Packaging material characteristics contributing to shelf-life of rusk

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Abstract

Bakery products are especially accessible to activity of exterior effects, principally moisture and gasses (oxygen). Applied packaging materials protect products from these effects with own barrier properties.

In this paper quality and shelf-life of two types of rusk, a commercial one and rusk with fibers were tested in relation with physic-mechanical and barrier properties of the most often used packaging materials for packaging of the rusk. The variety of packaging materials comprise OPP (oriented polypropylene foil), OPP/OPP (oriented polypropylene foil/oriented polypropylene foil), met OPP (metallized oriented polypropylene foil) OPP/metOPP (oriented polypropylene foil/metallized oriented polypropylene foil) and PET/AL/PE (polyester/aluminum/polypropylene).

Two slices of each type of rusk were packed in selected packaging materials and stored at ambient temperature. As indicators of unfavorable changes caused during storing following sensor characteristics: moisture, acidity and peroxides were tested during 6 month. The results concerning sensor and chemical analyses proved that packaging materials, attributed with better barrier properties, like OPP/met OPP and PET/AL/PE, are favourable in preserving quality of both type of rusk during prolonged storing, contrary to commonly used OPP or OPP/OPP materials.

Key words: packaging materials, packing, rusk, shelf-life

Introduction

Packaging has to protect food from different undesirable influences and positively contribute to shelf-life. Major functions that packaging materials and packing for bakery products should be expected to satisfy are the same as the demands that suit to all food products but there are also some specific ones. Specific considerations for choosing a particular type of packaging material for bakery products like low moisture, gases, aroma, fat and light (visible and UV) barrier and good mechanical properties are highly appreciated in order to ensure complete protection of a product [1, 2].

Packaging materials, depending on the nature of the material and production technology, show different protection properties like permeability of water vapor, gases and light. Bakery products are usually packed in one of these materials: paper coated with polyethylene (PE) or polyvinylene chloride (PVDC), lacquer cellophane or polymer coated cellophane, oriented polypropylene foils (OPP), monofoils or duplex foils, different multilayer polymer foils or combined metallized foils are practiced, as well as modified atmosphere. Modified atmosphere is directly related to new investments and greater costs [1, 3, 4].
Rusk is a type of bakery product attributed with prolonged shelf-life beneficial in certain diets [5]. Generally, market is offering a poor assortment of rusk-type products, particularly rusk of altered nutritive value. The period between seventies and eighties of the 20th century is marked as the decade of alimentary fibers, since it has been estimated that diet of technologically developed society and town population is characterized by high content of energy and small consumption of alimentary fibers. By adding sugar beet fibers to rusk, its attributes concerning functional food, are significantly increased. This way rusk is becoming the food with authentic claims on both the short and long term health gains. In the formulation of new value-added products, it is worth emphasizing that sugar beet fibers are low in phytic acid contrary to fibers originated from different cereals [6].

Rusk shelf-life is related to the composition and quality of raw materials, above all the type and quality of used fat. Electromagnet radiation and/or oxygen presence is accelerating fat deterioration and has an adverse influence on rusk taste and odor [5, 7]. Rusk is readily lacking characteristic aroma and absorbs smells from the surrounding. Concerning rusk, packaging materials and packing have two major functions: preservation and protection of the contents for required shelf and use life, thus significantly contributing to products quality [8-10].

In evaluating the contribution of packaging materials to rusk keeping quality, mechanical and barrier properties, above all optimal permeability of light, water vapor and oxygen, are of particular interest [11-14].

The objective of this investigation is testing physic-mechanical and barrier properties of five different packaging materials for packaging of two rusk types and determining the contribution of these properties to the shelf-life of rusk over a period of 6 month.

**Materials and methods**

**Material**

Sensor and chemical changes during storing were tested on two types of rusk: commercial product was taken from producing line at local producer AD "Hleb" Novi Sad and rusk with fibers was prepared in the laboratory on pilot plant.

Rusk was packed in following packaging materials:
- OPP - **Monofoil**, oriented polypropylene foil, declared thickness 30 μm;
- OPP/OPP - Duplex foil, oriented polypropylene foil/oriented polypropylene foil, declared thickness 20/20 μm;
- metOPP - Oriented polypropylene metallized foil, declared thickness 20 μm;
- OPP/ metOPP - Duplex foil, oriented polypropylene foil/metallized oriented polypropylene foil, declared thickness 20/20 μm;
- PET/Al/PE - polyester/aluminum/polyethylene, declared thickness 12/7/50 μm;

**Methods**

**Rusk preparation**

Rusk with fibers was prepared in the laboratory on pilot plant. Following bread formula was practiced: white flour (ash content 0.52% d.m., protein content 10.7% d.m.) 95%, fibrex 5% (a commercial product from sugar beet fibers - Denisco Sugar AB), baker's yeast - 3%, salt - 2%, shortening for rusk - 5% all of commercial grade and water according to farinograph absorption. Tin bread was baked according to standard AACC baking procedure and 24 hours after baking loaf was cut in slices 0.9 cm thick. In order to getting rusk, bread slices were placed on a tin and
baked in the oven at 200°C, approximately 10 min, until light brown color. After cooling at ambient temperature slices of either type of rusk were packed in different packaging materials.

**Packing and storage conditions of rusk**
During the whole testing period, two slices of rusk (either commercial or with fibers) packed in above mentioned materials were stored 6 month at room temperature (T=20°C±1°C), maintained by air condition and controlled by digital thermometer and displayed to day light. Tests were performed in fresh samples (0 month) and after storing period of 2, 4 and 6 month.

**Properties of the packaging materials**
The thickness, tensile strength and elongation before tearing, water vapor and gas permeability of the packaging materials were determined. All the experiments were carried out by means of standard methods and modern equipment in accredited laboratory.

The main physico-mechanical and barrier properties were evaluated according to standard procedures [15]:
- thickness, SRPS G.S2.73
- tensile strength and elongation before tearing, SRPS G.S2.734
- permeability of gases, CO2, N2, O2, by method of Lyssy, according to DIN 53380, using apparatus Lyssy GPM-200 along with belonging gas chromatograph Gasukuro Kogyo GC-320 and integrator HP 3396A [16].
- water vapor permeability, by gravimetric method ASTM E-96

Repeated measurements were taken for each property: five to ten replicates for thickness, five replicates for tensile strength and elongation at break.

**Quality of rusk**
The sensor quality of rusk (either commercial or with fibers) was assessed by five trained panelists according to ISO 4120 standard. Following rusk characteristics were determined mastication, odor and taste. Each element of quality has been assessed in three general assessment of the intensity and quality of rusk is expressed as the sum of all individual ratings of the quality element. The sensory properties of the product were determined after 0, 2, 4 and 6 month [17].

Rusk was also evaluated periodically through moisture content (standard AACC procedure), acidity and peroxides [17]. Experiments were run in six replicates. Results were expressed as mean values.

**Shelf life determination**
Shelf life was estimated in relation to odor, taste, acidity and peroxide changes [17].

**Statistical analysis**
The results concerning commercial rusk and rusk with fiber (moisture content and acidity) were statistically tested by analysis of multivariance MANOVA and discriminative test. ANOVA functions and Roy test both with 0.05 significance level were used as univariant statistical procedures to assess significant differences among means [18].

**Results and discussion**
Mechanical properties of the foil are important for successful application and keeping integrity of the packed content. The results of determination of thickness, tensile strength and elongation before tearing are given in figures 1-3:
Packaging material characteristics contributing to shelf-life of rusk

Figure 1. Thickness packaging materials (μm)

Figure 2. Tensile strength of packaging material (N/15mm)
Figure 3. Elongation (%)

The overall thickness of the OPP/OPP and OPP/met/OPP materials is above 40 μm, which is in accordance with the declared values for monomaterials. The sample PET/Al/PE has the overall thickness of over 82 μm, which is also in compliance with the declared values for the thickness of monomaterials.

Obtained results for tensile strength confirmed the good mechanical characteristics of oriented polypropylene foil as it was also stated by Pringer & Baner [19]. More specifically, the samples OPP/OPP and OPP/met/OPP have the tensile strength over 10 N 15 mm in transversal and about 68 N 15 mm in longitudinal direction. The PET/Al/PE sample has very similar tensile in longitudinal and transversal direction, thus positively contributing to the safe packing procedure. As well as good protection of wrapped rusk slices, during the whole storing period.

 Barrier characteristics of tested foils, important for the quality of rusk are presented in figures 4 and 5.

Figure 4. Gas barrier characteristics of packaging materials
Great gas permeability, particularly carbon dioxide and oxygen, was noticed in OPP and OPP/OPP materials. This is in accordance with the characteristics of applied foils. As expected, due to metallization, materials metOPP and OPP/metOPP, gas barrier is significantly improved but only multilayer material, PET/Al/PE, is practically impermeable for all tested gasses, figure 4.

Packaging material, OPP is permeable for water vapor, contrary to other tested materials. PET/Al/PE foil is attributed with complete protection for gasses and water vapor, figure 5. According to literature data [12, 20] regarding the barrier properties to gases, OPP can be classified as non barrier polymer, OPP/OPP, met/OPP and OPP/met/OPP as medium and PET/Al/PE as high barriers. Figures 1 and 5 point that relative permeability of polymer materials of the same thickness (OPP and met/OPP) is related to the layer characteristics. These data indicate that the water vapor permeability (figure 5) is relatively low in OPP/metOPP and PET/Al/PE, except for samples (OPP and OPP/OPP). The best barrier attributes in terms of gas permeability (figure 4) are those of the metallized triple foil (PET/Al/PE and OPP/met/OPP) contrary to OPP/OPP and OPP foil. The results are in agreement with the known metallization effect which improves barrier properties of packaging materials [1, 11].

In tables 1-6 the changes in the sensory characteristics of the rusk (either commercial or with fibers) in relation with the type of packaging material during the 6 month storage period are presented.

Changes in rusk moisture content are in accordance with water vapor permeability of packing material, table 1 and 2. Statistical tests, (Manova and Roy test) with 0.05 significance level show that rusk moisture depends on packing material characteristics, i.e. water barrier and storing time since p<1. During six month storing, moisture loss of rusk packed either in OPP or OPP/OPP foil is more than 20%, contrary to packaging material attributed with better barrier water vapor characteristics, where moisture loss was round 10%. Related to packaging material,
rusk with fibers exhibit the same moisture changes as the commercial product, table 2. Discriminative analysis of moisture content in both types of rusk proved that there is a close relation between packaging material and moisture, i.e. packaging material contributes to the changes of moisture, and in tables 1 and 2 the highest values are noted.

Due to the best barrier characteristics, the least moisture loss of rusk is experienced with PET/Al/PE packaging material. Moisture change in both types of rusk is related to their mastication and loss of crispness. During storing, the greatest adverse changes in mastication scores, for both types of rusk, are detected in samples packed in materials attributed with high water vapor permeability (OPP, OPP/OPP and metOPP). These results are in accordance with Robertson’s statements [1].

Table 1. Moisture content (%) and mastication (score 0-3) of commercial rusk

<table>
<thead>
<tr>
<th>Packaging materials</th>
<th>Shelf-life (months)</th>
<th>0 month</th>
<th>2 month</th>
<th>4 month</th>
<th>6 month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
</tr>
<tr>
<td>OPP</td>
<td>7.43±0.21</td>
<td>0.964</td>
<td>6.03±0.32</td>
<td>0.966</td>
<td>5.40±0.30</td>
</tr>
<tr>
<td>OPP/OPP</td>
<td>7.43±0.35</td>
<td>0.963</td>
<td>6.28±0.23</td>
<td>1.000</td>
<td>6.05±0.22*</td>
</tr>
<tr>
<td>metOPP</td>
<td>7.40±0.35</td>
<td>0.996</td>
<td>6.78±0.17*</td>
<td>1.000</td>
<td>6.45±0.19*</td>
</tr>
<tr>
<td>OPP/metOPP</td>
<td>7.40±0.14</td>
<td>0.996</td>
<td>6.83±0.27*</td>
<td>0.518</td>
<td>6.65±0.38*</td>
</tr>
<tr>
<td>PET/AL/PE</td>
<td>7.42±0.26</td>
<td>0.955</td>
<td>7.18±0.15*</td>
<td>0.946</td>
<td>6.67±0.28*</td>
</tr>
</tbody>
</table>

Mastication scores: 0 - not satisfying, 1 - satisfying; 2 - good; 3 - very good

During storing period, great permeability of gasses detected in packaging materials OPP and OPP/OPP, fig. 4 contributed to odor and taste changes in both types of rusk. Changes in acidity and peroxides are related to odor (referring to non-desired hydrolytic changes in fat and proteins) and taste (referring to oxidative changes), respectively tables 3-6. Though packaging material metOPP has a significantly lower permeability of gasses, its characteristics were not favorable for rusk packaging, probably due to inappropriate metal foil thickness. Adverse taste and odor changes in either type of rusk were not detected in samples packed in materials attributed with low permeability of gasses or in impermeable ones, OPP/metOPP and PET/AL/PE, respectively.
Packaging material characteristics contributing to shelf-life of rusk

Table 2. Moisture content (%) and mastication (score 0-3) of rusk with fibers

<table>
<thead>
<tr>
<th>Packaging materials</th>
<th>Shelf-life (months)</th>
<th>0 month</th>
<th>2 month</th>
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<tbody>
<tr>
<td></td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
</tr>
<tr>
<td>OPP</td>
<td>8.42±0.23</td>
<td>0.976</td>
<td>7.23±0.14</td>
<td>1.000</td>
<td>6.45±0.14</td>
</tr>
<tr>
<td>OPP/OPP</td>
<td>8.42±0.23</td>
<td>0.976</td>
<td>7.88±0.17*</td>
<td>1.000</td>
<td>6.93±0.21*</td>
</tr>
<tr>
<td>metOPP</td>
<td>8.40±0.14</td>
<td>0.996</td>
<td>7.88±0.29*</td>
<td>0.948</td>
<td>6.91±0.23*</td>
</tr>
<tr>
<td>OPP/metOPP</td>
<td>8.38±0.15</td>
<td>0.946</td>
<td>7.50±0.20*</td>
<td>0.996</td>
<td>7.50±0.26*</td>
</tr>
<tr>
<td>PET/AL/PE</td>
<td>8.42±0.28</td>
<td>0.981</td>
<td>8.00±0.07*</td>
<td>1.000</td>
<td>7.90±0.42*</td>
</tr>
</tbody>
</table>

Mastication scores: 0 - not satisfying, 1 - satisfying; 2 - good; 3 - very good
P-test of conclusion
* - the highest positive contribution

Over the whole storing period rusk acidity was not affected much by the quality of packaging material and in all samples was below the limiting value of 3.0, tables 3 and 4 [15]. Statistical tests point at a significant influence of packaging materials during storing period, since p<1 (Tables 3 and 4). A slight increase in acidity of both rusk types was detected at the level of 11 to 12% and can be attributed to the changes in fats. Packaging materials characterized with better barrier attributes (OPP/metOPP and PET/AL/PE) exhibit superior protective effect, proved by statistically estimated contribution and by rusk odor scores after six month, tables 3 and 4. Fibers in rusk were not contributing to retarding odor changes in the wrapped unit.

Table 3. Acidity (ml 0.1 M NaOH) and odor (score 0-3) of commercial rusk

<table>
<thead>
<tr>
<th>Packaging materials</th>
<th>Shelf-life (months)</th>
<th>0 month</th>
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<th>4 month</th>
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</tr>
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<tbody>
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<td></td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
</tr>
<tr>
<td>OPP</td>
<td>1.89±0.10</td>
<td>0.999</td>
<td>2.05±0.07</td>
<td>0.999</td>
<td>2.12±0.05</td>
</tr>
<tr>
<td>OPP/OPP</td>
<td>1.89±0.06</td>
<td>0.998</td>
<td>2.09±0.02</td>
<td>0.906</td>
<td>2.11±0.07</td>
</tr>
<tr>
<td>metOPP</td>
<td>1.88±0.07</td>
<td>0.999</td>
<td>1.95±0.05*</td>
<td>0.999</td>
<td>2.10±0.08</td>
</tr>
<tr>
<td>OPP/metOPP</td>
<td>1.88±0.09</td>
<td>0.998</td>
<td>2.00±0.04*</td>
<td>0.928</td>
<td>2.04±0.13*</td>
</tr>
<tr>
<td>PET/AL/PE</td>
<td>1.88±0.04</td>
<td>1.000</td>
<td>1.94±0.04*</td>
<td>0.859</td>
<td>2.00±0.15</td>
</tr>
</tbody>
</table>

Odor scores: 0 - stale; 1 -satisfying; 2 - good ; 3 - very good
P-test of conclusion
* - the highest positive contribution
Table 4. Acidity (ml 0.1 M NaOH) and odor (score 0-3) of rusk with fibers

<table>
<thead>
<tr>
<th>Packaging materials</th>
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<td>P</td>
<td>Mean value and standard deviation</td>
<td>P</td>
<td>Mean value and standard deviation</td>
</tr>
<tr>
<td>OPP</td>
<td>1.95 ± 0.04</td>
<td>0.998</td>
<td>2.12 ± 0.12</td>
<td>1.000</td>
<td>2.20 ± 0.32</td>
</tr>
<tr>
<td>OPP/OPP</td>
<td>1.95 ± 0.16</td>
<td>0.994</td>
<td>2.07 ± 0.29</td>
<td>0.997</td>
<td>2.15 ± 0.10</td>
</tr>
<tr>
<td>metOPP</td>
<td>1.95 ± 0.11</td>
<td>0.996</td>
<td>2.07 ± 0.05</td>
<td>0.996</td>
<td>2.15 ± 0.14</td>
</tr>
<tr>
<td>OPP/metOPP</td>
<td>1.95 ± 0.10</td>
<td>0.979</td>
<td>2.00 ± 0.49</td>
<td>0.994</td>
<td>2.09 ± 0.07</td>
</tr>
<tr>
<td>PET/AL/PE</td>
<td>1.95 ± 0.13</td>
<td>0.991</td>
<td>2.02 ± 0.69</td>
<td>0.999</td>
<td>2.03 ± 0.15</td>
</tr>
</tbody>
</table>

Odor scores: 0 - stale; 1 - satisfying; 2 - good; 3 - very good
p-test of conclusion
* - the highest positive contribution

In both types of rusk, during storing period peroxides changed insignificantly, but still it was worth emphasizing the contribution of packaging material properties, particularly good oxygen barrier, in retarding fat oxidative changes, as it was stated by Robertson [1] and Pajin [21]. The slight rise in peroxides, in both types of rusk is accompanied with changes in rusk taste. This sensor characteristics were more valuable in scoring the contribution of packaging material to rusk keeping quality. They are in accordance with estimated gases and moisture barrier of OPP/metOPP and PET/AL/PE emphasizing the contribution of those packaging materials, tables 5 and 6. The greatest change in taste is experienced with the product packed in metOPP foil, probably due to inappropriate foil thickness. By comparing packaging materials and rusk type, a slight positive contribution of fibers on rusk wrapped in multilayer foils was noticed, but this needs to be tested. On the whole, packaging material characteristics prove to be the most important for protecting either type of rusk quality over a period of 6 month.

Table 5. Peroxides (mg O₂/kg) and taste (score 0-3) in commercial rusk

<table>
<thead>
<tr>
<th>Packaging materials</th>
<th>Shelf-life (months)</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPP</td>
<td>0⁰</td>
<td>0³</td>
<td>0²</td>
<td>0³</td>
<td>0.04¹</td>
</tr>
<tr>
<td>OPP/OPP</td>
<td>0⁰</td>
<td>0¹</td>
<td>0¹</td>
<td>0²</td>
<td>0.02¹</td>
</tr>
<tr>
<td>metOPP</td>
<td>0⁰</td>
<td>0²</td>
<td>0³</td>
<td>0³</td>
<td>0.02⁰</td>
</tr>
<tr>
<td>OPP/metOPP</td>
<td>0³</td>
<td>0³</td>
<td>0³</td>
<td>0³</td>
<td>0³</td>
</tr>
<tr>
<td>PET/AL/PE</td>
<td>0³</td>
<td>0³</td>
<td>0³</td>
<td>0³</td>
<td>0³</td>
</tr>
</tbody>
</table>

Taste scores: 0 - non acceptable; 1 - acceptable; 2 - good; 3 - very good
Table 6. Peroxides (mg O₂/kg) and taste (score 0-3) in rusk with fibers

<table>
<thead>
<tr>
<th>Packaging materials</th>
<th>Shelf-life (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>OPP</td>
<td>0°</td>
</tr>
<tr>
<td>OPP/OPP</td>
<td>0°</td>
</tr>
<tr>
<td>metOPP</td>
<td>0°</td>
</tr>
<tr>
<td>OPP/metOPP</td>
<td>0°</td>
</tr>
<tr>
<td>PET/AL/PE</td>
<td>0°</td>
</tr>
</tbody>
</table>

Taste scores: 0 - non acceptable; 1 - acceptable; 2 - good; 3 - very good

Conclusions

Based on data related to the contribution of different packaging materials and rusk quality it can be stated:

- Quality of packed rusk is not influenced by the fiber content in the product contrary to barrier characteristics of a packaging material.
- All tested packaging materials (OPP, OPP/OPP, met/OPP, OPP/met/OPP, PET/AL/PE) were attributed with good physic-mechanical characteristics enabling regular packaging process and good preservation of the integrity of packed rusk.
- Materials OPP/met/OPP and PET/AL/PE were characterized with low permeability of gases and water vapor thus positively contributing to moisture loss and retarding oxidative changes in both rusk types, pointing that metal layer should be either of adequate thickness or double protected.
- Commercial rusk and rusk with fibers packed in the packaging materials attributed with good barrier properties, OPP/met/OPP and PET/AL/PE foil, showed the highest stability during storage contrary to commonly used OPP or OPP/OPP foils.
- In a period of 6 months, quality (acidity and peroxides) and sensor characteristics (mastication, odor and taste) of commercial rusk and rusk with fibers can be preserved unchangeable only if rusk was packed in material with enhanced barrier properties.
- Pertinent data contribute to understand the relation between characteristics of packaging material and rusk quality during a longer period of storing. Results indicate that commonly used packaging materials (OPP or OPP/OPP) should be replaced with multi layer packaging materials, attributed with good water vapor and gas barrier enable long term storing at ambient temperature, eliminating the need of either modified atmosphere or smart packaging, i.e. new investments.

Acknowledgement

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