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STUDY ON THE EFFECTIVENESS OF LAVENDER ESSENTIAL OIL FOR ANTIFUNGAL PROTECTION OF STRAWBERRIES IN POSTHARVEST

Francisca CORITAR, Iuliana POPESCU, Daniela Nicoleta SCEDEI, Monica-Cristina DRAGOMIRESCU, Olimpia IORDANESCU, Renata Maria ȘUMĂLAN

University of Life Sciences "King Mihai I" from Timisoara, 119 Calea Aradului, 300645, Timișoara, Timiș, Romania

Corresponding author emails: renatasumalan@usvt.ro, daniela.scedei@usvt.ro

Abstract

Post-harvest fungal decay, particularly caused by Botrytis cinerea (grey rot), is the primary source of economic losses in the strawberry supply chain for sales markets. The main objective of the study was to evaluate the use of lavender essential oil (LEO) Munstead cultivar to extend the shelf life of strawberries while monitoring antifungal activity and preserving nutritional quality over 12 days of storage. The chemical composition of LEO, as determined by GC-MS, highlights a predominant profile of esters and monoterpenols. The in vitro antifungal activity of Botritis cinerea using the „poisoned medium" method was determined for: 0.25; 0.5; 1; 2; 4; 8; 10; 12; 14(%). The results demonstrated a concentration-dependent inhibitory effect of LEO on mycelial growth. The minimum concentration with a fungistatic effect was 1%, and 8% had a fungicidal effect, providing the best efficacy and practical applicability. For the in vivo test, coating mixtures based on sodium alginate, enriched with LEO at 1%, 2%, and 4%, were used. Treatments with LEO-enriched alginate reduced strawberry weight loss by 6.8%, decreased fungal incidence, and maintained firmness and ascorbic acid content.

Key words*: alginate nanoparticles, Botrytis cinerea, edible coatings, lavender essential oil, postharvest.*

INTRODUCTION

Strawberry fruits (*Fragaria* × *ananassa*) are some of the most appreciated fruits worldwide due to their special sensory qualities and rich content in bioactive compounds, such as vitamin C, anthocyanins, and other natural antioxidants. With a high water content, a high respiration rate, and a fragile tissue structure, strawberries are highly perishable, making them extremely susceptible to post-harvest spoilage. In the storage, transport, and marketing stages, quantitative and qualitative losses are substantial, significantly affecting the supply chain and producers' profitability (Romanazzi et al., 2016; Terry et al., 2013). Microbial degradation is one of the main causes of post-harvest losses in horticultural products, with a major impact on food quality and food safety (Șumălan R.M., 2022).

Among the factors responsible for post-harvest degradation, fungal diseases are the main cause of strawberry losses. *Botrytis cinerea*, the etiological agent of grey rot, is the most common and destructive pathogen of strawberries in the post-harvest period (Petrasch et al., 2019). Recent studies have demonstrated the effectiveness of alternative antifungal control strategies in maintaining post-harvest strawberry quality, reducing spoilage, and preserving organoleptic properties (Șumălan et al., 2021). *Botrytis cinerea* can infect fruits in the field, at early stages of development, and during storage, developing rapidly through the appearance of mycelium and grey fruiting, softening of tissues, and depreciation of commercial appearance. The effective control of this pathogen is a major challenge in the post-harvest technology of small fruits (Ribeiro et al., 2021). Traditionally, the fight against post-harvest fungal diseases has relied on chemical fungicides. However, the intensive use of these substances has led to pathogen resistance, the accumulation of chemical residues on fruits, and growing concerns about food safety and environmental impact. In this context, there is increased demand from consumers and industry to identify and use alternative, natural, and sustainable solutions that protect fruits without compromising their quality and safety (Tripathi & Dubey, 2004).

In recent years, essential oils have gained particular interest as natural antifungal agents, due to their complex biological activity and broad-spectrum of action. They contain volatile compounds, such as monoterpenes, sesquiterpenes, and esters, which can interfere with the structure of microorganisms' cell membranes, inhibiting the growth and development of pathogenic fungi. Numerous studies have highlighted the effectiveness of essential oils in controlling phytopathogens and reducing post-harvest spoilage in fruits (Burt, 2004; Hyldgaard et al., 2012; Prakash et al., 2015).

The application of essential oils, including as vapours, has demonstrated significant potential for controlling fungi responsible for post-harvest spoilage and maintaining fruit quality, as shown for lavender, mint, and basil (Șumălan et al., 2020).

Lavender essential oil (*Lavandula angustifolia* Mill., LEO) is recognised for its antimicrobial, antioxidant, and antifungal properties and is used in both the food and pharmaceutical industries. Recent studies have highlighted a significant variability in the yield and chemical composition of lavender essential oil depending on genotype and pedoclimatic conditions (Costea et al., 2023; Boelens & Jiménez, 1991; Lis-Balchin, 2002).

The chemical composition of lavender essential oil is dominated by monoterpenols and esters, especially linalool and linalyl acetate, compounds responsible for both its characteristic aroma and its high biological activity (Cavanagh & Wilkinson, 2002; Lis-Balchin, 2002; Bakkali et al., 2008; Coriţar, 2024). These constituents give the essential oil a high potential to prevent microbial alteration of horticultural products by inhibiting the growth of phytopathogenic bacteria and fungi.

However, the direct application of essential oils is limited by their high volatility and potential effects on the sensory properties of fruits and vegetables, which require the development of alternative application systems and methods to control the release of active substances (Ribeiro et al., 2024; Baschetti et al., 2020).

In this regard, the use of biopolymer-based edible films is a promising strategy for protecting fruit in the post-harvest period (Hassan et al., 2018; Valdés et al., 2017).

To protect fruits during the post-harvest period, they delay respiration and ripening and limit the growth and multiplication of spoilage microorganisms (Valizadeh et al., 2024). Sodium alginate is valued for its biocompatibility, biodegradability, and non-toxicity, being approved for use in food applications. In addition, incorporating bioactive compounds, such as essential oils, into the polymer matrix enables controlled release of antimicrobial substances (Pandey et al., 2022; Baschetti et al., 2020; Donsì & Ferrari, 2016).

In the polymer matrix, controlled release of antimicrobial substances is enabled, enhancing the effectiveness of post-harvest protection without significantly affecting fruit properties (Baschetti et al., 2020).

Edible films act as semi-permeable barriers, reducing water loss and they gas exchange, and can simultaneously function as controlled-release systems for bioactive compounds, including essential oils. Integrating lavender essential oil into the alginate matrix can improve its stability and antifungal effectiveness (Valdés et al., 2017).

In the polymer matrix, the controlled release of antimicrobial substances is allowed, increasing the effectiveness of post-harvest protection without significantly affecting the sensory properties of the fruits (Pandey et al., 2022; Baschetti et al., 2020).

MATERIALS AND METHODS

The biological material used

The study was carried out using LEO from the Munstead cultivar, harvested in 2024, from the experimental field located in Mănăstur, Arad County, western Romania. The plant material was harvested at the optimal flowering stage to ensure a high content of bioactive volatile compounds. The essential oil was obtained by hydro-distillation and stored in dark-coloured glass containers at a low temperature (5+1°C) until practical use.

The phytopathogen, *Botrytis cinerea*, from the microbial collection of the discipline of Microbiology, Faculty of Engineering and Applied Technologies, code BC-15-2016, stored on PDA medium, was used to evaluate the antifungal efficacy of LEO. The fungal inoculum was obtained from 72-hour-old

cultures in the active mycelial growth phase. All experimental steps were carried out under sterile conditions to prevent external contamination and to ensure the reproducibility of the results.

Essential Oil Chemical Composition Analysis (GC-MS)

The chemical composition of lavender essential oil was determined by gas chromatography-mass spectrometry (GC-MS) using an Agilent 7890A GC-MS system equipped with an HP-5MS capillary column (30 m × 0.25 mm × 0.25 μm). Helium was used as a carrier gas at a constant flow rate of 1 mL/min. The injector temperature was maintained at 250°C, and the compounds were ionised at 70 eV. The mass spectra were recorded in electron impact ionisation (EI).

The identification of the compounds was achieved by comparing mass spectra with reference libraries and using retention indices. The results were expressed as relative percentages of the total essential oil composition.

In vitro evaluation of antifungal activity

The *in vitro* antifungal activity of lavender essential oil was evaluated using the poisoned medium technique (Pitt, 2008). The malt extract agar (MEA) medium was used to support optimal fungal development. LEO was incorporated into the MEA medium (30 mL) at different concentrations to achieve the following percentages: 0.25, 0.5, 1, 2, 4, 8, 10, 12, and 14%. After solidification, using a sterile cork borer, the medium was cut at two distal places, and mycelial discs of *Botrytis cinerea* (Ø 8 mm) were subsequently distributed from mycelium in the active growth phase. The inoculated plates were incubated at 25 ± 1°C in the dark for 5 days. Each concentration was tested in four replicates (n = 4), and the experiment was repeated independently to ensure reproducibility. If the fungal growth was 0, the mycelial disc was transferred to an LEO-free medium to determine whether the effect was fungistatic or fungicidal. Mycelial growth was evaluated by measuring two diameters perpendicular to the mycelial colonies, and the percentage of growth inhibition was calculated by reference to the control using the following calculation formula:

$$MGI\ \% = (C - TLEO)/C \times 100$$

Where:

MGI - mycelial growth inhibition (%);

C - average diameter of fungal mycelia in control (mm);

T-LEO- average diameter of fungal mycelia for essential oil treatments (mm).

Obtaining the coating mixture based on LEO-enriched alginate nanoparticles

The alginate nanoparticle solution was formulated based on sodium alginate and used as a delivery system for LEO using the AquaWave 9381 ultrasonic bath (Barnstea Lab-line) according to the Valizadeh, 2024 protocol. Briefly, the base solution was prepared by dissolving 0.25% sodium alginate (250 mg/100 g distilled water) with constant stirring until a homogeneous dispersion was obtained. To stabilise the nanoparticles' structure, a 0.06% calcium chloride solution (60 mg/100 g water) was used, applied according to the ion cross-linking method.

For emulsification of the essential oil, Tween 80 (0.2%) was added. LEO has been incorporated at concentrations of 1%, 2%, and 4%. This method was also used for the LEO-0 as a control. The coating solutions were transferred to spray ampoules and stored in the refrigerator until use.

In vivo testing of coating mixtures based on LEO-enriched sodium alginate and evaluation of fruit quality indicators

For the evaluation of the *in vivo* effect, strawberry fruits (*Fragaria* × *ananassa*) were used, selected for uniformity in terms of size, maturity, and absence of visible defects, with 30 fruits/cover treatment variant. Before applying the LEO-enriched coating solutions, the fruits were washed with distilled water and allowed to dry at room temperature.

The coating solutions were applied by uniform spraying. After application, the fruits were allowed to dry at room temperature to form the protective film. A third of the fruits thus prepared were used to test the antifungal effect, for which they were artificially inoculated with a spore suspension of *Botrytis cinerea* at a density of 5×10^5/ml, applied by spraying. After drying, the strawberries were placed in the containers and stored under conditions similar to those of the non-inoculated treatment at 5 ± 1°C for 12 days. At the end of storage, quality

indicators (weight loss, firmness, total soluble sugar content, pH), and the degree of fungal spoilage (FSD %).

To establish the FSD % (fungal spoilage degree), the Botrytis Spoilage Severity (BSS) was estimated for each treatment variant using the formula:

$$BSS = \Sigma (r \times n)$$

Where:

r - grade assigned to the degree of severity: 0 - for unaltered; 1 - altered 1-25%; 2 altered 26-50%; 3- altered 51-75%; 4 - altered 76-100%.

n - number of fruits with the same grade.

Formula for estimating the degree of fungal spoilage:

$$FSD\ \% = (BSS \times 100)/BF$$

Where: BF-initial number of inoculated strawberries multiplied by grade 4.

Statistical analysis

Statistical analysis was performed using one-way analysis of variance (ANOVA) to evaluate the effect of treatments on the measured parameters. When significant differences were detected, Tukey's multiple-comparison test was used to separate the means at the $p < 0.05$ significance level. All experimental data were expressed as mean ± standard deviation (SD), based on three independent replicates.

RESULTS AND DISCUSSIONS

Chemical composition of essential oil (GC-MS)

The chemical composition of lavender essential oil used in the study is presented in Table 1.

Table 1. Chemical composition (%) of lavender essential oil (Munstead cultivar) determined by GC-MS

No.	Identified compound		t_R (min.)	LRI_C	LRIr	C (%)
1	α-Thujene	MH	7.05	920	918	0.09
2	α-Pinene	MH	7.25	938	937	0.17
3	Camphene	MH	7.77	954	956	0.11
4	3-Octanone	O	9.15	986	984	0.78
5	β-Myrcene	MH	9.28	990	991	0.67
6	Butanoic acid, butyl ester	O	9.56	994	995	0.13
7	Acetic acid, hexyl ester	O	10.15	1016	1011	0.49
8	p-Cymene	MH	10.46	1025	1024	0.20
9	D-Limonene	MH	10.63	1029	1030	0.24
10	Eucalyptol	MO	10.69	1033	1034	0.54
11	β-trans-Ocimene	MO	10.98	1036	1037	1.17
12	cis-β-Ocimene	MO	11.35	1040	1039	0.67
13	Linalool oxide (cis)	MO	12.17	1074	1075	0.24
14	Linalool oxide (trans)	MO	12.76	1085	1084	0.11
15	**Linalool**	MO	13.32	**1100**	**1099**	**29.50**
16	Octen-1-ol acetate	O	13.64	1104	1106	0.89
17	3-Octanol acetate	O	14.07	1110	1111	0.16
18	Camphor	MO	14.82	1145	1144	0.18
19	Propanoic acid, 2-methyl-, hexyl ester	O	15.06	1168	1170	0.12
20	**1-Terpineol**	MO	16.10	**1188**	**1189**	**4.05**
21	2-Cyclohexen-1-one, 4-(1-methylethyl)-	MO	16.29	1198	1200	0.52
22	Butanoic acid, hexyl ester	O	16.65	1214	1216	0.67
23	**Linalyl acetate**	MO	18.67	**1255**	**1256**	**43.24**
24	Bornyl acetate	MO	19.73	1285	1283	0.15
25	Geranyl isobutyrate	MO	19.84	1292	1290	3.72
26	Epoxy- **β** -terpenyl acetate	MO	21.82	1340	1341	0.20
27	Epoxy-α-terpenyl acetate	MO	21.93	1346	1345	0.12
28	Nerol acetate	MO	22.31	1364	1362	0.17
29	Geraniol acetate	MO	22.96	1388	1382	0.38
30	Hexanoic acid, hexyl ester	O	23.21	1394	1393	0.17
31	3,7-Nonadien-2-ol, 4,8-dimethyl-	MO	23.30	1396	1395	0.06
32	**β-Caryophyllene**	SH	24.09	**1406**	**1405**	**4.11**
33	α-Bergamotene	SH	24.61	1415	1414	0.16
34	α-Caryophyllene	SH	25.21	1422	1420	0.09
35	**β-Farnesene**	SH	25.30	**1444**	**1446**	**3.51**

No.	Identified compound		t_R (min.)	LRI_C	LRIr	C (%)
36	Germacrene D	SH	26.02	1482	1480	0.56
37	β-Sesquiphellandrene	SH	26.16	1490	1488	0.07
38	γ-Cadinene	SH	27.02	1514	1513	0.13
39	Caryophyllene oxide	SO	28.98	1580	1581	1.42
40	Hexahydrofarnesyl acetone	SO	36.25	1846	1845	0.09
	Total constituents		-			**≈100.00**
	from which					
MH (monoterpene hydrogenase)						1.48
MO monoterpene oxygenase						85.02
SH sesquiterpene hydrogenate						8.63
SO sesquiterpene oxidizate						1.51
Other oxygenated compounds						3.36

The relative content of volatile compounds was calculated as a percentage of the total area of chromatographic peaks obtained in ICT mode, which was set to 100%. Of the compounds identified, linalyl acetate and linalool were the most abundant, confirming that the essential oil analyzed belonged to a chemotype dominated by esters and monoterpene alcohols. These compounds are frequently associated with antifungal activity, which may explain the effectiveness later observed in biological tests. The results obtained are in line with the literature on Lavandula angustifolia essential oils (Cavanagh & Wilkinson, 2002; Lis-Balchin, 2002; Bakkali et al., 2008; Costea et al., 2023).

Antifungal activity of LEO established in vitro

The application of lavender essential oil (LEO) resulted in a progressive reduction in the mycelial growth of *Botrytis cinerea* with increasing concentration, compared to the control sample characterized by vigorous mycelium development. At low concentrations (0.25% and 0.5%), LEO showed a weak to moderate fungistatic effect, causing partial inhibition of fungal growth. At a concentration of 1%, a pronounced fungistatic effect was observed, and increasing the concentration to 2% intensified the inhibitory effect. At concentrations of 4% and above, mycelial growth was completely inhibited, indicating a fungicidal effect of lavender essential oil on *Botrytis cinerea*. The results presented in Table 2 show a concentration-dependent inhibition, with the fungistatic effect being evident starting at a concentration of 1% LEO, and the fungicidal effect being observed at concentrations of 4% and above.

The appearance of mycelial growth in the presence of different concentrations of LEO is illustrated in Figure 1, where progressive inhibition of fungal growth is observed with increasing LEO concentration.

Table 2. Percentage of mycelial growth inhibition (MGI) for *Botrytis cinerea* in the presence of LEO and assessment of antifungal effect

LEO (%)	MGI (%)	Biological effect
Control 0	0.00	Vigorous growth
0.25	16.3	Weak fungistatic effect
0.5	48.6	Moderate fungistatic effect
1	74.3	Fungistatic effect
2	90.7	Fungistatic effect
4	100	Fungicidal effect
8	100	Fungicidal effect
10	100	Fungicidal effect
12	100	Fungicidal effect
14	100	Fungicidal effect

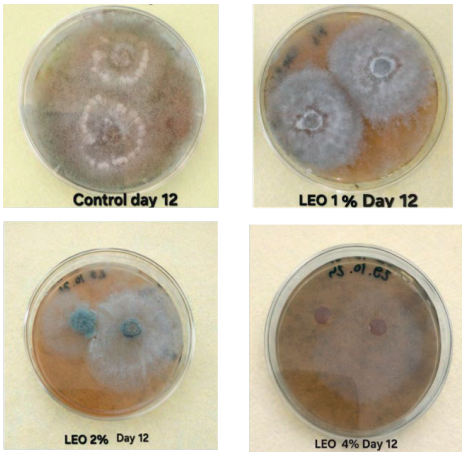

Figure 1. *In vitro* antifungal activity of lavender essential oil (LEO) on the mycelial growth of *Botrytis cinerea* on the MEA medium after 12 days of incubation at 25°C

Effect of treatments on strawberry quality parameters

The effect of treatments with alginate-based films enriched with lavender essential oil on the main quality parameters of strawberries after 12 days of storage is shown in Table 3. Compared to the control, LEO treatments moderately influenced weight loss, fruit firmness, soluble dry matter (TSS) content, pH, and ascorbic acid content. The lowest weight loss was observed in the 4% treatment, suggesting a better water-holding capacity in the fruit. The firmness of the fruits was relatively similar across the variants, indicating that the treatments applied did not cause major changes in tissue consistency. In terms of soluble dry matter content, treatment with 1% LEO recorded the highest value, suggesting better maintenance of soluble sugars. pH values showed little variation between treatments, indicating the stability of fruit acidity during refrigerated storage. Also, the ascorbic acid content was slightly higher in the variant treated with 1% LEO, suggesting a possible protective effect of the treatment on ascorbic acid stability.

Table 3. The effect of treatments with alginate-based films enriched with lavender essential oil on the quality parameters of strawberries after 12 days of storage

Treatment	Weight loss (%)	Firmness (lb)	SST (°Brix)	pH	Ascorbic acid (mg/100 g)
Control	0.073 ± 0.015	0.218 ± 0.012	6.82 ± 0.24	3.45 ± 0.08	21.46 ± 1.55
LEO 1%	0.076 ± 0.010**	0.230 ± 0.019	7.44 ± 0.35	3.52 ± 0.06**	22.97 ± 2.13
LEO 2%	0.074 ± 0.011	0.200 ± 0.024**	6.70 ± 0.39**	3.48 ± 0.05***	20.66 ± 1.59**
LEO 4%	0.068 ± 0.007***	0.216 ± 0.008***	6.70 ± 0.21***	3.50 ± 0.07	19.94 ± 2.02***

In vivo evaluation of antifungal protection

The degree of fungal spoilage of strawberry fruits, according to Figure 3, significant differences from the control variant for V2 variants with 2% LEO content and for V3 with 4% LEO. For V1, the 1% LEO mixture shows no statistically significant differences.

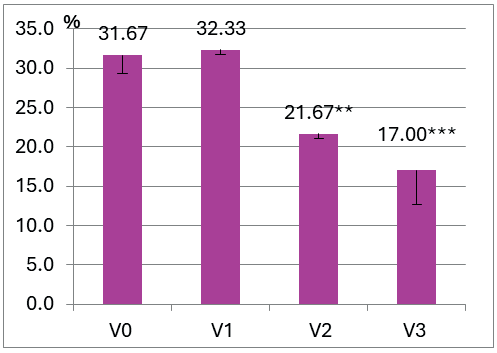

Figure 3. The fungal spoilage degree (FSD %) of strawberry fruits after 12 days since the edible coating treatments were applied

Compared with the literature, the results of the present study are consistent with observations on the use of essential oils and alginate-based edible coatings for controlling phytopathogens and maintaining the quality of soft fruits. Several studies have demonstrated that essential oils such as lavender, mint, and basil can inhibit the growth of phytopathogenic fungi and help maintain fruit quality during storage (Burt, 2004; López-Reyes et al., 2010; Nazzaro et al., 2013). Reducing weight loss, maintaining firmness, stability of soluble dry matter content, and pH, as well as preserving ascorbic acid content, demonstrate the effectiveness of this approach in delaying post-harvest degradation processes.

The incorporation of essential oils into biopolymer matrices, such as alginate, represents a promising strategy to improve the stability and controlled release of bioactive compounds. However, further studies are necessary to optimize the concentrations used, to evaluate possible effects on the sensory characteristics of fruits, and to assess the effectiveness of such systems under real storage and transport conditions. Future research may contribute to the development of sustainable technologies for postharvest protection and quality preservation of fresh fruits and vegetables.

CONCLUSIONS

The results of this study highlight the potential of lavender essential oil as a natural antifungal agent and the effectiveness of alginate nanoparticles as a vehicle for post-harvest application.

The *in vivo* evaluation of strawberry post-harvest quality indicated that treatments with alginate nanoparticles enriched with lavender essential oil help maintain the fruits' physicochemical parameters during refrigerated storage.

In particular, the 1% concentration of lavender essential oil showed an optimal balance between antifungal efficacy and preservation of nutritional value, confirming the role of alginate in the controlled release of bioactive compounds.

Overall, the proposed strategy can be considered a sustainable and environmentally friendly alternative for post-harvest conservation of strawberries, with the potential to be integrated into modern fresh fruit quality management systems. Further research is needed to optimize technological parameters and assess applicability on an industrial scale.

REFERENCES

Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils – A review. *Food and Chemical Toxicology*, 46(2), 446–475.

Baschetti, M., G., Minelli, M., & Del Nobile, M. A. (2020). Controlled release of natural antimicrobials for food preservation. *Trends in Food Science & Technology*, 103, 134–145.

Boelens, M., H., & Jiménez, R. (1991). Chemical composition of Spanish lavender oils. *Journal of Essential Oil Research.*

Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods—A review. *International Journal of Food Microbiology*, 94(3), 223–253.

Calo, J., R., Crandall, P., G., O'Bryan, C., A., & Ricke, S. C. (2015). Essential oils as antimicrobials in food systems – A review. *Food Control*, 54, 111–119.

Cavanagh, H., M. A., & Wilkinson, J. M. (2002). Biological activities of lavender essential oil. *Phytotherapy Research*, 16(4), 301–308.

Chemat, F., Vian, M., A., & Cravotto, G. (2012). Green extraction of natural products: Concept and principles. *International Journal of Molecular Sciences*, 13, 8615–8627.

Coritar Francisca, Iuliana Popescu, Ersilia Alexa, Renata Sumalan, (2024) Preliminary results regarding the essential oil extraction yield and the compositional diversity obtained from 5 lavender cultivars growing in Vinga fields, Arad County. *Journal of Horticulture, Forestry and Biotechnology,* Vol. 28 (2), pp. 253-260

Costea, T.; Străinu, A., M., & Gîrd, C. E. (2023). Botanical characterisation, chemical composition and antioxidant activity of Romanian lavender (Lavandula angustifolia Mill.) flowers.

Dhital, R., Mora, N., B., Watson, D., G., Kohli, P., & Choudhary, R. (2018). Efficacy of alginate-based edible coatings incorporating essential oils to improve shelf life and quality of fresh produce. *Food Packaging and Shelf Life*, 18, 18–26.

Donsì, F., & Ferrari, G. (2016). Essential oil nanoemulsions as antimicrobial agents in food. *Food Engineering Reviews.*

Gupta, V., Thakur, R., Barik, M., & Das, A. B. (2023). Effect of high amylose starch-natural deep eutectic solvent-based edible coating on quality parameters of strawberry during storage. *Journal of Agriculture and Food Research*, 11, 100487

Hassan, B., Chatha, S., A. S., Hussain, A. I., Zia, K., M., & Akhtar, N. (2018). Recent advances on polysaccharides, lipids, and protein-based edible films and coatings: A review. *International Journal of Biological Macromolecules,* 109, 1095–1107.

Hernández-Muñoz, P., Almenar, E., Del Valle, V., Vélez, D., & Gavara, R. (2008). Effect of chitosan coating combined with postharvest calcium treatment on strawberry quality during refrigerated storage. *Food Chemistry*, 110, 428–435.

Hyldgaard, M., Mygind, T., & Meyer, R. L. (2012). Essential oils in food preservation: Mode of action, synergies, and interactions with food matrix components. *Frontiers in Microbiology*, 3, 12. https://doi.org/10.3389/fmicb.2012.00012

Jayaprakasha, G., K., Rao, L., J. M., & Sakariah, K. K. (2003). Antioxidant activities of flavidin in different in vitro model systems. *Bioorganic & Medicinal Chemistry*, 11, 5141–5146.

Lis-Balchin, M. (2002). Lavender: The genus Lavandula. Taylor & Francis.

López-Reyes, J., G., Spadaro, D., Gullino, M., L., & Garibaldi, A. (2010). Efficacy of plant essential oils on postharvest control of rot caused by fungi on fruit. *Crop Protection*, 29, 112–118.

Nazzaro, F., Fratianni, F. De Martino, L., Coppola, R., & De Feo, V. (2013). Effect of essential oils on pathogenic bacteria. *Pharmaceuticals*, 6, 1451–1474.

Pandey, V., K., Islam, R., U., Shams, R., & Dar, A... H. (2022). A comprehensive review on the application of essential oils as bioactive compounds in nano-emulsion-based edible coatings of fruits and vegetables. *Applied Food Research*, 2(1), 100042.

Pavlath, A., E., Orts, W. (2009). Edible films and coatings: Why, what, and how? *Food Science and Nutrition*, 1, 1–24.

Petrasch, S., et al. (2019). Grey mould of strawberry, a devastating disease caused by Botrytis cinerea. *Molecular Plant Pathology*.

Pitt, J.,, I., & Hocking, A. D. (2009). Fungi and Food Spoilage (3rd ed.). Springer.

Prakash, B. et al. (2015). Essential oils as natural preservatives to control fungal spoilage. *Food Control*.

Ribeiro, A., M., Estevinho, B.,, N., & Rocha, F. (2021). Preparation and incorporation of functional ingredients in edible films and coatings. *Food and Bioprocess Technology*, 14(2), 209–231.

Ribeiro, I., S., Maciel, G., M., Bortolini, D., G., Fernandes, I., de A. A., Maroldi, W., V., Pedro, A. C., Rubio, F., T. V., & Haminiuk, C. W. I. (2024). Sustainable innovations in edible films and coatings: An overview. *Trends in Food Science and Technology*, 143.

Romanazzi, G., Smilanick, J., L., Feliziani, E., & Droby, S. (2016). Integrated management of postharvest gray mold on fruit crops. *Postharvest Biology and Technology*, 113, 69–76. https://doi.org/10.1016/j.postharvbio.2015.11.003

Șumălan, R., M., Beinsan, C., Șumălan, R., Ciulca, S., & Popescu, S. (2021). Study on minimizing the fungal spoilage index of strawberry fruits during storage with preservation of the organoleptic and curative properties. *Journal of Horticulture, Forestry and Biotechnology*, 25(1).

ȘumalanM., Kuganov, R., Obistioiu, D., Popescu, I., Radulov, I, Alexa, E., Negrea, M, Salimzoda, Sumalan, Cocan, I. (2020) Assessment of Mint, Basil, and Lavender Essential Oil Vapour-Phase in Antifungal Protection and Lemon Fruit Quality. *Molecules*; 25(8):1831.

Șumălan, R. M., & Șumălan, R. L. (2022). Microbial Deterioration of Postharvest Horticultural Products, Ed EUROBIT, Timisoara, ISBN 978-973-132-872-0

Terry, L. A., et al. (2013). Health-promoting properties of fruits and vegetables. *Journal of the Science of Food and Agriculture.*

Tripathi, P., Dubey, N. K., & Shukla, A. K. (2008). Use of essential oils as post-harvest botanical fungicides in the management of grey mould of grapes caused by Botrytis cinerea. *World Journal of Microbiology and Biotechnology*, 24, 39–46.

Valizadeh, A., et al. (2024). Alginate nanoparticles containing *Lavandula angustifolia* essential oil as a potent, biocompatible, and low-cost antitumor agent. *Polymer Bulletin*, 81(2), 1861–1874.

Valdés, A., Ramos, M., Beltrán, A., Jiménez, A., & Garrigós, M. C. (2017). State of the art of antimicrobial edible coatings for food packaging applications. *Coatings*, 7(4), 56. https://doi.org/10.3390/coatings7040056

Velickova, E., Winkelhausen, E., Kuzmanova, S., Alves, V., D., Moldão-Martins, M. (2013). Impact of chitosan-beeswax edible coatings on the quality of fresh strawberries. *Food Science and Technology International*, 19, 473–482.