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Physicochemical Quality Evaluation of Fresh-Cut Rosemary (*Rosmarinus officinalis* L.) Packed and Stored in Biodegradable Film

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Abstract. Fresh-cut herbs satisfy consumer demand owing to the convenience of buying them in food shopping malls as quickly accessible products. Food packaging has an important role in the food industry nowadays, because it helps to preserve the quality of fresh-cut food products at the production and sales sites and provides safety during storage. The aim of this research was to evaluate the quality changes of fresh-cut rosemary packed and stored in biodegradable film packaging. Rosemary has been packed in several materials – two biodegradable packaging materials, NatureFlex™ NVS INNOVIA film, Nature Works® PLA P-360 containers with hermetically pressed PLA cap and "breathable" conventional BOPP Propafilm™ P2GAF film. The samples were analysed over time at 0, 3, 5, 8, 10 and 12 days of storage at a temperature of +5 ±1 °C in terms of physicochemical quality: O_2 and CO_2 concentration, mass loss, pH, content of soluble solids (ºBrix) and tested sensory evaluation. The analysis of the obtained results showed that the cellulose based biodegradable NatureFlex™ NVS INNOVIA film was a good way to prolong the storage time of fresh-cut rosemary and ensure sensory quality and high physiochemical quality during the preservation period.
Key words: rosemary, storage, packaging materials, physiochemical quality, sensory properties.

Introduction

Freshly cut herbs are a very popular product for their ease of using and nutritional quality. It should be added that these products are highly perishable and susceptible to microbiological deterioration and contamination, which compromises the sensory and nutritional quality of the product and increases the risk of disease (Iturralde-García *et al.,* 2022). Studies of scientific articles have proven that properly selected packaging material extends the shelf life of fresh products. For example, scientists emphasise that the packaging forms a physical barrier between the packed products and the external environment. Also from a technological point of view, the packaging material forms an isolated area to protect food products from faster spoilage and damage during transportation and storage (Antosik *et al.,* 2021; Carpena *et al.,* 2021; Augspole *et al.,* 2019). Packaging management can be evaluated in the product supply chain and the use of biodegradable packaging materials which is obtained from renewable sources is one of the essential factors to increase food sustainability after harvesting (Vieira, Alves & Moldao, 2022).

Scientific studies have proven that recycled plastics can be used for packaging materials, thus not causing pollution by accumulating a large amount of waste that adversely affects the existence of our planet's ecosystem. Therefore, companies are willing to invest in the use of more eco-friendly plastics that can be used as bio-based packaging material that may store packaged products and take advantage of residues that would be discarded otherwise as well as increase the storage time of foods products (Dutta & Sit, 2022; Kirse-Ozolina, Muizniece-Brasava & Veipa, 2019). Scientists from France evaluated the latest published scientific studies and concluded that the most advanced technologies in the field of packaging clearly have a greater demand for the latest eco-friendly packaging materials with greater efficiency in maintaining the food quality and safety during storage.

Scientists have raised some key questions. First, present day lifestyle requires packaged foods with an extended storage time. Second, costumers are increasingly worried about good eating practice and noxious influence of chemical additives in foodstuffs. People all over the world want to consume more

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natural and healthier foods. Third, an increase in plastic packaging materials is a global problem. Therefore, the packaging materials should be designed according to their use (Baghi *et al.,* 2022). Metal and glass containers often had been used for packaging of food products. But because of the great advantages of plastic – it is light, with optimal mechanical and optical properties, low cost, mouldable, resistant to corrosive chemicals, impermeable to water and gases, low density – nowadays the use of plastic containers has become global. Moreover, plastic-based packaging usually contains different antimicrobials and antioxidants for the development of modified atmospheres (Hernández-García *et al.,* 2021). In addition, it allows for the printing of relevant information for the consumer.

Several reports have shown that COVID–19 has played a major role in the food system worldwide. The packaging industry has faced real challenges during the pandemic and its impact will be continued. In addition, natural polymers have often been characterised as a potential bio-based, biodegradable and next generation packaging material in comparison with synthetic polymer materials (Dutta & Sit, 2022; Srisa *et al.,* 2022).

Rosemary, attached to the *Lamiaceae* family, is known as a medicinal and aromatic plant with high antioxidant capacity. Rosemary is widespread in several regions of different countries and it is used in traditional medicine as well as food, perfume, etc. It is characterised with a variety of chemotypes (Yeddes *et al.,* 2022). In comparison with other herbs, rosemary can be defined as a natural source of a variety of metabolites with diverse biological properties. The rosemary is rich with antioxidants and has antiviral, antibacterial, antihyperglycemic, antidepressant, neuroprotective and anti-inflammatory properties (Yeddes *et al.,* 2022).

The objective of this experiment was to evaluate the quality changes of fresh-cut rosemary packed and stored in biodegradable film packaging.

Materials and Methods

Plant material and preparation of samples

The object of the research was collected from three-year-old rosemary (*Rosmarinus officinalis* L.) harvested in the polycarbonate greenhouse of the Laboratory of Horticulture and Beekeeping, the Latvia University of Life Sciences and Technologies, Institute of Soil and Plant Sciences, 56°39′45.5″ N 23°45′16.7″ E (Jelgava, Latvia). Before packaging, the samples of rosemary were rinsed in drinking water and drained at a temperature of 19 ±1 °C in air flow for 3 minutes and immediately were packaged at 20 ±0.05 g in airtight conventional and biodegradable packaging materials presented in Figure 1. Packed rosemary was stored in the commercial freezer/cooler "Elcold" refrigerator at a temperature of +6 ±1 °C.

DuniForm PP (polypropylene) containers (size 14.5 × 20.5 × 3.5 cm) were placed in pre-prepared (size 18.0 × 14.0 cm) pouches made of cellulose based biodegradable NatureFlex™ NVS INNOVIA film and hermetically melted using the packaging equipment (*EUROMATIC*, Italia). The same DuniForm PP containers were hermetically pressed by "breathable" conventional polymer BOPP Propafilm™ P2GAF film covered with an anti-dewing coating by means of *SEAL 300 Faverani* (Italia) equipment. Fresh-cut rosemary was packed by cellulose based biodegradable breathable Nature Works® PLA P-360 containers with hermetically pressed PLA caps. At each time of measurement, three identical packages for each packaging material were randomly selected on sampling days. Determination of the quality parameters of the samples was carried out before

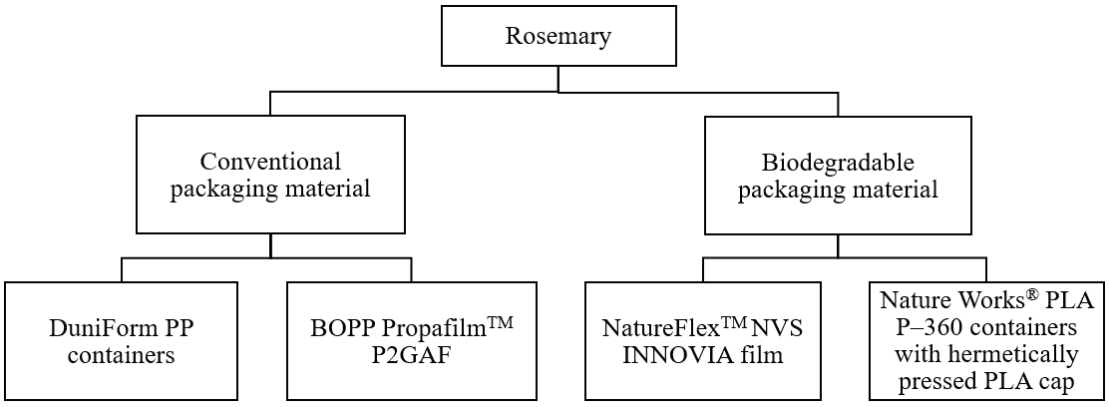


Figure 1. Structure of performed experiments.

packaging and during storage every two days, for a period of up to twelve days, in three repetitions on the 0, 3rd, 5th, 8th, 10th and 12th days, nine measurement repetitions of each sample were performed. The results are reported as mean values of all determinations.

The dynamics of gas composition (%) oxygen (O_2) and carbon dioxide (CO_2) were determined by a gas analyser OXYBABY®V O_2/CO_2. Analyses were performed in triplicate (Mastromatteo, Conte & Nobile, 2012).

Mass loss calculation (%) was performed by standard method *LVS ISO 1422:1997* with a digital precision balance ±0.01 g *Precisa* (Germany).

pH value measurements were determined by standard method *LVS ISO 5542:2010* using a *JENWAY 3520* pH meter using Hydrogen-ion activity. The pH electrode was dipped into a mixture of homogenised sample and distilled water. For a more precise measurement, the calibration of the pH meter was done using "Two-point calibration procedure".

Soluble solids content (°Brix) was determined at a temperature of 20 ±2 °C using the handheld digital refractometer *KRUSS HR18 Manual Refraktometer* (Germany).

Sensory evaluation measures were determined under natural light conditions at a temperature of 20 ±2 °C according to a method developed by Latvian scientists Straumite *et al.* (2012) as well as by Romanian scientists Cătunescu *et al.* (2012). The shades of green colour were described according to the colour scale developed by the Royal Horticultural Society of England (RHS). Seven trained panellists in the evaluation of products were involved.

Statistical analyses. The results were processed by mathematical and statistical methods. Two-way analyses of variance (ANOVA; $p \leq 0.05$) were used to determine significance of differences in atmosphere content (CO_2 and O_2) in packages, changes between weight losses, total soluble solids content, pH value by different packed rosemary samples.

Results and Discussion

The mass losses mainly arise due to higher water vapour permeability of polylactide (PLA) films (Krasnova *et al.,* 2012). It is proven that during storage, the product's water losses depend on the water vapour permeability of packaging materials. As result of our research, it was observed that mass loss of rosemary packaging was significant during 12 storage days. It was established that in biodegradable Nature Works® PLA P-360 containers, mass losses substantially increased to 2.77 ±0.1% already during 12 storage days. The mass losses from packages made of cellulose based biodegradable film NatureFlex™ NVS INNOVIA during 12 storage days didn't exceed 0.99 ±0.1%. Whereas in packaging made of hermetically sealed "breathable" conventional film BOPP Propafilm™ P2GAF, during 12 storage days mass losses gained 0.09 ±0.1%, presented in Figure 2. Latvian scientists Krasnova *et al.* (2012) say that the mass losses mainly arise due to higher water vapour permeability of PLA films.

Similar mass losses were reported by researchers Lee and Chandra (2018) – at the end of a 16-day storage period at 10 °C in dark room total fresh biomass loss for lettuce in Anti-Fog-PP and Non-PPP were 2.2% and 2.7% respectively. Scientists from Brazil (Lisboa *et al.,* 2022) highlighted that the moisture loss can be defined as the general factor of fresh-cut rosemary's weight loss during storage. As the reason, different properties of packaging materials in the case of water vapour barrier were mentioned. Stored in non-appropriate packaging, aromatic and medicinal plants can be affected by permeating gases which is why losses of main ingredients can be observed. Water vapour, oxygen and carbon dioxide can be defined as

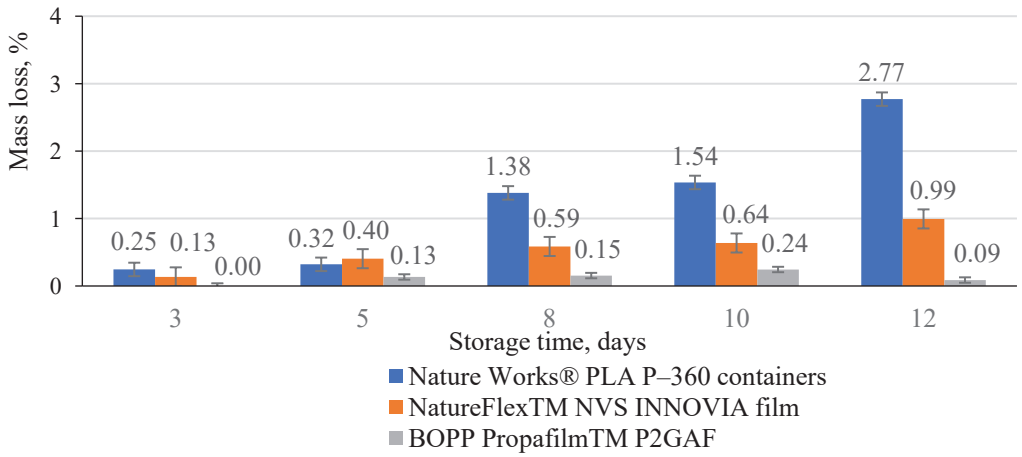


Figure 2. Rosemary's mass loss during storage.

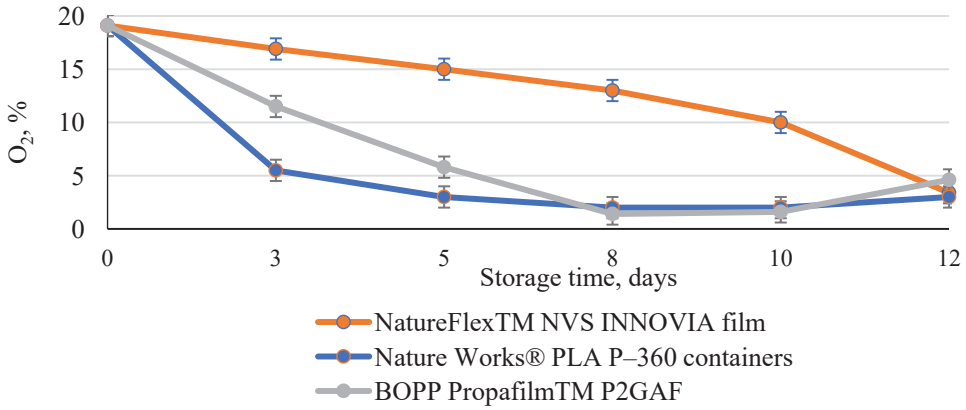


Figure 3. Dynamics of oxygen (O_2) for rosemary during storage.

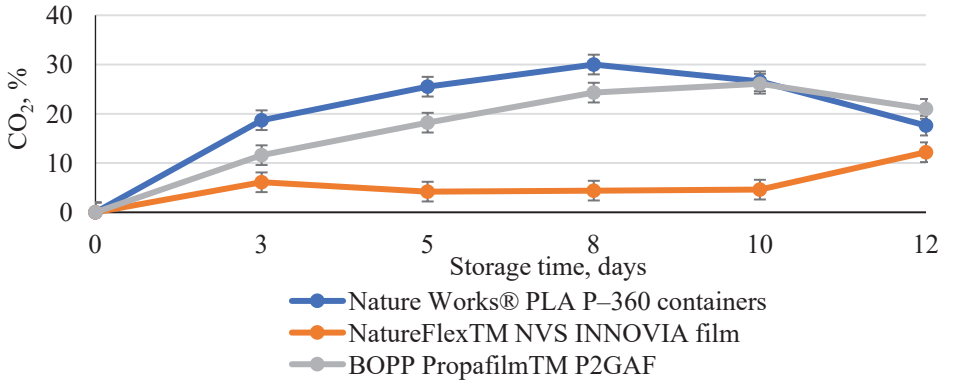


Figure 4. Dynamics of carbon dioxide (CO_2) for rosemary during storage.

general factors that affect the physical and chemical quality of herbs during storage.

According to Brazilian scientists (Lisboa *et al.,* 2022), packaging materials can minimise respiration of fresh aromatic and medicinal plants. A good gas barrier dissolved in the product and/or around it, reduces the process of respiration as well as the metabolic processes during the herbs' storage. Another target of the research work was to assess the dynamic of gas composition – oxygen and carbon dioxide – inside each hermetically sealed package headspace within the storage time. Because of plants' breathing, oxygen content decreased to 3.4% during the 12-day long rosemary storage, presented in Figure 3. The decrease of oxygen content in different packaging was changeable. For "breathable" conventional film BOPP Propafilm™ P2GAF which is hermetically sealed, the decrease of oxygen content for rosemary was significant: 1.4% at the 8th day and 1.6% at the 10th day of storage.

Very positive results were observed during oxygen content analysis inside packaging with fresh-cut rosemary, cellulose based biodegradable breathable Nature Works® PLA P-360 containers with hermetically pressed PLA caps. The content of oxygen in storage time decreases from 19.1% to 3.0% (Figure 3). Researcher Saltveit (1997) has accepted in his research that higher concentration of carbon dioxide (5–10%) and lower concentration of oxygen (1–3%) has been recommended as a suitable environment for the storage of several fresh plants, thus reducing the quality of the product.

Inside the biodegradable breathable Nature Works® PLA P-360 containers with hermetically pressed PLA caps and "breathable" conventional film BOPP Propafilm™ P2GAF, after 12 days storage the CO_2 amount increased 17 and 21 times respectively (Figure 4).

The increase of CO_2 in sealed cellulose based biodegradable film NatureFlex™ NVS INNOVIA rosemary packaging was not high – not more than 4.2–4.6%, and that concentration remained constant at the 5th, 8th and 10th storage days. At the end of storage, CO_2 increased to 12.2%. Food scientists have proven that observations prove that both conventional breathable and biodegradable packaging

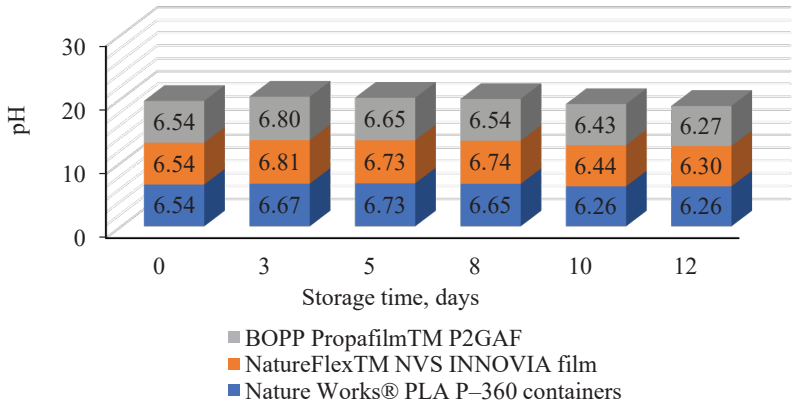


Figure 5. Changes of pH in rosemary during storage.

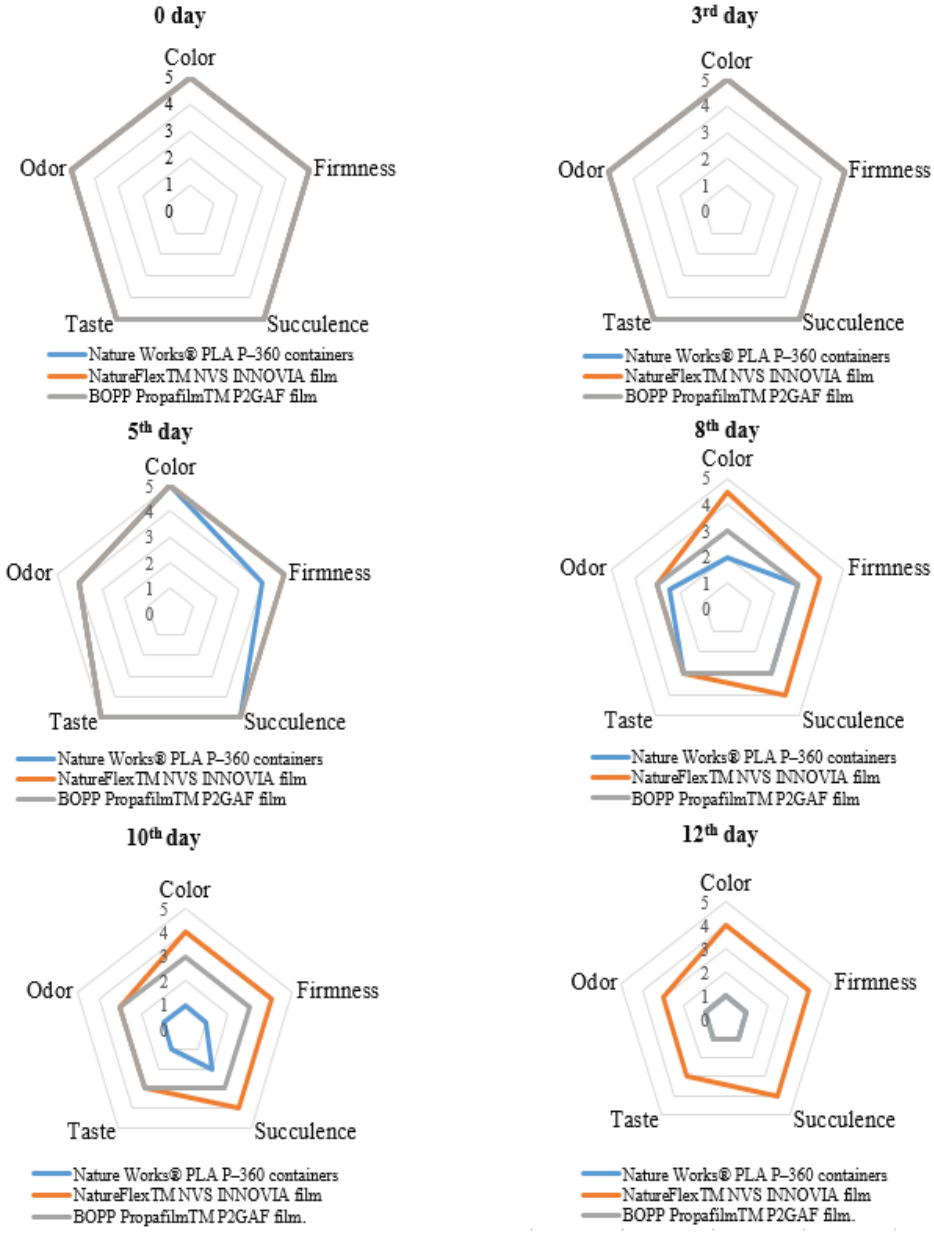


Figure 6. Changes in sensory quality of rosemary under different packaging during storage, in scores.

films with an appropriate O_2 transmission rate play an important role in development of equilibrium modified atmosphere and in quality of packages of fresh shredded carrots during storage (Augspole *et al.,* 2019). Researchers Lisboa *et al.* (2022) reported that inside of the packaging, the permeation of oxygen to the environment because of oxidation influences the alteration of the colour and flavour of many medicinal species. In the case of carbon dioxide, the permeation of water vapour from packaging to the environment influences the changes in respiration as well as the loss of carbonation.

For rosemary samples, packed in different kinds of materials, significant differences in soluble solids content (ºBrix) values during the 12 day long storage were not found ($p>0.05$). In BOPP Propafilm™ P2GAF, NatureFlex™ NVS INNOVIA film and Nature Works® PLA P-360 containers it was 8.5 ºBrix.

In our experiment, in the case of pH changes, for rosemary samples no statistical variance ($p>0.05$) was detected (Figure 5).

The results of sensory analysis during storage are presented in Figure 6. For all packaging material, losses in quality started in the 5th day of storage. For Nature Works® PLA P-360 containers, losses in firmness and odour were observed, but for BOPP Propafilm™ P2GAF film and NatureFlex™ NVS INNOVIA film, losses in firmness were observed first. In the 8th day of storage, significant losses in all sensory parameters were observed for BOPP Propafilm™ P2GAF film and Nature Works® PLA P-360 containers. After the 10th day of storage, minimal scores (1 point) were observed in colour, odour, taste and firmness for Nature Works® PLA P-360 containers. In the 12th day of storage, similar minimal results were observed for all described indices for BOPP Propafilm™ P2GAF film as well as for Nature Works® PLA P-360 containers. Because of obtained results, these two variants of packaging material can not be recommended after the 8th and 10th day of storage, respectively.

This packaging material preserves all optimal sensory indices of plant material. In the research of Romanian scientists about dill and parsley (Cãtunescu *et al.,* 2012), the sensory evaluation had similar results to our experiment's data.

Conclusions

1. Our obtained results show that the investigated cellulose based biodegradable NatureFlex™ NVS INNOVIA film is applicable for fresh-cut rosemary storage in packaging, maintaining quality for up to 12 days.

2. The packaging material NatureFlex™ NVS INNOVIA preserves all optimal sensory indices of plant material.

3. In the case of freshly cut rosemary's packaging, the results approved the possibility to use biodegradable packaging films as a successful alternative to the conventional polymers.

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