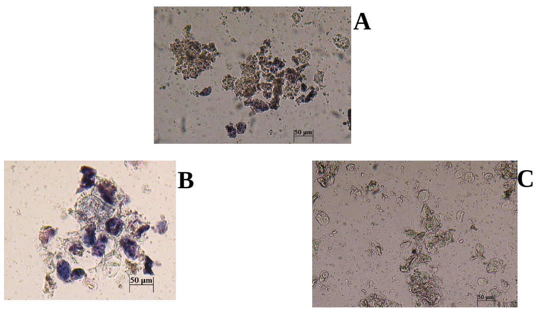

Fig. 6 Appearance of rye bread starch granules; temperature in oven +130 ± 3 ºC; thermal treatment time 20 min: A – fresh rye bread, B – in thermo resistant combined polymer film packed rye bread; C – in Mylar®OL12AF film packed rye bread

Therefore, the microbiological risk exists. As a result, for maximal starch granules protection lower treatment temperatures and shorter processing time could be recommendable.

Bread as a solid is “soft” like many other foodstuffs, is comprised, at a macroscopic level, of two phases − a fluid (water) and a solid (cell wall material). When viewing a cross-section of breadcrumb, it is apparent that the solid phase is entirely connected; those portions that are not breadcrumb, but merely breadcrumbs [30].

Within present experiment it was found, that bread crumb becomes softer during thermal treatment process of packed bread (Fig. 7 and Fig. 8) and the softening is influenced by kind of packaging material. It was observed, that bread crumb in thermo resistant combined polymer film packaging during thermal treatment 40 min at +130 ± 3, +140 ± 3 and + 150 ± 3 ºC becomes softer by 1.8, 1.9 and 1.5 times respectively (Fig. 7). At the same time, crumb of bread packed in Mylar®OL12AF film pouches, become softer only by 1.2, 1.8 and 1.3 times (Fig. 8) at previously mentioned thermal treatment conditions.

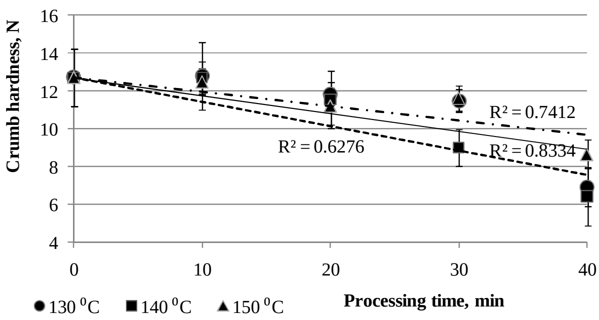

Fig. 7 Changes of bread crumb hardness in thermo resistant combined polymer film packaging during thermal treatment

Bread crumb different softening during thermal treatment process could be explained by various water vapor permeability of used film, which formed different water vapor partial pressure in the head space of pouches.

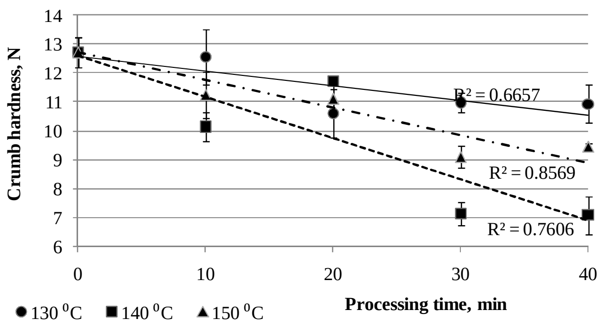

Fig. 8 Changes of bread crumb hardness in Mylar®OL12AF film packaging during thermal treatment

During the baking process, dough experiences major physical and biochemical changes due to heat exposure which lead to the transformation from raw dough to bread with two distinctive structures, i.e., the crust and the crumb. The crust is associated to the brown surface of bread while crumb is the inner brown spongy structure beneath the crust. The crust, which is formed through Maillard reaction and caramelize during baking, has several important functions on bread properties. The thickness and characteristics of the crust to a large extent define the product and give its name [31].

In general, bread crust is referred as a marketing tool that attracts customers through its appearance, aroma, and flavor [31].

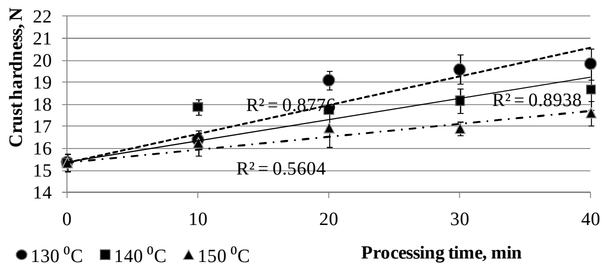

Fig. 9 Changes of rye bread crust hardness in thermo resistant combined polymer film packaging during thermal treatment

It was established, that hardness of bread crust increases within thermal treatment process of packaged bread, what mainly could be explained by moisture evaporation within bread reiterative heating. The changes of rye bread crust hardness during bread heating are not relevant. Bread crust becomes harder by 1.3, 1.2 and 1.1 times within heating at ambient temperature +130 ± 3, +140 ± 3 and + 150 ± 3 ºC respectively (Fig. 9).

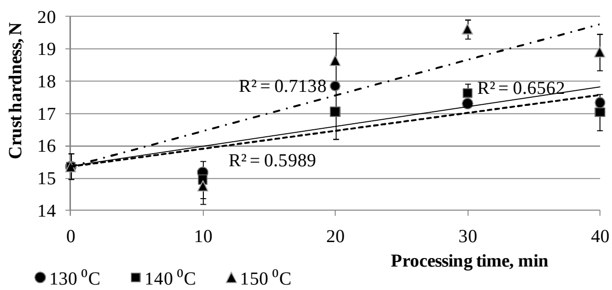

Fig. 10 Changes of rye bread crust hardness in Mylar® OL12AF film packaging during thermal treatment

However, if bread was packaged in Mylar®OL12AF film, the hardness of rye bread crumb increases only by 1.1, to 1.2 times (Fig. 10) at the same previously mentioned heating conditions.

V. Conclusion

In the current research it was proved, that kind of polymer films significantly influence rye bread quality parameters during thermal treatment. Therefore, thermo resistant combined polymer film as packaging material could be more recommendable for packaged of rye bread for thermal treatment than Mylar®OL12AF film.

The changes of rye bread quality parameters in pouches made from combined polymer film within thermal treatment process are not negative: the volume of starch granules increases as a result of water vapor accumulation in the head space of pouches and in flash pores as well, in this way due to low water vapor permeability of thermo resistant combined polymer material film the water vapour partial pressure increases, promoting the swelling of starch granules; bread crumb and crust hardness changes was not so substantial.

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