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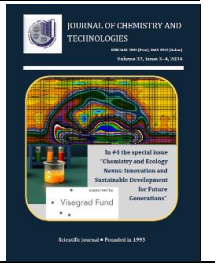

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# DEVELOPMENT OF ECO-FRIENDLY PACKAGING BASED ON BEES PRODUCTS AND PLANT EXTRACTS AND EVALUATION OF ITS ANTIBACTERIAL POTENTIAL

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## Abstract

**The aim of our research is to develop the environmentally friendly and reusable antimicrobial packaging based on the beeswax with antibacterial agents: propolis and sage extracts and evaluation of its storage abilities and antibacterial properties. During the experiment were used cotton fabrics, beeswax, propolis, sage leaves, emulsifiers and antioxidants were used as materials for the development of the packaging. Samples of beeswax wraps were produced using three technologies. The obtained samples were tested for food storage ability (for bread, cheese and sausages) and antimicrobial activity against *S. aureus, E. coli, P. auroginosa* and *C. albicans*. Obtained wraps samples have been tested on a basic set of products available in every household: bakery products, hard cheeses and ready-made sausages. Beeswax wrapping prepared by all methods was found to be the best for cheese storage. Results of the experiment on the determination of the antimicrobial activity of beeswax wraps and antimicrobial agents against *S. aureus, E. coli, P. aeruginosa, C. albicans* have shown that sage extract has high activity against *S. aureus* and moderate activity against *E. coly* and *P. aeruginosa*. Propolis oily extract possess moderate activity against tested microorganisms and both extracts had low antifungal activity. Determination of the antimicrobial activity of beeswax wraps and antimicrobial agents against *S. aureus, E. coli, P. aeruginosa, C. albicans* have shown moderate and low activity against microorganisms and no antifungal activity. Summing up we could conclude that beeswax wraps can act as a promising packaging for a food products.**

*Keywords:* Beewax; propolis; sage extract; eco-packaging; food preservation; antimicrobial activity.

# РОЗРОБКА ЕКОЛОГІЧНОЇ УПАКОВКИ НА ОСНОВІ ПРОДУКТІВ БДЖІЛЬНИЦТВА ТА РОСЛИННИХ ЕКСТРАКТІВ ТА ОЦІНКА ЇЇ АНТИБАКТЕРІАЛЬНОЇ АКТИВНОСТІ

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## Анотація

**Метою досліджень є розробка екологічного антимікробного пакування багаторазового використання на основі бджолиного воску з екстрактами прополісу та шавлії, а також оцінка його здатності до зберігання продуктів харчування та антибактеріальних властивостей. Як матеріали для розробки упаковки були використані бавовняні тканини, бджолиний віск, прополіс, листя шавлії, емульгатори та антиоксиданти. Зразки обгорток з бджолиного воску були виготовлені за трьома технологіями. Зразки були протестовані на здатність до зберігання харчових продуктів (хліба, сиру та ковбас) та антимікробну активність щодо *S. aureus*, *E. coli, P. auroginosa* та *C. albicans*. Найкращі результати щодо збереження споживчих властивостей виявлені під час зберігання сиру. Екстракт шавлії має високу активність щодо *S. aureus* та помірну активність щодо *E. coly* і *P. aeruginosa*. Олійний екстракт прополісу має помірну активність проти досліджуваних мікроорганізмів, а обидва екстракти – низьку протигрибкову активність. Визначення антимікробної активності бджолиних воскових обгорток проти *S. aureus, E. coli, P. aeruginosa*, *C. albicans* показало помірну та низьку активність проти мікроорганізмів та відсутність протигрибкової активності. Можна зробити висновок, що обгортки з бджолиного воску можуть бути перспективним пакувальним матеріалом для харчових продуктів.**

*Ключові слова:* бджолиний віск; прополіс; екстракт шавлії; екоупаковка; консервування харчових продуктів; антимікробна активність

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## Introduction

Food spoilage is a metabolic process and microbial contamination and oxidation of nutrients are its two main reasons. Food loss caused by the spoilage, causes considerable environmental and economic effects and by different estimations 10-30% of food were lost by retailers, foodservice and consumers [6; 14; 18].

One of the possible ways to prevent spoilage of food is antimicrobial packaging that posess not only conventional barrier properties but also microbial inhibiting. In addition to antimicrobial properties, such packaging should be characterized by the following properties: functionality; cost-effectiveness; and environmental friendliness [1; 3; 7; 11; 14; 18; 23].

Beeswax based packaging can be a good alternative due to many benefits. The inclusion of beeswax, which is a powerful water repellent, in packaging materials can lead to improved moisture protection and mechanical properties, as well as the appearance of fresh produce. Also it was found that beeswax is effective against gram-positive and gram-negative bacteria as well as fungi. The antimicrobial effects of beeswax had been found to have the antimicrobial effects against the bacteria from the genera *Bacillus, Escherichia, Listeria, Proteus, Pseudomonas, Salmonella, Staphylococcus*; yeast from the genera *Candida, Rhodotorula*; and molds from the genera *Aspergillus* and *Geotrichum* [5; 9; 10; 16; 19].

Another beesproduct – propolis is widely used in the food and pharmaceutical industry and can also be used as an active ingredient in the production of natural packaging materials. It contains resins (50 %), flavonoids and phenolic acids; waxes (up to 30 %), essential oils (10%), pollen (5%), and other organic substances (5 %), which have a potential antimicrobial properties against more than 100 strains of microorganisms (on gram-positive bacteria – delays the growth of white and aureus *Staphylococci*, hemolytic *Streptococcus*, gram-negative bacteria – delays the growth of paratyphoid pathogens, toxic infections and *Candida fungi*) [7; 17; 21; 25].

These bees products have found an application in the natural and biodegradable packaging materials development. In the numerous researches inclusion of propolis extracts to food packaging products or biopolymers film matrix such as chitosan, starch, κ-carrageenan, gelatin, agar, and biopolymers have shown opportunities for producing active packaging films that are very safe and environmentally friendly compared to petroleum-based plastic packaging films [16;17]. And recent progress in the development and manufacture of food-grade films/coatings containing beeswax (e.g., emulsion and blended films, bilayers, bionanocomposites, and antimicrobial materials) has shown that its incorporation into polysaccharide and protein-based emulsion films effectively improves their hydrophobicity, water vapor and UV/visible light barrier properties, and tensile properties [3; 8; 16; 19].

Extracts from medicinal plants that have antitumour, anti-inflammatory, and antioxidant effect have also demonstrated antimicrobial properties. Thus, antimicrobials from natural extracts that are used in food packaging application could fulfill the primary goal of maintaining food quality while delivering additional health benefits, such as nutritional supplements [3;12;24;27].

Sage *(Salvia officinalis)* is one of the herbs with a great potential for use as a functional ingredient for the development of active food packaging due to its well-known antioxidant, antibacterial, and antifungal effects. These beneficial activities are positively related to phenolic compounds, such as phenolic diterpenoids (carnosic acid, carnosol, rosmanol), phenolic acids (caffeic acid, rosmarinic acid, ferulic acid) and flavonoids (luteolin derivatives, apigenin derivatives. Inclusion of sage extracts as antibacterial agents in packaging systems has excellent potential for extending the shelf life and improving the quality of several food products. In addition to being a preservative, it can also be used to prevent adverse physical and chemical changes of the products [2; 13; 15].

In our researches we focused on the development of the environmentally friendly and reusable antimicrobial packaging based on the beeswax with antibacterial agents: propolis and sage extracts and evaluation of its food preservation abilities and antibacterial properties.

## Materials and methods

*Materials and chemicals*

In the experiment were used cotton fabric (DSTU GOST 21790:2008), beeswax (DSTU 4229:2003), propolis samples (DSTU 4662:2006), Sage leaves (UA /2356/01/01), ethyl alcohol 96 % (DSTU 4221:2003), propolis

extract alcohol 10 % (UA /5422/01/01 Manufacturer JSC Vitamins, Uman), Vitamin E (UA/0717/02/01), emulsion wax (TU U 24.1-22942814.018-2001), cetyl alcohol (CAS NO. 36653-82-4). All chemicals were commercially available at the local market and were of analytical grades.

*Propolis oily extract 10 %* was prepared according the technic given by the [25].

*Sage ethanolic extract 10 %* The sage extract was obtained by the maceration method, the ratio of raw material to extragent was 1 : 10. A 50 % aqueous solution of ethyl alcohol was used as an extragent, obtained by mixing the corresponding volumes of 96 % ethyl alcohol and purified water. Taking into account the absorption coefficient, 500 ml of 50 % ethanol and 40 g of raw material were taken. The raw material was poured with the calculated volume of extractant and left to infuse for 7 days, stirring occasionally. After this period, the extract was filtered through a filter steamer and left for 2 days for purification at 10 °C. After that, the extract was filtered again.

*Sage dense extract.* Ethanol extracts of sage were evaporated using a Buchi R-134 rotary evaporator (Switzerland) to a residual moisture content of no more than 30 %. The evaporation temperature in the water bath was 60 °C, and the operating range of vacuum depth was 50–35 mBar.

*Preparation of wrap samples*

In preparing the wrap samples we used the 3 technological methods [26]:

*According to the 1st method,* a homogeneous alloy of beeswax and 10 % propolis oil extract was prepared and applied to a cotton fabric.

Stage 1. Raw materials (beeswax, propolis and sunflower oil) were weighted on scales (TBE-0,21-0,001-a-2) according to the formulations (table 1)

Stage 2. Propolis from stage 1 was grinded. The mortar with sunflower oil was placed on the waterbath heated to 60°C. After heating of sunflower oil the grinded propolis was portionaly added to it at constant mixing 100 rpm. The process of propolis oil extraction takes 1 hour at constant temperature 60 °C and mixing. After in a hot state the extract was filtrated through gauze filter and transferred to the stage 3.

Stage 3. The beeswax from stage 1 was placed in a mortar and melted in a water bath at 60 °C. Than propolis sunflower oil extract and Vit E was added to melted beeswax at constant mixing. After obtaining the homogenous alloy of beeswax and propolis oily extract (10 min) it was transferred on the stage 4.

Stage 4. The alloy of beeswax and propolis oily extract was poured out in a heated to 60°C bath. Cotton fabric was immersed in the alloy and than rolled between two heated to 60°C rollers. After that the fabric was cooled down by air from cooling fan.

Stage 5. The fabric was cut into wraps of required sizes.

*According to the 2nd method* Beeswax wraps with oily propolis and dense sage extracts were prepared by emulsion method

Stage 1. Raw materials (beeswax, propolis and sunflower oil, sage dense extract, cetyl alcohol, emulsive wax) were weighted on scales according to the formulations (table 1).

Stage 2. Propolis from stage 1 was grinded. The mortar with sunflower oil was placed on the waterbath heated to 60 °C. After heating of sunflower oil the grinded propolis was portionaly added to it at the constant mixing 100 rpm. The process of propolis oil extraction takes 1 hour at constant temperature 60 °C and mixing. After that the extract in the hot state was filtrated through gauze filter and transferred to the stage 3.

Stage 3. The beeswax from the stage 1 was placed in a mortar and melted in a water bath at 60 °C. Than emulsifiers were added to melted beeswax at constant mixing according to the given formulations (table 1). After obtaining of homogenous alloy (10 min) it was transferred on the stage 4.

Stage 4. To the alloy from the stage 3 was added Sage dense extract and conducted emulsification at 1000 rpm at 60 °C.

Stage 5. To the alloy from stage 4 was added propolis oily extract from stage 2 and Vit E at constant mixing.

Stage 6. The emulsion of beeswax, sage dense extract and propolis oily extract was poured out in a heated to 60 °C bath. Cotton fabric was immersed in the alloy and then rolled between two heated to 60 °C rollers. After this fabric was cooled down by air from pneumatic fan.

Stage 7. The fabric was cut into wraps of required sizes.

*According to the 3nd method,* a wax base was prepared and applied to a cotton cloth. After that, the wax wrap was sprayed with alcohol extracts of propolis and sage and dried until the ethanol evaporated completely. The yield of the extracts was 2 ml per 600 $cm^2$ (Yudina et al., 2022).

Stage 1. The beeswax was placed in a mortar and melted in a water bath at 60 °C.

Stage 2. Cotton fabric was immersed in the

bath with melted beeswax and then rolled between two heated to 60 °C rollers. After this fabric was cooled down by air from pneumatic fan.

Stage 3. Propolis and sage ethanolic extracts were sprayed on a waxed fabric and then dried from ethanol residues using an air dryer in a stream of air at 20 °C.

Stage 4. The fabric was cut into wraps of the desired size.

The formulation of wrap samples obtained by described methods and the results of evaluation of their appearance are given in the Table 1.

*Table 1*

**Formulations of beeswax wraps**

| № of sample | Formulation | Method | Description |
|---|---|---|---|
| 1. | Beeswax -49 %<br>Propolis oil extract 10 % -50<br>Vit E – 1% | 1st | The wrap is soft, oily to the touch, homogeneous, does not hold its shape when formed, with a slight smell of wax |
| 2. | Beeswax -59 %<br>Propolis oil extract 10 % -40<br>Vit E – 1 % | 1st | The wrap is soft, oily to the touch, homogeneous, does not hold its shape when formed, with a slight smell of wax and propolis |
| 3. | Beeswax -30 %<br>Propolis oil extract 10 % -50<br>Sage dense extract 5 %<br>Cetyl alcohol -10<br>Emulsive was 4<br>Vit E – 1 % | 2st | The wrap is soft, oily to the touch, brownish, homogeneous, does not hold its shape when formed, with a slight herbal odor |
| 4. | Beeswax -40 %<br>Propolis oil extract 10 % -40<br>Sage dense extract 5 %<br>Cetyl alcohol -10<br>Emulsive was 4<br>Vit E – 1 % | 2st | The wrap is soft, oily to the touch, brownish, homogeneous, does not hold its shape when formed, with a slight herbal odor |
| 5. | Beeswax -100 %<br>Propolis ethanolic extract 10 % –<br>2 ml/600 cm² | 3d | The wrap is dense, homogeneous, holds its shape when formed, with a slight smell of wax |
| 6. | Beeswax -100 %<br>Sage ethanolic extract 10% –<br>2 ml/600 cm² | 3d | The wrap is dense, homogeneous, holds its shape when formed, with a slight smell of wax |
| 7. | Beeswax -100 %<br>Propolis ethanolic extract 10 % –<br>2 ml/600 cm²<br>Sage ethanolic extract 10 % –<br>2 ml/600 cm² | 3d | The wrap is dense, homogeneous, holds its shape when formed, with a slight smell of wax |
| 8. | Beeswax 100% without antimicrobials | 1st | The wrap is dense, homogeneous, holds its shape when formed, with a slight smell of wax |
| 9. | Control – polyethylene film | | |

*Evaluation of wraps storage ability*

The following products were tested to evaluate the ability of wrapping samples to preserve food quality:

*White bread (*loaf "Sliced ordinary" of Kulinichi TM) storage terms given by manufacturer 48 h.

*Dutch cheese* 45 % fat (TM "Slavia") storage terms given by manufacturer 120 days in flow-pack packaging, after opening store 7 days at temperature +4–6 °C.

*Sausages Shkolnye (Saltovsky Meat Plant)* ) storage terms 20 days at 0–5 °C.

All samples were stored at room temperature 20±5 °C and relative humidity 40 %, with revision every 3 days. Visual evaluation was carried out according to the following parameters: appearance, odor, presence of signs of microbiological spoilage by 5 point scale, where

1 – high quality (product appearance has no changes),

2 – above average (minor changes in appearance,

3 – average (presence of weathering or staling),

4 – below average (presence of spoilage signs),

5 – low (complete spoilage of the product).

*Microbiological studies*

All samples (№ 1–8) were tested for antimicrobial activity. Microbiological studies have been conducted in the microbiological laboratory of JSC “Red star”. Analysis conducted according DSTU ISO 20645:2009 for wrap samples.

*Sample preparation.*

The wrap samples were cut into pieces of 2×2 cm in size. The antimicrobial activity was

determined by the agar diffusion method [2].

Wrap samples were placed in Petri dishes containing casein agar (CA) free of bacteria. Plates with CA agar containing *Escherichia coli* (ATCC 25922) *Pseudomonas aeruginosa* (ATCC 9027) *Staphylococus aureus* (ATCC 6538P) and *Candida albicans* ATCC 885/653 ($10^8$ CFU/ml) were placed on top of the Petri dishes with wrap samples. The plates were incubated for 18-24 h at 37°C. The total diameter of the sample and the growth retardation zone, the diameter of the sample were measured and the width of the growth inhibition zone was calculated using the formula (1)

$$H = D - d/2, \quad (1)$$

where D – is the total diameter of the sample and the inhibition zone, mm,

D – is the diameter of the sample.

## Results and discussion

*Comparing technological approaches*

Description of obtained wraps samples is given in the table 1. When developing the technology were several approaches that have their pros and con.

By the first and second methods has been achieved uniform distribution of antibacterial components in the packaging. In this case, the wrap is more stable and homogeneous. Beeswax is a hydrophobic substance and prevents the penetration of moisture and air from the external environment, and the fabric base impregnated with wax is perfectly modeled, taking the shape of the packaged product, thus creating an optimal environment inside the package that prevents the product itself from drying out. But introducing more extracts into the composition of the impregnation for wrapping, it is necessary to increase the amount of auxiliary substances that will stabilize the composition, and accordingly the rheological properties of the impregnation will change, it becomes more plastic, the amount of the hydrophilic phase in it increases and, accordingly, it becomes less moisture resistant. The second technology by itself is more complex and energy-consuming, and additional excipients are required to ensure the introduction of hydrophilic plant extracts into the hydrophobic base. In addition, a greater amount of antimicrobial agents is required to ensure pronounced antimicrobial properties.

Wraps obtained by the third method have coating of antibacterial agents on the surface of the packaging. This method of production preserves the moisture-resistant properties of the packaging, and antimicrobial substances inhibit the growth of microorganisms in direct contact with the product. In this case, we have a very simple low-cost technology, and reduced amount of antimicrobial components, but another problem is the washing off of the top layer containing antimicrobial components during use.

*Determination of storage ability of beeswax wraps*

Obtained wraps samples have been tested on a basic set of products available in every household: bakery products, hard cheeses and ready-made sausages. Results of the experiment on the determination of the storage ability of beeswax wraps are given in the Table 2 and on the figures 1–3.

*Table 2*

**The results of evaluation of the storage abilities of the beeswax wraps samples**

| № of sample | Bread samples | | | Cheese | | | Sausages | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 days | 6 days | 9days | 3 days | 6 days | 9 days | 3 days | 6 days | 9days |
| 1. | soft, mold-free | stale at the edges, without mold | mold-free bread crumbs | No changes | No changes | No changes | No changes | sticky with a stale odor | sticky with mold spots |
| 2. | soft, mold-free | stale at the edges, without mold | mold-free bread crumbs | No changes | No changes | No changes | No changes | sticky with a stale odor | sticky with mold spots |
| 3. | soft, mold-free | stale at the edges, without mold | mold-free bread crumbs | No changes | No changes | No changes | No changes | sticky with a stale odor | sticky with mold spots |
| 4. | soft, mold-free | stale at the edges, without mold | mold-free bread crumbs | No changes | No changes | No changes | No changes | sticky with a stale odor | sticky with a stale odor |
| 5. | soft, mold-free | soft, mold-free | soft, mold-free | No changes | No changes | No changes | No changes | No changes | sticky with a stale odor |

*Continued from Table 2*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6. | soft, mold-free | soft, mold-free | soft, mold-free | No changes | No changes | No changes | No changes | No changes | sticky with a stale odor |
| 7. | soft, mold-free | soft, mold-free | soft, mold-free | No changes | No changes | No changes | No changes | No changes | sticky with a stale odor |
| 8. | soft, mold-free | soft, mold-free | soft, mold-free | No changes | No changes | No changes | No changes | No changes | sticky with a stale odor |
| (plastic wrap) | soft, mold-free | soft, a slight moldy smell has appeared | soft, with signs of mold | No changes | Slight signs of white mold at the ages | Slight signs of white mold at the ages | sticky with mold spots | sticky with mold spots | sticky with mold spots |


**Fig. 1. Visual evaluation of bread samples by 5 point scale**

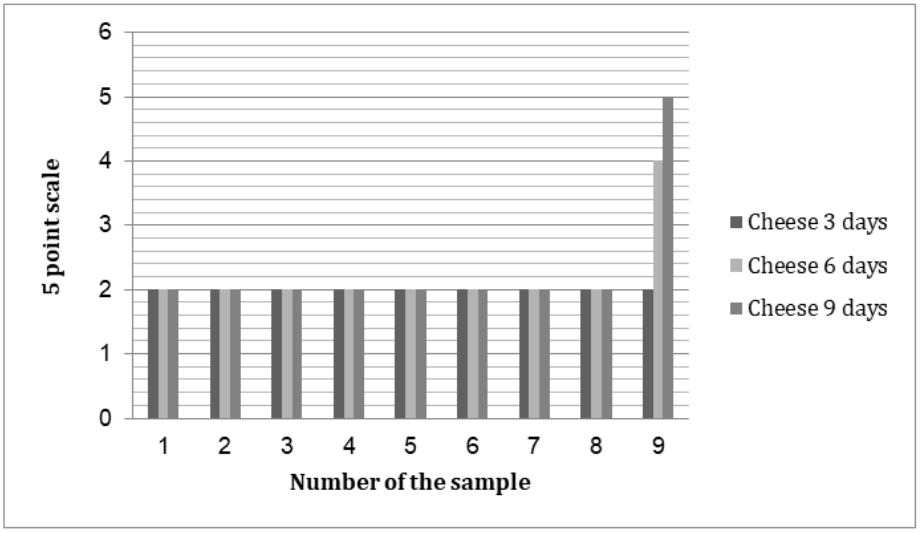


**Fig. 2. Visual evaluation of cheese samples by 5 point scale**

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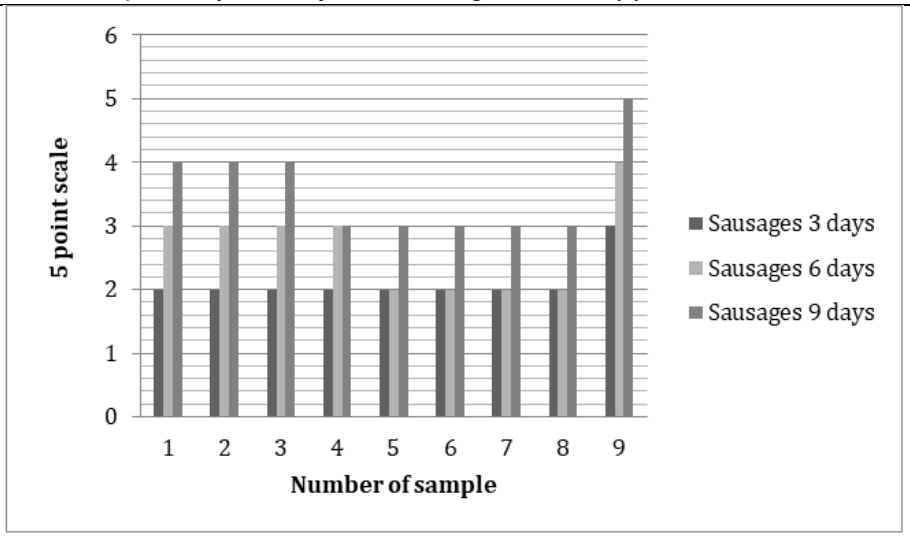


**Fig. 3. Visual evaluation of sausages samples by 5 point scale**

The quality of ready-to-eat food products, such as the ones we have chosen, depends on many factors, first of all on the technology of their preparation and the quality of the initial products, the presence of preservatives, primary factory packaging, transportation and storage conditions until reaching the final consumer. Within the storage period of products, several important changes contribute to the decreasing consumer acceptance. For bread these changes include physicochemical processes such as the crumb firming process, water migration within the crumb, crust and the environment, the loss of flavor and microbial spoilage. Maintaining cheese quality during storage also requires protection against dehydration and reduction of undesirable microorganisms, especially pathogens. Storage properties of sausage products depend mainly on their processing technologies presence and amount of preservatives in formulations and primary packaging.

Beeswax wrapping prepared by all methods was found to be the best for cheese storage. Even under inadequate storage conditions, the cheese samples remained in the 2nd or 3rd points (above average and average quality) compared to traditional plastic wrap (4–5 points).

Bread stored in wrappers made according to the 1st and 2nd method with the addition of emulsifiers showed a tendency to dry out and weathering faster than other samples, but there were no signs of microbiological spoilage observed. This can be explained by the increase in air permeability caused by a decrease in the density and viscosity of the wrapper with the addition of more aqueous phase and emulsifiers. And the best bread is stored in wrappers obtained by the 3rd method.

As for sausages, no clear correlation was found between the method of preparing the wrapper, the content of antibacterial agents and the quality of the stored product.

*Determination of antimicrobial activity of beeswax wraps*

Results of the experiment on the determination of the antimicrobial activity of beeswax wraps and antimicrobial agents against *Staphylococus aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans* are given in the Table 3 and on the figures 4–7.

*Table 3*

**Antimicrobial activity of beeswax wraps**

| № of the sample | Staphylococus aureus (ATCC 6538P) | | Escherichia coli (ATCC 25922) | | Pseudomonas aeruginosa (ATCC 9027) | | Candida albicans ATCC 885/653 | |
|---|---|---|---|---|---|---|---|---|
| | Zone of inhibition, mm | Estimation | Zone of inhibition, mm | Estimation | Zone of inhibition, mm | Estimation | Zone of inhibition, mm | Estimation |
| 1. | 0 | No activity | 0 | No activity | 0 | No activity | 0 | No activity |
| 2. | 0 | No activity | 0 | No activity | 0 | No activity | 0 | No activity |
| 3. | 15,3 | moderate activity | 12,5 | moderate activity | 8.5 | low activity | 0 | No activity |
| 4. | 13,2 | moderate activity | 10,2 | moderate activity | 10.5 | low activity | 0 | No activity |
| 5. | 5 | low activity | 4 | low activity | 5.5 | low activity | 0 | No activity |

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*Continued from Table 3*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6. | 5 | low activity | 5 | low activity | 6.0 | low activity | 0 | No activity |
| 7. | 7 | low activity | 5 | low activity | 7.5 | low activity | 0 | No activity |
| 8. | 12.5 | moderate activity | 7,5 | low activity | 10.3 | moderate activity | 0 | No activity |
| Propolis oily extract 10% | 18.3 | moderate activity | 15.5 | moderate activity | 13.5 | moderate activity | 10.5 | low activity |
| Sage extract 10% | 20 | High activity | 7 | low activity | 5 | low activity | 10 | low activity |

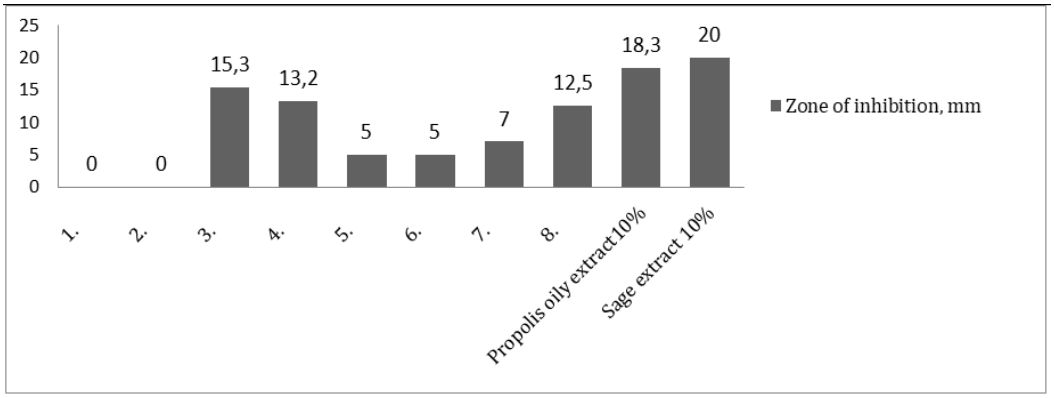


**Fig. 4. Antimicrobial activity of the beeswax wrap samples against *Staphylococus aureus* (ATCC 6538P)**

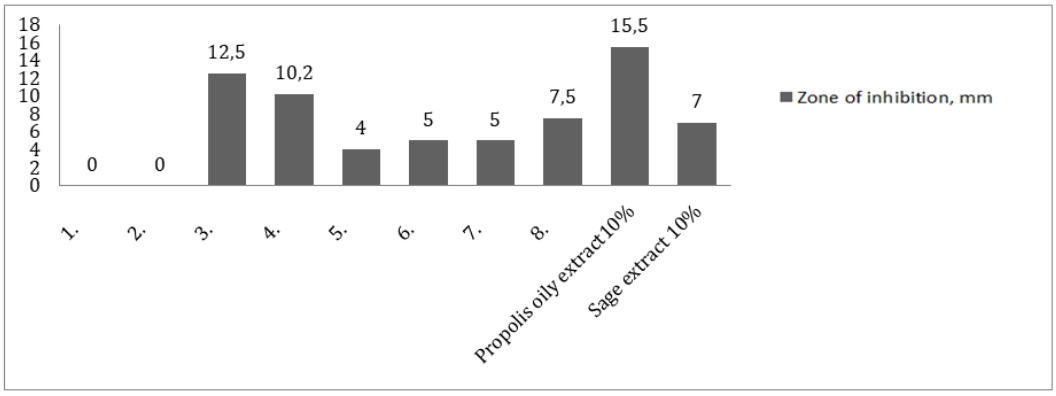


**Fig. 5. Antimicrobial activity of the beeswax wrap samples against *Escherichia coli* (ATCC 25922)**

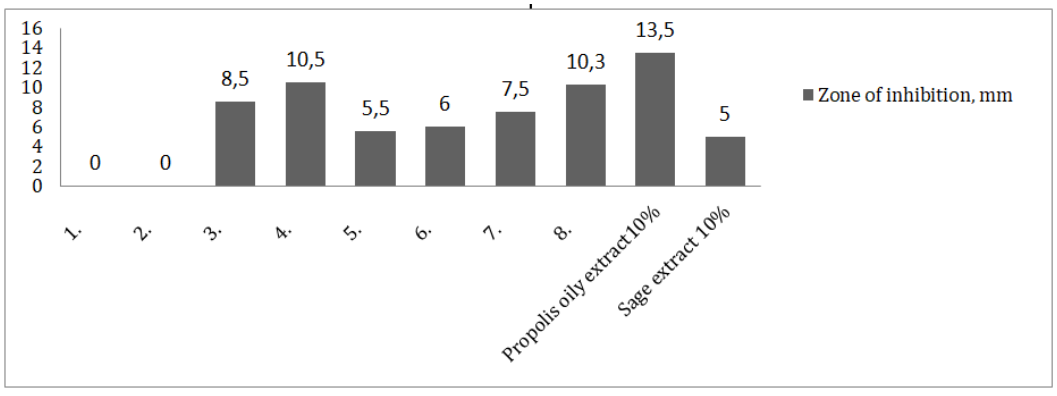


**Fig. 6. Antimicrobial activity of the beeswax wrap samples against *Pseudomonas aeruginosa* (ATCC 9027)**

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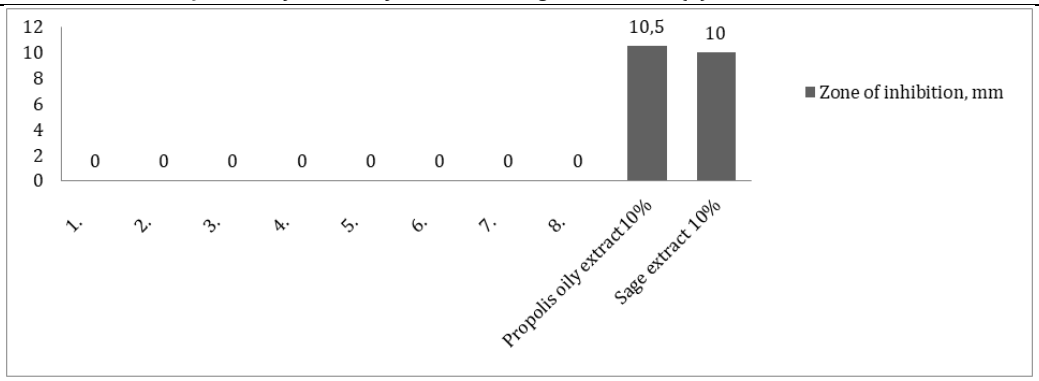


**Fig. 7. Antimicrobial activity of the beeswax wrap samples against *Candida albicans* ATCC 885/653**

Sage extract has shown high activity against *S. aureus* and moderate activity against *E. coly* and *P. aeruginosa.* Propolis oily extract possess moderate activity against tested microorganisms and both extracts had low antifungal activity.

Film samples obtained by the 2nd method have moderate activity against *S. aureus* and *E. coly* and low activity against *P. aeruginosa*. This can be explained by the presence of emulsifiers and stabilizers that affect the rheological properties of the coating and, as a result, the release of antimicrobials from the wrapping coating.

Activity of the samples obtained by the 3d method against *S. aureus* and *E.coly* was low and for *P. aeruginosa* moderate. For the control beeswax wraps without antibacterials was observed moderate activity against *P. aeruginosa S. aureus* and low activity against *E.coly*.

In the samples obtained by the 1st method no antimicrobial activity was observed. All samples of wraps showed no activity against fungi.

These results can be explained by the different mechanisms of antibacterial substances release from wraps obtained by different methods. Wraps by 2nd method with the addition of propolis and sage extracts better protected products from the effects of microorganisms, but by introducing more extracts into the composition of the impregnation for wrapping, it is necessary to increase the amount of excipients emulsifiers that will stabilize the composition. These emulsifiers from one hand enhance release of antibacterials but from the other hand the rheological properties of the formulation will change, it becomes more plastic, the amount of the hydrophilic phase in it increases and, accordingly, it becomes less moisture resistant and favorable conditions for the growth of microorganisms are created inside the package. In the wraps obtained by spraying (3d) method, the growth of microorganisms was inhibited due to antibacterial substances applied to the surface of the wrapper. And it is known that beeswax itself has antimicrobial properties and this may explain the antimicrobial effect of beeswax wraps without the addition of propolis and sage extracts.

It is advisable to continue research in this direction regarding the use of a wider range of antibacterial and antifungal agents, and the study of the antibacterial activity of the developed wrappers in relation to other groups of food microorganisms and fungi, as well as considering the possibilities of storing a wider range of food products.

## Conclusion

1. The perspective of using antimicrobial packaging of food products as a possible way to reduce food waste has been determined. Aspects of the use of beekeeping products and plant extracts as components of antibacterial packaging are considered.
2. Three technological approaches to the production of an antibacterial ointment based on beeswax are proposed
3. The obtained samples of beeswax wraps were tested on a basic set of food products (bread, cheese, sausages) and found that Beeswax wrapping prepared by all methods was found to be the best for cheese storage.
4. Determination of the antimicrobial activity of beeswax wraps and antimicrobial agents against Staphylococus aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans have shown moderate and low activity against microorganisms and no antifungal activity.
5. It is advisable to continue research in this direction regarding the use of a wider range of antibacterial and antifungal agents, and the study of the antibacterial activity of the developed wrappers in relation to other groups of food microorganisms and fungi, as well as considering the possibilities of storing a wider range of food

products.

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