Packaging and Storage of Products: Opportunities and Technologies

E.O. Ermolaeva
Institute of Engineering, Department of Quality Management, Federal State Budgetary Educational Institution of Higher Education, Kemerovo State University, Kemerovo, Russia.

Yu. I. Dymova
Institute of Engineering, Department of Quality Management, Federal State Budgetary Educational Institution of Higher Education, Kemerovo State University, Kemerovo, Russia.

N.B. Trofimova
Institute of Engineering, Department of Quality Management, Federal State Budgetary Educational Institution of Higher Education, Kemerovo State University, Kemerovo, Russia.

Yu. V. Ustinova
Institute of Engineering, Department of Quality Management, Federal State Budgetary Educational Institution of Higher Education, Kemerovo State University, Kemerovo, Russia.

К. Yu. Kozyakova
Institute of Engineering, Department of Quality Management, Federal State Budgetary Educational Institution of Higher Education, Kemerovo State University, Kemerovo, Russia.

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Abstract

The theoretical and experimental substantiation of the use of packaging to preserve the consumer qualities of the product during its storage, as well as the application of the principles of HACCP in production, ensuring stability of safety and quality of products. The results can be used for further research aimed at proving and justifying an increase in the shelf life of bakery products.

Keywords

Hazards, Bakery Products, Packaging.

Introduction

The freshness of bread is one of the main indicators of its quality. When storing bread, there is a decrease in its quality associated with the processes of staling and drying. The crust of

fresh bread is smooth, hard and brittle; during storage, it becomes soft, elastic; the soft, easily compressible, non-crumbling crumb of fresh bread becomes harder, less compressible and crumbles more. When storing bread at the same time with a change in the rheological properties of the crumb, its taste and aroma change (Romanov, 2009; Zhao et al., 2019; Thanakkasaranee, 2018; Jideani, Vogt, 2016; Jan et al., 2017; Lee et al., 2019).

Increasing the shelf life of fresh baked goods is an important task facing bread producers. One way to preserve freshness during storage is to choose the right packaging (Thanakkasaranee, 2018; Jideani, Vogt, 2016; Jan et al., 2017; Lee et al., 2019; Braga et al., 2018; Silva et al., 2018; Tan et al., 2015; Fasihi et al., 2019).

For research, the following types of packaging were selected to help preserve the freshness of bread:

- Paper packaging;
- Microperforated shrink film (MTP);
- Polypropylene film (PP);
- Polyvinyl chloride (PVC);
- Combined packaging (polypropylene paper).

The choice of these types of packaging is determined by the following factors:

- Permission for contact with food products;
- The need to install additional. equipment at the enterprise;
- Increase in the cost of the product;
- The use of packaging by manufacturers of bakery products.

For breads prepared using liquid starter without brewing, the effect of different types of packaging on the preservation of freshness has not been studied. For the selected bread from a mixture of rye and wheat flour “Fitness with raisins” prepared using liquid yeast without tea leaves, we studied the change in organoleptic, physico-chemical and microbiological parameters during storage.

According to GOST R 52961-2008 "Bakery products from rye and a mixture of rye and wheat flour. General specifications" the shelf life of bakery products from a mixture of rye and wheat flour is established and agreed upon in the established order by the manufacturer for the product of a specific name, depending on its recipe composition, type of packaging material and method of packaging.

Materials and Methods

The generally accepted, standard and special test methods were used, incl. sociological, organoleptic, physico-chemical, as well as instruments of quality, statistical processing of experimental data, etc. Studies were carried out in three to five times repetition. The results were processed by methods for calculating the statistical reliability of measurements using Microsoft Excel programs.

Results and Discussion

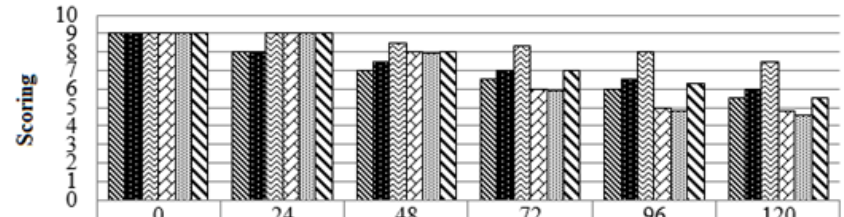
To study the effect of packaging on preserving the freshness of bread, trial baking was carried out. Bread was produced from a mixture of rye and wheat flour using liquid sourdough without tea leaves, control samples without packaging. The experimental samples (except for the control one) after complete cooling were packed into the studied types of packaging and put into storage at an unregulated air temperature of 18 ± 2 ° C and relative humidity of 70 ± 5%.

The change in the quality of bread from a mixture of rye and wheat flour during storage was evaluated after 24, 48, 72, 96, 120 hours from the moment of removal from the oven according to organoleptic (taste, smell, crumb condition, surface and shape), physicochemical parameters (moisture, porosity and crumbiness of bread crumb) and microbiological indicators.

To conduct a study of the effect of packaging on maintaining the freshness of bread from a mixture of rye and wheat flour, 90 samples of bread from a mixture of rye and wheat flour "Fitness with raisins" were produced, 15 samples of each were packed in paper packaging, microperforated shrink film (hereinafter referred to as MTP), polypropylene film (hereinafter referred to as PP), into a film of polyvinyl chloride (PVC), combined packaging, the remaining 15 samples were control samples and were examined without packaging. The studies were carried out in 3 replicates.

Organoleptic evaluation of the obtained samples was carried out by the method of scoring, developed by us on the basis of the technique proposed by the authors (Romanov, 2009; Braga et al., 2018; Silva et al., 2018; Tan et al., 2015).

The scoring system (scale) is presented in the tasting sheet for assessing the quality of molded bread from a mixture of rye and wheat flour during storage, shown in Figure 1. A sensory assessment was carried out by a commission of 6 people. The members of the commission recorded the evaluation results in the tasting list as well.

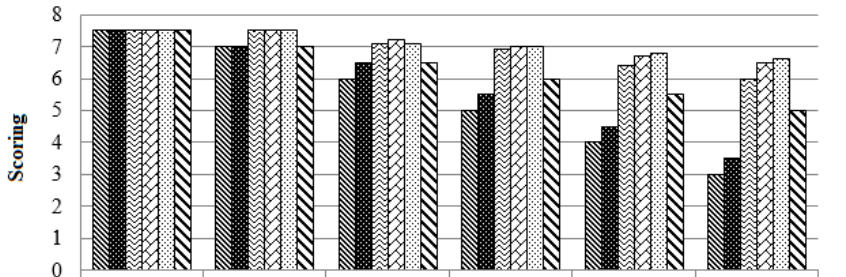


	0	24	48	72	96	120
Without packaging	9	8	7	6,5	6	5,5
Paper	9	8	7,5	7	6,5	6
MTP	9	9	8,5	8,3	8	7,5
PP	9	9	8	6	5	4,8
PVC	9	9	7,9	5,9	4,8	4,6
Combined	9	9	8	7	6,3	5,5

Figure 1 Tasting sheet for evaluating the quality of heavy bread from a mixture of rye and wheat flour during storage

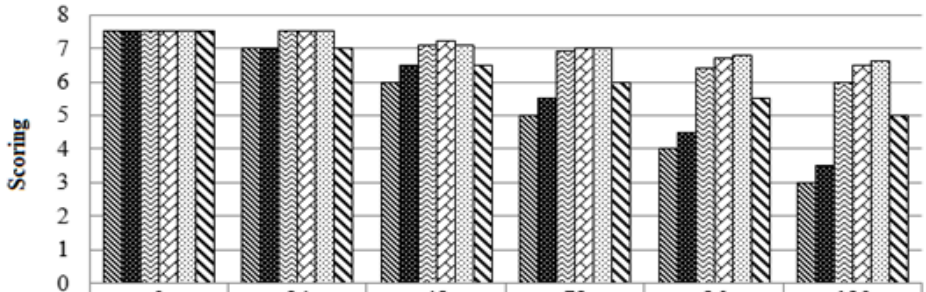
Organoleptic evaluation of bread was carried out in accordance with a 30-point scale. Changes in the organoleptic indicators of the quality of bread during storage are shown in figures 2-3.

Figure 2 shows that during storage, the organoleptic indicator (taste) worsens. This is mainly due to the loss of volatile flavoring substances and processes of protein and starch retrograde. In a regulated shelf life of up to 72 hours from the moment of production of the control sample and samples in the studied packages, the taste changed, but remained fresh without any foreign taste.



	0	24	48	72	96	120
Without packaging	7,5	7	6	5	4	3
Paper	7,5	7	6,5	5,5	4,5	3,5
MTP	7,5	7,5	7,1	6,9	6,4	6
PP	7,5	7,5	7,2	7	6,7	6,5
PVC	7,5	7,5	7,1	7	6,8	6,6
Combined	7,5	7	6,5	6	5,5	5

Figure 2 Change in the taste of prototypes during storage



	0	24	48	72	96	120
Without packaging	7,5	7	6	5	4	3
Paper	7,5	7	6,5	5,5	4,5	3,5
MTP	7,5	7,5	7,1	6,9	6,4	6
PP	7,5	7,5	7,2	7	6,7	6,5
PVC	7,5	7,5	7,1	7	6,8	6,6
Combined	7,5	7	6,5	6	5,5	5

Figure 3 Change in the state of the crumb prototypes during storage

After 96-120 hours of storage, the bread packaged in a polypropylene package and a polyvinyl chloride package had a slight taste of mustiness due to insufficient air permeability, while the bread packed in a microperforated shrink film retained the taste of fresh bread. Samples of bread, packaged in paper, did not differ fundamentally from the control and had an unexpressed taste, since the paper packaging does not have adhesions, which makes it leaky. A sample packaged in a combination package (polypropylene paper) had a mild taste.

It is known that the structure of bread crumb is characterized by the presence of pores limited by inter-pore walls that make up the spongy skeleton. The inter-pore walls of the crumb consist of a continuous mass of coagulated protein, inside of which are swollen, partially gelatinized starch grains interspersed. In fresh bread, starch grains with their entire surface are closely adjacent to the mass of coagulated protein.

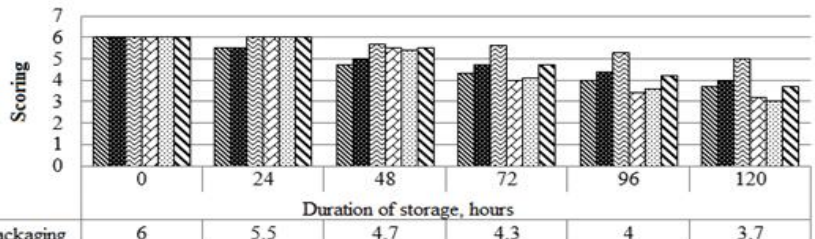
The data presented in Figure 2 show that the condition of the crumb worsens over time in all tested bread samples, but there are differences depending on the type of packaging used. In control samples and samples packed in paper, after 48 hours, the crumb deteriorated due to natural drying and staling of bread. Experts noted greater resistance and effort when biting off a slice, as well as the cost of efforts to chew a bitten portion compared to other samples. Accordingly, the elasticity of the crumb with light pressure on it with fingers showed strong resistance to finger pressure and low deformation.

In the crumb of stale bread, the grains of partially gelatinized starch are clearly visible, since a thin air layer is formed around part of their surface.

In bread, packed in a combination package, unlike paper, the drying process proceeds more slowly due to a peculiar microclimate. This is due to the fact that this type of packaging has paper in its combination, which has the ability to "breathe", while the elasticity of the crumb of the samples in question was characterized by strong resistance to pressure.

The best indicators of the state of the crumb were determined for samples packed in polypropylene packaging and polyvinyl chloride packaging. These types of packages have great tightness and provide favorable conditions for maintaining the freshness of the crumb. The crumb of the studied samples packed in a polypropylene package and a package of polyvinyl chloride was easily amenable to finger pressure, but did not completely restore its original structure. Lower values were noted for samples packed in microperforated shrink film due to the presence of microperforations in it. The latter makes it possible for the bread under study to "breathe" and leads to loss of crumb moisture and, accordingly, a decrease in elasticity.

From figure 4 it is seen that during storage such an organoleptic indicator as smell worsens. This, as in the case of the study of taste, is associated with the loss of volatile taste and aromatic substances and processes of protein and starch retrograde. In a regulated shelf life of up to 72 hours from the moment of production of the control sample and samples in the studied packages, the smell changed, but remained fresh.



	0	24	48	72	96	120
Without packaging	6	5,5	4,7	4,3	4	3,7
Paper	6	5,5	5	4,7	4,4	4
MTP	6	6	5,7	5,6	5,3	5
PP	6	6	5,5	4	3,4	3,2
PVC	6	6	5,4	4,1	3,6	3
Combined	6	6	5,5	4,7	4,2	3,7

Figure 4 Change in the smell of prototypes during storage

After 96 hours, the bread, packed in a polypropylene package and a package of polyvinyl chloride, had a slight smell of stale bread due to insufficient air permeability, while bread packed in a microperforated shrink film retained the smell of fresh bread. Samples of bread packaged in paper did not differ fundamentally from control samples and had a mild odor, since paper packaging is a "breathing" material and prevents moisture concentration in the bag, which leads to wetting of the surface layer of bread and deterioration of smell. A

sample packaged in a combination package (polypropylene paper) had an unexpressed odor.

According to the results of the organoleptic evaluation, it follows that changes in the surface and shape of bread samples from a mixture of rye and wheat flour were not fixed regardless of the type of packaging studied, this is justified by the fact that the samples of the bread under study were packaged after they were completely cooled, which did not lead to wetting the surface layer of bread and the deterioration of its appearance and shape.

Samples of bread from a mixture of rye and wheat flour using liquid sourdough without tea leaves in the package for 48 hours of storage did not have noticeable differences in organoleptic characteristics and were assigned to the quality category "Excellent" and "Good", respectively. After 48 hours of storage, the signs of staling were found in the control samples: the surface of the bread lost its gloss, the taste and smell became less pronounced, and the crumb of bread became crumbly. The first signs of staling in products using packaging appeared after 72 hours of storage. The research results showed that the polypropylene film (PP) and the film of polyvinyl chloride (PVC) slow down the drying process more efficiently with respect to other studied packages, but the taste and smell compared with the samples of products packaged in other types of packages had a noticeable lag. This is due to the fact that PP and PVC packages are leak proof, which creates their own microenvironment inside the package.

For a more objective assessment, along with an organoleptic quality assessment, we conducted studies of the physical and chemical parameters of bread (moisture, acidity, crumbling).

Humidity is an important indicator of the freshness of bread. High humidity reduces the nutritional value of bread, as due to the water in it the nutrient content is reduced. In addition, bread with high humidity molds faster. Therefore, for each type of bread, the maximum norm of humidity is established.

The crumb and crusts of bread have uneven moisture: the crumb moisture is much higher than the crust moisture. So, in rye-wheat bread, the moisture content of the crumb is 50%, the moisture content of the crust is 14-15%. The moisture content of the crust is not standardized.

Bread having a higher humidity is considered defective and should not go on sale. In bread with high humidity, the crumb has a large glassy porosity.

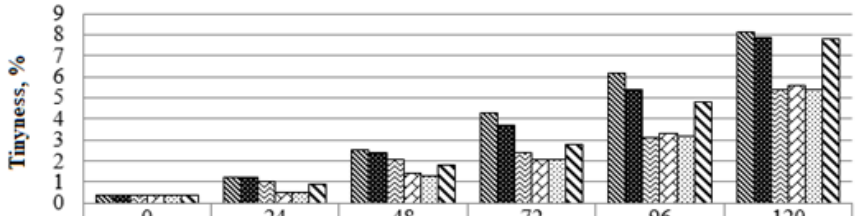
Moisture testing of bread from a mixture of rye and wheat flour "Fitness with raisins" depending on the type of packaging was determined in the laboratory of the company "Leninsk-Kuznetsk bakery".

The research results presented in Figure 4 show that during storage, there was a decrease in the moisture of the bread crumb. A noticeable change in the moisture content of the crumb was established during storage of control samples and samples packed in paper and combination packaging compared to the data from the day of baking and the last day of the study, the humidity decreased by 7.0%. For bread samples packaged in microperforated shrink film, a moisture change of –5.0% was recorded. The smallest change in crumb moisture was detected in bread samples packed in PP, PVC. The moisture content of the crumb in bread samples packed in PP and PVC decreased slightly - by 3.0%.

Thus, it is possible to control the moisture content of bread from a mixture of rye and wheat flour during storage with properly selected packaging. The best results were recorded for samples of rye-wheat bread, packed in PP and PVC.

When staling bread, the compressibility and elasticity of the crumb decreases and its crumbiness increases. The stale the bread, the more clearly visible layers of air, indicating a decrease in the volume of starch grains, which is usually considered as the reason for the increased crumbiness of the crumb.

Changes in the crumbiness of the crumb of the experimental and control bread samples during storage are presented in Figure 6.



	0	24	48	72	96	120
Without packaging	0,4	1,2	2,5	4,3	6,2	8,1
Paper	0,4	1,2	2,4	3,7	5,4	7,9
MTP	0,4	1	2,1	2,4	3,1	5,4
PP	0,4	0,5	1,4	2,1	3,3	5,6
PVC	0,4	0,5	1,3	2,1	3,2	5,4
Combined	0,4	0,9	1,8	2,8	4,8	7,8

Figure 6 Change in the crumbiness of bread samples from a mixture of rye and wheat flour, depending on the type of packaging during storage

The data in Figure 6 shows that crumb of bread packed in PP and PVC crumbled to a lesser extent. By the end of storage, the crumb crumbiness of the control bread samples was 8.1%, and in bread samples packed in paper, paper and paper products, combined packaging - 7.9%, 5.4% and 7.8%, respectively.

In the process of storing bread there are changes in the structure of its crumb, which affects the crumbly products. From the graph in Figure 6 it follows that by the end of the storage of bread (after 120 hours, from the moment of removal from the oven), the crumbiness in the control samples increased by 7.7% compared to the initial value. The crumbiness of bread crumb in the studied types of packaging, namely in PP, PVC, MTP increased by 5.2%, 5.0% and 5.0%, respectively.

Acidity is determined by the presence in the bread mainly of lactic and acetic acids, which are formed during the fermentation of the dough. Moderate acidity promotes better absorption of bread and gives it a pleasant taste. High acidity of bread is harmful, as it can increase the fermentation processes in the digestive organs

The acidity of the bread allows you to judge the correctness of the process and the quality of the bread. The acidity of bread is expressed in degrees Turner. Under the degree of Turner understand the amount of 1 N. a solution of sodium hydroxide (potassium), necessary to neutralize the acids contained in 100 g of bread crumb.

Studies have shown that acidity did not undergo a change during storage, whether the test rye-wheat bread is independently packaged or not.
To make a decision on the choice of packaging for bakery products, a microbiological assessment of the quality of Fitness with Raisins bread during storage was also carried out.

SanPiN 2.3.2.1078-01 regulates the determination of the following microbiological parameters for bakery products: KMAFAnM, BGKP (coli form), S. aureus, bacteria of the genus Proteus, pathogenic microorganisms, including salmonella, as well as the content of toxic elements (lead, arsenic, cadmium, mercury), mycotoxins (aflatoxin B1, deoxynivalenol, T-2 toxin, zearalenone), pesticides (hexachlorocyclohexane, DDT and its metabolites, hexachlorobenzene, organomercury pesticides, 2,4-D acid, its salts, esters) radionuclides (cesium-137, strontium-90). The content of toxic elements, mycotoxins, pesticides and radionuclides was not determined, since their presence in the raw materials is unacceptable.

Microbiological studies were carried out in accordance with the requirements of the following documents:

- KMAFAnM in accordance with GOST 10444.15-94;
- BGKP (coliforms) according to GOST R 50474-93;
- S. aureus according to GOST 10444.2-94;
- Yeast and mold according to GOST 10444.12-88;
- Residual antibiotics (Proteus) according to GOST 28560-90.

The results of microbiological studies of bread "Fitness with raisins" are presented in Tables 1 and 2.

Table 1 Change in the level of KMAFAnM in the studied bread samples during storage, depending on the type of packaging

No.	Type of packaging	No. p / p Type of packaging Duration of storage, hours					
		0	24	48	72	96	120
		CFU /g					
1	Without packaging	$7,5\times10^1$	8×10^1	$8,1\times10^1$	$8,3\times10^1$	2×10^2	4×10^2
2	Paper	$7,5\times10^1$	8×10^1	$8,1\times10^1$	$8,3\times10^1$	2×10^2	4×10^2
3	ICC	$7,5\times10^1$	9×10^1	$1,7\times10^2$	$2,5\times10^2$	$3,6\times10^2$	5×10^2
4	PP	$7,5\times10^1$	1×10^2	$2,6\times10^2$	$3,9\times10^2$	$5,3\times10^2$	7×10^2
5	PVC	$7,5\times10^1$	$1,2\times10^2$	$3,7\times10^2$	6×10^2	$8,4\times10^2$	$1,1\times10^3$
6	Combined	$7,5\times10^1$	$8,3\times10^1$	$8,5\times10^1$	$8,6\times10^1$	$2,2\times10^2$	$4,4\times10^2$

Table 2 Change in the level of mold in the studied bread samples during storage, depending on the type of packaging

No.	Type of packaging	No. p / p Type of packaging Duration of storage, hours					
		0	24	48	72	96	120
		CFU /g					
1	Without packaging	15	20	25	30	35	40
2	Paper	15	20	25	30	35	40
3	ICC	15	21	26	31	36	41
4	PP	15	22	27	32	39	45
5	PVC	15	22	28	34	43	55
6	Combined	15	20	25	30	35	40

Bacteria of the genus Proteus, S. aureus, and pathogenic bacteria, including salmonella, were not detected in the studied samples during storage.

Since, according to the results of organoleptic evaluation, to preserve individual quality indicators of bakery products, different types of packages were recommended, we conducted a comprehensive assessment of organoleptic indicators of Fitness with Raisin bread. To preserve taste and smell, paper, combined and microperforated shrink films are recommended for use; to preserve the state of the crumb during storage, use polypropylene and polyvinyl chloride packaging.

To conduct a comprehensive assessment, experts of the tasting commission established weighting factors for quality indicators: organoleptic - 0.5; physical and chemical - 0.2; microbiological - 0.3. Further, all quality indicators were ranked by degree of importance for the consumer with the arrangement of weighting factors. The ranking results are presented in Table 3.

Table 3 Quality indicators of bread "Fitness with raisins" with an indication of weighting factors

Indicators	Indicator weight coefficient	Indicators	Indicator weight coefficient
Organoleptic	0,5	Taste	0,15
		Crumb condition	0,125
		Smell	0,1
		The form	0,075
		Surface	0,05
Physicochemical	0,2	Humidity	0,1
		Acidity	0,1
Microbiological	0,3	KMAFAnM	0,15
		fungus	0,15

Further, for a comprehensive assessment of the Fitness with Raisin bread, depending on the packaging, the results of previous studies were used as the main data. The research results are presented on a 5 point scale (5 points - the maximum score and, accordingly, 1 point - the minimum).

The arithmetic average of the estimates of individual indicators (in points) was calculated by the formula:

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

Where $\sum_{i=1}^{n} x_i$ - the sum of the ratings for a specific indicator (taste, crumb condition, smell, etc.) of one product sample;

n is the number of ratings.

To characterize the scatter of the totality of estimates, we determined the standard deviation for each unit indicator by the formula:

$$S = \sqrt[n]{\frac{\sum_{i=1}^{n}(x - x_{cp.})^2}{n-1}} \qquad (2)$$

where x - assessments for a specific indicator (taste, crumb condition, smell, etc.) of one product sample;

$x_{cp.}$- average assessment results for a specific indicator (taste, crumb condition, smell, etc.) of one product sample;

n - number of ratings.

Average values of consumer criteria and deviations from them are given in Table 4.

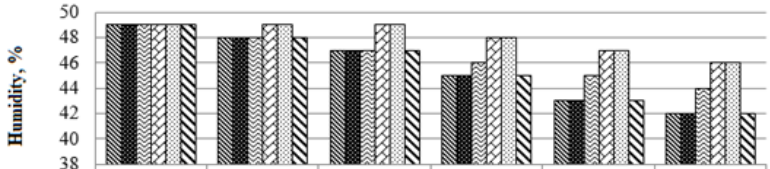
Table 4 The Results of a comprehensive assessment of bread samples "Fitness with raisins" depending on the type of packaging

	Without packaging	Paper	ICC	PP	PVC	Combined
Taste	0,75±0,03	0,75±0,03	0,60±0,02	0,60±0,02	0,60±0,02	0,60±0,02
Crumb condition	0,13±0,01	0,13±0,01	0,25±0,01	0,63±0,03	0,63±0,03	0,38±0,02
Smell	0,50±0,02	0,50±0,02	0,40±0,02	0,40±0,02	0,40±0,02	0,50±0,02
The form	0,38±0,02	0,38±0,02	0,38±0,02	0,38±0,02	0,38±0,02	0,38±0,02
Surface	0,25±0,01	0,25±0,01	0,25±0,01	0,25±0,01	0,25±0,01	0,25±0,01
Humidity	0,20±0,01	0,20±0,01	0,40±0,02	0,50±0,02	0,50±0,02	0,30±0,01
Acidity	0,50±0,02	0,50±0,02	0,50±0,02	0,50±0,02	0,50±0,02	0,50±0,02
KMAFAnM	0,75±0,03	0,60±0,02	0,60±0,02	0,45±0,02	0,30±0,01	0,60±0,02
fungus	0,75±0,03	0,60±0,02	0,75±0,03	0,60±0,02	0,30±0,01	0,60±0,02
Total Points:	4,20±0,02	3,90±0,02	4,13±0,02	4,30±0,02	3,85±0,02	4,10±0,02

The results of a comprehensive assessment revealed the leader among packages - polypropylene packaging. The results presented in table 4 indicate that the packaging of polypropylene:

- Unlike a package made of polyvinyl chloride, it provides protection against the formation of microorganisms, and therefore against mold, which in turn can serve as a basis for prolonging the increase in the shelf life of Fitness with Raisins bread from three to five days;
- Provides maximum preservation of the organoleptic indicator of the state of the crumb and the physico-chemical indicator of moisture.

Additionally, studies were conducted on the requirements of bakery manufacturers. An expert commission was convened to select packaging evaluation criteria. As a result, evaluation criteria were formed by which samples of the studied packages were compared. The comparison results are presented in Figure 5.



	0	24	48	72	96	120
Without packaging	49	48	47	45	43	42
Paper	49	48	47	45	43	42
MTP	49	48	47	46	45	44
PP	49	49	49	48	47	46
PVC	49	49	49	48	47	46
Combined	49	48	47	45	43	42

Figure 5 Change in humidity of bread crumb from a mixture of rye and wheat flour during storage, depending on the type of packaging

According to the results of comparative Figure 5, it can be concluded that the packaging made of polypropylene is a leader in packaging properties, mainly because the packaging made of polypropylene has excellent transparency and gloss, the bread looks bright and attractive in such a package, the packaging has great strength and elasticity, it is well cooked, the bag can be sterilized with dry hot air, hot bread can be packaged in a perforated bag, etc.

Conclusions

Thus, the use of polypropylene packaging in the production of bakery products will not only make the sold bread more attractive, but also to some extent solve the important problem associated with maintaining the established quality indicators of bakery products during storage, which makes it possible for bread producers to sell their products to other regions, expanding sales markets.

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Tasting Sheet for Evaluating the Quality of Heavy Bread from a Rice and Wheat Flour Mixture in the Storage Process

Surname, name of the taster _____

Represented Organization _____

Position held _____

Type of test packaging _____

The name of indicators	Quality Score Scale			Taster rating in points				
	Excellent	Good	Satisfactorily	Storage time, day				
				1	2	3	4	5
Taste: characteristic of the standardized characteristic, without extraneous taste	9 - 6	5,7 – 3	2,7 – 0,3					
Crumb condition: crumbling, elasticity, crumb color, chewing	7,5 – 5	4,75 – 2,5	2,25 – 0,25					
Smell: inherent to the normalized characteristic, without extraneous smell	6 – 4	3,8 – 2	1,8 – 0,2					
Surface	4,5 – 3	2,85 – 1,5	1,35 – 0,15					
The form	3 - 2	1,9 – 1	0,9 - 0,1					
TOTAL:	30 - 20	19 - 10	9 - 1					

Taster Signature _____

Date _____

Tasting Sheet for Evaluating the Quality of based Bread from a Rice and Wheat Flour Mixture in Storage

Surname, name, patronymic of the taster _____

Represented Organization _____

Position held _____

Type of test packaging _____

The name of indicators	Quality Score Scale			Taster rating in points				
	Excellent	Good	Satisfactory	Storage time, day				
				1	2	3	4	5
Taste: characteristic of the standardized characteristic, without extraneous taste	9 - 6	5,7 – 3	2,7 – 0,3					
Crumb condition: crumbling, elasticity, crumb color, chewing	7,5 – 5	4,75 – 2,5	2,25 – 0,25					
Smell: inherent to the normalized characteristic, without extraneous smell	6 – 4	3,8 – 2	1,8 – 0,2					
Surface	4,5 – 3	2,85 – 1,5	1,35 – 0,15					
form	3 - 2	1,9 – 1	0,9 - 0,1					
Total:	30 - 20	19 - 10	9 - 1					

Taster Signature _____

Date _____