Branka Levaj[1], Ana Dobrinčić[1], Zrinka Čošić[1], Maja Repajić[1] Original scientific paper

Fresh-cut Potatoes Treated with Fennel Essential Oil during Storage at 8 °C

Abstract

The aim of this study was to investigate the effect of treatment with fennel essential oil (FEO) on the shelf life of fresh-cut potatoes (FCP) and on the sensory characteristics of raw and subsequently boiled and fried potatoes. Peeled and sliced potatoes were immersed in an aqueous solution containing different FEO concentrations (0 (water control), 25, 125, and 250 mg L-1) for 15 min, then drained, vacuum packaged, and stored at 8 °C for 12 days. The CIELAB color parameters and aerobic mesophilic bacteria count (AMB) of the raw FCP and the sensory characteristics of the raw, boiled and fried samples were determined. AMB decreased with increasing FEO content, and this trend was generally maintained during storage. Slight negative changes in color were observed with increasing FEO content and with storage time. Fennel taste and odor in raw and boiled potatoes increased with increasing FEO content, while FEO odor after frying was only slightly pronounced in FEO-250 on day 0. Despite the antibacterial activity of FEO, spoilage of FCP was not prevented during storage. In general, after 6 days, the best results in terms of absence of browning and off-odor of raw and off-taste and sour taste of boiled and fried FCP were obtained with 25 mg L-1 FEO treatment.

Keywords: *fresh-cut potato, fennel essential oil, aerobic mesophilic bacteria, sensory characteristic, boiled and fried potato*

Introduction

Fresh-cut potatoes (FCP) or minimally processed potatoes are peeled, cut and packed in individual packages, thus they are ready-to-cook potato products. Despite their suitability for use and convenience, FCP is highly perishable because peeling and cutting damage the cells of the tissue and the product is susceptible to microbiological growth and browning. As a result, FCP loses overall quality, and all of these are limiting factors for the shelf life of FCP (Dite Hunjak et al., 2020a). Therefore, different approaches to extend shelf life, physically or chemically, are being investigated. Browning is the result of the formation of brown pigments as a consequence of oxidase-catalyzed transformation of phenolic compounds to quinone and further complex non-enzymatic reactions of polymerization. Among the many investigated chemical agents (antioxidants or enzyme inhibitors) known as anti-browning agents, natural essential oils extracted from certain plant species are also attracting the attention of scientists, especially when chemical preservatives are to be avoided (Liu et al., 2019). Essential oils are complex, concentrated mixtures of various chemical compounds derived from plants that exhibit antioxidant properties and antimicrobial activity, but are also highly aromatic (Luo et al., 2019). In addition to its promising stabilizing effect on FCP, rosemary essential oil, for example, may also have undesirable effects on color (Luo et al., 2019) or even taste. The antimicrobial effect of fennel essential oil against certain bacteria and microorganisms in general is well documen-

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ted in the scientific literature (Anwar et al., 2009; Açıkgöz et al., 2017), but its application in the processing of FCP is unknown. The success of the applied treatment is reflected not only in the absence of browning or microorganisms during storage, but also in its influence on the sensory characteristics of both raw and cooked FCP (e.g., boiled, fried, etc.) (Dite Hunjak et al., 2020a; Dite Hunjak et al., 2020b). Appropriate selection of essential oils and their use in FCP processing could also contribute to enriching the aroma profile of potato. The aim of this study was to investigate the effects of fennel essential oil treatment on the shelf life of fresh-cut potatoes and on the sensory characteristics of raw and subsequently cooked and fried ones.

Material and methods

Plant material

Potato tubers (*Solanum tuberosum* L.) of cultivar cv. Birgit were harvested in October 2020 in the Slavonia region (Croatia), treated with sprout inhibitors (Gro Stop Basis and Gro Stop Fog, Certis Europe B.V., United Kingdom), and stored in the dark (8 °C/RH about 100%) until the experiment. Bitter fennel essential oil (FEO) (Ireks Aroma, Zagreb, Croatia) was used for the experiment.

Sample preparation

Solutions of FEO (25, 125, and 250 mg L^{-1}, FEO-25, FEO-125, and FEO-250, respectively) were prepared by mixing a given amount of FEO with hot water and then cooled to room temperature (20 °C). After selecting healthy and uniform potato tubers and after washing and draining, tubers were peeled by hand and cut into slices (0.4 cm) using a commercial slicer (Multipraktik MCM3201B, BOSCH, Germany). Immediately after slicing, potatoes were dipped in FEO solutions (solution:potato = 1:1) and kept under gentle agitation for 15 min. As control samples, slices were dipped in water only (FEO-0) under the same conditions. After draining, potato samples (150 g) were vacuum packaged (SmartVac SV 750, Status, Metlika, Slovenia) in a double-layer (100 and 130 µm) polyamide/polyethylene (PA/PE) vacuum bag (Status, Metlika, Slovenia) and stored at 8 °C for 12 days. Analyses were performed on the day of sample preparation (day 0), day 6, day 9, and day 12; accordingly, the sample code was the FEO concentration on the day of storage, e.g., FEO-0-0 (control sample on the day of preparation) or FEO-250-12 (samples treated with an FEO concentration of 250 mg L^{-1} on day 12).

Cooking treatments

Sensory monitoring of raw and cooked FCP was performed before (0) and during storage on the 6^{th}, 9^{th}, and 12^{th} days of storage. Accordingly, cooked FCP samples (boiling and frying) were freshly prepared before sensory analysis. Boiling was carried out in distilled water (water:sample = 5:1) at 100 °C for 15 min, while frying was performed in sunflower oil (oil:sample = 5:1) at an initial temperature of 170 °C for 3-5 min. After boiling or frying, excess surface water or oil from the slices was soaked up with a paper towel (Dite Hunjek et al., 2020b).

Microbiological analysis

Analysis of AMB was performed by the Horizontal method - Colony count method at 30 °C (HRN EN ISO 4833:2008) on the 0^{th}, 6^{th}, 9^{th} and 12^{th} day of storage of the raw FCP. Dilutions were prepared with peptone water (0.1%, *m/V*) and applied in duplicate (1 mL) to plate counting agar (Biolife, Milan, Italy). The plates were incubated at 30±1°C for 72±3 h in a drying oven (FN -500, Nueve, Ankara, Turkey). Results were expressed as mean values of log CFU g^{-1} (Pelaić at al., 2022).

Color analysis

The CIELAB color parameters (*L**-lightness, *a**-red/green, and *b**-yellow/blue) of the raw FCP slices were measured on the three slices per sample using a colorimeter (CR-5, Konica Minolta, Tokyo, Japan) equipped with a D65 light source with 2° angle observers (Dite Hunjek

et al., 2020a; Repajić et al., 2019). Measurements were performed on the 0th, 6th, 9th, and 12th storage days of the raw FCP. Total color difference was calculated ($\Delta E^* = \sqrt{(L^*_x - L^*_0)^2 + (a^*_x - a^*_0)^2 + (b^*_x - b^*_0)^2}$), where L^*_0, a^*_0, and b^*_0 were obtained by measuring sample FEO-0-0. The results were expressed as mean±standard deviation.

Sensory monitoring

Sensory characteristics of raw, boiled and fried samples were evaluated by Quantitative Descriptive Analysis (QDA) in a sensory laboratory equipped according to International Organization for Standardization guidelines (ISO, 2007) at room temperature by a panel of 5 trained faculty members. All samples were served at room temperature on coded plates. Panelists rated the quality of the samples using a standard five-point scale, which was scored from 1 - absent to 5 - very pronounced, as described by Dite Hunjek et al. (2020b) and Repajić et al. (2019). The color of raw and boiled samples was evaluated as browning intensity as: 1 - no browning (white or cream), 2 - no browning (yellow), 3 - light browning, 4 - medium browning and 5 - complete browning, but the color of fried samples was evaluated as 5 - characteristic color of fried potatoes, which gradually decreased to 0, which is the highest deviation of characteristic color. In boiled and fried samples potato and fennel odor and taste, sourness, off-odor and off-taste were also evaluated. Obtained scores of tested characteristics are shown in figures.

Statistical analysis

The influence of FEO concentration and storage time was statistically analyzed by analysis of variance (ANOVA) at a significance level of $p \leq 0.05$ using Statistica ver. 8.0 software (Statsoft Inc., Tulsa, USA).

Results and discussion

In all samples AMB count was lower than 3.5 $\log_{10}$ CFU g^{-1} (Figure 1) what is under the limit defined by legislation Zakon o higijeni hrane i mikrobiološkim kriterijima za hranu (83/2022) i Vodič za mikrobiološke kriterije za hranu (2011).

With increase of FEO concentration AMB counts were lower, although after the 6th day an increase was observed at all FEO concentrations. The results of FEO-25 and FEO-0 were almost identical except for 9th day, suggesting that the FEO concentration of 25 mg L^{-1} is too weak to have a noticeable effect on AMB.

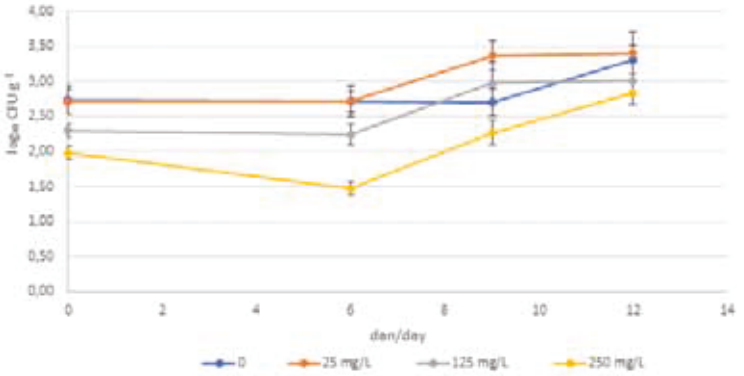


Figure 1. Microbial analysis of aerobic mesophilic bacteria (AMB) of fresh-cut potatoes during 12 days' storage at 8 °C

Slika 1. Mikrobiološka analiza aerobnih mezofilnih bakterija (AMB) u "fresh-cut" krumpirima tijekom 12 dana skladištenja pri 8 °C

Results of color parameters are presented in Table 1 and Table 2. FEO treatment had a significant effect on *a**, but not on *L** and *b**, while storage time significantly affected all color parameters (Table 2). Lightness (*L** values) was measured in a range from 69.31±1.88 (FEO-250-12) to 73.53±1.17 (FEO-0-0) (Table 1). These values are consistent with previous average values obtained for the same potato cultivar, e.g., 72.87±0.11 (Dite Hunjek et al., 2020a) and 70.05±0.15 (Dite Hunjek et al., 2020b). The brightest samples were FEO-0 and FEO-25 (the lowest FEO concentration) immediately after the treatment. In general, there was no clear trend of color changes during storage for all samples. Similar observations could be derived for the other two color parameters (Table 1). The values of parameter *a** (redness (+)/green (-)) were extremely low, from -0.54±0.14 in FEO-0- to 2.33±0.19 in FEO-250-9, which is also in agreement with previous results (Dite Hunjek et al., 2020a; Dite Hunjek et al., 2020b). FEO concentration had a significant effect on *a*,* i.e., in FEO-0-0 *a** was the lowest and with increasing FEO concentration *a** also increased. The storage time also had a significant effect on *a**, where *a** mostly showed an increasing trend during storage. The values of parameter *b** (yellow (+)/blue (-)) were in the yellow spectrum and they showed an increasing trend with increasing FEO concentration (without statistical significance), as well as during storage (statistically significant). They ranged from 32.74±1.24 (FEO-0-0) to 40.40±1.55 (FEO-125-12), and these values are similar to previously obtained results (Dite Hunjek et al., 2020a; Dite Hunjek et al., 2020b). The total color difference (*ΔE**) summarizes the changes in *L**, *a** and *b** to provide better insight into the color change. Overall, the *ΔE** of samples FEO-0 and FEO-25 were mostly around or below 6 and were lower than those of samples FEO-125 and FEO-250 (Table 1). According to Yang et. al. (2012), the perception of color difference between 3 and 6 is "appreciable", while between 6 and 12 is "much". According to the results, only two samples (FEO-125-12 and FEO-250-9) had a *ΔE** value greater 8. All samples showed a "noticeable" color difference during the storage, and it seems that FEO had a slight negative influence. Similar results were observed in the study by Luo et al. (2019) with rosemary essential oil and fresh-cut potatoes.

Table 1. Color parameters of fresh-cut potatoes during 12 days' storage at 8 °C
Tablica 1. Parametri boje „fresh-cut" krumpira tijekom 12 dana skladištenja pri 8 °C

Sample/ Uzorak	Days/ dani	*L**	*a**	*b**	*ΔE**
FEO-0	0	73.53±1.17	-0.54±0.14	32.74±1.24	-
	6	69.51±1.06	1.15±0.31	36.57±0.37	5.89±0.63
	9	71.56±1.57	0.56±0.66	34.68±2.97	3.75±3.12
	12	70.48±1.14	0.40±0.23	36.61±2.52	5.58±1.62
FEO-25	0	73.42±1.38	0.45±0.15	34.71±3.90	4.59±1.19
	6	70.69±0.43	0.98±0.29	38.04±1.31	6.29±1.17
	9	72.84±1.31	1.09±0.15	37.58±0.45	5.30±0.75
	12	69.86±0.47	1.26±0.30	37.57±2.16	6.52±1.92
FEO-125	0	69.31±1.88	1.21±0.07	35.11±2.00	5.50±2.37
	6	71.66±0.38	0.73±0.65	33.56±2.39	3.18±1.69
	9	71.52±0.42	1.05±0.12	38.05±0.90	5.91±1.13
	12	70.11±1.68	1.22±0.60	40.40±1.55	8.86±0.85
FEO-250	0	70.61±1.16	0.66±0.29	38.12±1.04	6.41±0.71
	6	71.66±0.71	0.97±0.19	35.38±3.47	4.92±1.30
	9	72.00±1.19	2.33±0.19	39.99±1.80	8.04±2.18
	12	69.98±1.21	1.00±0.35	38.21±1.24	6.73±2.04

Table 2. Analysis of variance of the influence of fennel essential oil concentrations and 12 days' storage on color parameters of fresh-cut potatoes

Tablica 2. Analiza varijance utjecaja koncentracije eteričnog ulja komorača i 12 dana skladištenja na parametre boje „fresh-cut" krumpira

Parameter/ Parametar	Source of variation/ Izvor varijacije			
	Concentration of essential oil/ Koncentracija eteričnog ulja		Storage time/ Vrijeme skladištenja	
	F	p	F	p
*L**	0,8500	0,476	3,2000	0,033*
*a**	5,1643	0,004*	4,4412	0,009*
*b**	2,1550	0,108	3,2440	0,032*

*p≤0,05

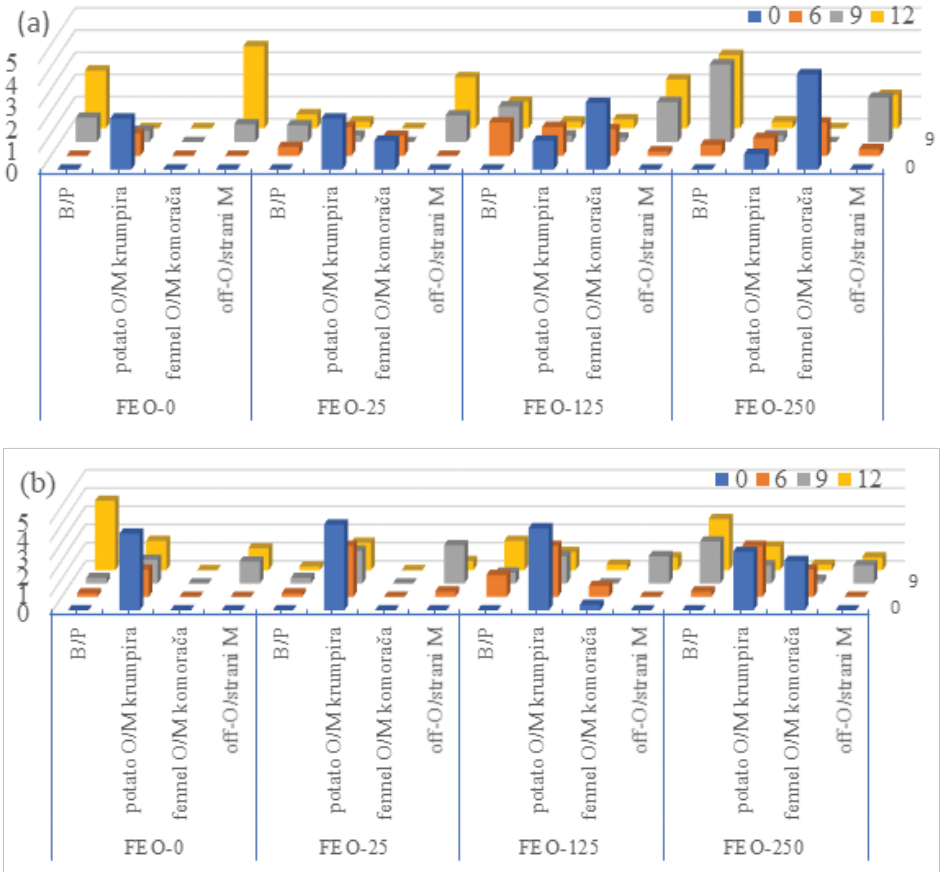
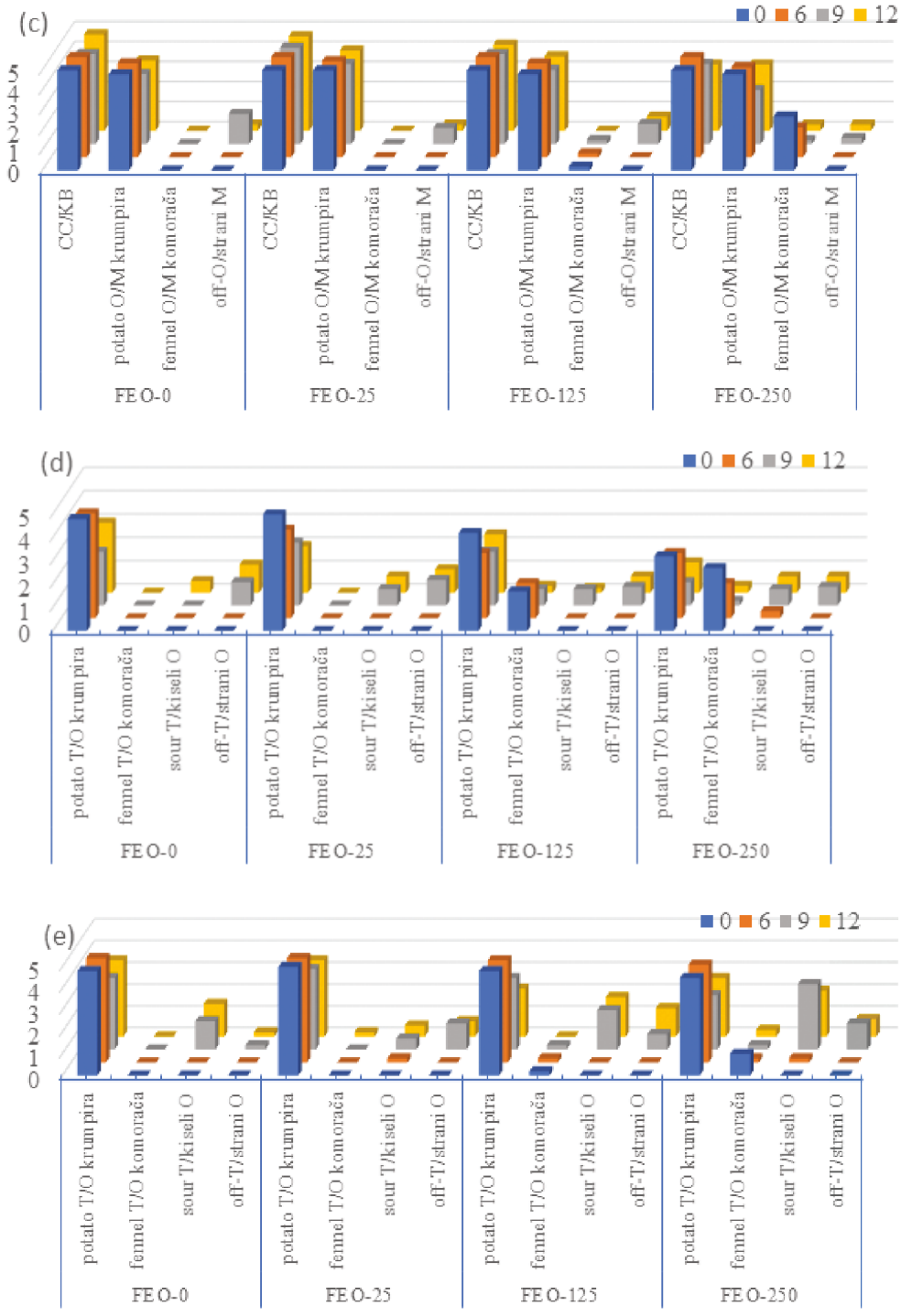


Figure 2. Sensory attributes of fresh-cut potatoes during 12 days of storage: color and odor of raw (a), boiled (b) and fried (c) as well as taste of boiled (d) and fried (e)
(B-browning; CC-characteristic color; O-odor; T-taste)

Slika 2. Senzorska svojstva "fresh-cut" krumpira tijekom 12 dana skladištenja: boja i miris sirovog (a), kuhanog (b) i prženog (c) te okus kuhanog (d) i prženog (e)


(c)
0 6 9 12
5
4
3
2
1
0
CC/KB
potato O/M krumpira
fennel O/M komorača
off-O/strani M
FEO-0
FEO-25
FEO-125
FEO-250
(d)
0 6 9 12
potato T/O krumpira
fennel T/O komorača
sour T/kiseli O
off-T/strani O
FEO-0
FEO-25
FEO-125
FEO-250
(e)
0 6 9 12
potato T/O krumpira
fennel T/O komorača
sour T/kiseli O
off-T/strani O
FEO-0
FEO-25
FEO-125
FEO-250

(P-posmeđivanje; KB-karakteristična boja; M-miris; O-okus)

Results of sensory analysis are presented in Figure 2 and Table 3. Due to the strong aroma of fennel, sensory analysis was very important to study the acceptance of fennel oil influence not only on color but also on odor of raw and cooked FCP as well as on taste of boiled and fried ones. Both sources of variation had a significant effect on almost all sensory properties of FCP, with few exceptions: FEO concentration on off-odor of raw and boiled FCP, off-odor of boiled and fennel odor of fried FCP. In addition, storage time affected the fennel odor of fried FCP (Table 3).

FEO-0 and FEO-250 were the most susceptible to browning, which is especially evident on the days 9 and 12 (Figure 2a). For FEO-125, browning was less pronounced, but it occurred as early as day 6. The results of sensory evaluation and instrumental measurement are only partially in agreement. According to both methods, the color of raw samples is satisfactory during the 6-day storage, with FEO-25 having less negative effect on the color and preserving it better than others FEO treatments even during longer storage. Similar observations apply also for boiled potatoes (Figure 2b). The color of fried FCP (Figure c) was evaluated as a characteristic color for fried potatoes and all samples obtained very high scores with FEO-0 obtaining the highest value. Moreover, it seems that FEO-0 and FEO-25 better preserved the color during storage than FEO-125 and FEO-250.

Table 3. Analysis of variance of the influence of FEO concentrations and 12 days' storage at on sensory attributes of fresh-cut potatoes

Tablica 3. Analiza varijance utjecaja koncentracije eteričnog ulja komorača i 12 dana skladištenja na senzorska svojstva „fresh-cut" krumpira

	Parametar/ parameter	Source of variation/ Izvor varijacije			
		FEO concentration/ koncentracija FEO		Storage time/ Vrijeme skladištenja	
		F	p	F	p
Sirovi/ Raw	B/P	20,6730	<0,001*	64,4585	<0,001*
	potato O/M krumpira	6,8056	<0,001*	51,5278	<0,001*
	fennel O/M komorača	65,0431	<0,001*	146,8554	<0,001*
	off-O/strani M	1,6878	0,176	193,5865	<0,001*
Kuhani/Boiled	B/P	40,5212	<0,001*	121,3001	<0,001*
	potato O/M krumpira	4,2760	0,007*	83,9870	<0,001*
	fennel O/M komorača	114,4068	<0,001*	42,3164	<0,001*
	off-O/strani M	2,5415	0,062	71,6445	<0,001*
	potato T/O krumpira	10,5860	<0,001*	25,1650	<0,001*
	fennel T/O komorača	139,6354	<0,001*	18,9410	<0,001*
	sour T/kiseli O	2,7230	0,050*	11,5493	<0,001*
	off-T/strani O okus	1,3028	0,279	58,0131	<0,001*
Prženi/Fried	CC/KB	8,3100	<0,001*	17,7300	<0,001*
	potato O/M krumpira	4,9350	0,003*	38,3120	<0,001*
	fennel O/M komorača	1,8478	0,145	0,3986	0,754
	off-O/strani M	19,1667	<0,001*	58,6667	<0,001*
	potato T/O krumpira	7,7020	<0,001*	67,0810	<0,001*
	fennel T/O komorača	11,6191	<0,001*	3,2381	0,026*
	sour T/kiseli O	21,2171	<0,001*	92,4640	<0,001*
	off-T/strani O okus	8,1322	<0,001*	39,3966	<0,001*

*p≤0,05; B-browning; CC-characteristic color; O-odor; T-taste/P-posmeđivanje; KB-karakteristična boja; M-miris; O-okus

Despite the increase in fennel odor with the increase in FEO concentration, potato odor was still pronounced. In general, potato odor was least pronounced in raw samples, in boiled more, and most pronounced in fried samples (Figures 2a, 2b and 2c). In contrast, fennel odor was the most pronounced in raw samples, in boiled less, and the least pronounced in fried samples; it was even absent in boiled and fried FEO-25. Although FEO concentration did not significantly affect the occurrence of off-odor in raw and boiled FCP, storage time did. After 6 days of storage, off-odor appeared in all samples, but it was stronger in the raw samples, less strong in boiled ones, and even lower in the fried ones. The higher the FEO concentration was, off-odor was lower (Figures 2a, 2b and 2c). Potato taste was pronounced in all samples, but with lower intensity as FEO concentration was higher and thus the intensity of the fennel taste. After 6 days of storage, sour taste and off-taste occurred in all samples. In boiled samples sour taste was more pronounced than the off-flavor, which is in contrast to the most of the fried samples. At higher FEO concentrations, sour taste and off-flavor were more pronounced in the fried samples, but not in boiled samples (Figures 2d and 2e). All panelists agreed that fennel odor and taste had positive sensory impact on odor and taste of FCP. Similar results were obtained by Luo et al. (2019) for potato treatment with rosemary essential oil.

Conclusion

AMB decreased with increasing FEO content, and in general this trend remained during storage. Slight negative changes in color were observed with increasing FEO content and with storage time. Fennel taste and odor attributes in raw and boiled potatoes increased with increasing FEO content, while FEO odor after frying was slightly pronounced only in FEO-250-0. Despite the antibacterial activity of FEO, spoilage of FCP was not prevented during storage. In general, after 6 days, the best results in terms of absence of browning and off-odor of raw and off-taste and sour-taste of boiled and fried FCP were obtained with 25 mg L^{-1} FEO treatment.

Acknowledgments

The results presented in the paper were the result of a scientific projects fully supported by Croatian Science Foundation „Innovative techniques in potato minimal processing (*Solanum tuberosum*) and its safety after preparation"(IP-2016-06-5343) and „Isolation and encapsulation of bioactive molecules of wild and cultivated nettle and fennel and effects on organism physiology" (IP-2018-01-4924).

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Izvorni znanstveni rad

"Fresh-cut" krumpir tretiran eteričnim uljem komorača tijekom skladištenja pri 8 °C

Sažetak

Cilj ovog istraživanja bio je ispitati učinak tretiranja eteričnim uljem komorača (FEO) na rok trajanja svježe rezanog krumpira (FCP) te na senzorske karakteristike sirovog te naknadno kuhanog i prženog krumpira. Oguljeni i narezani krumpiri potopljeni su 15 min u vodenu otopinu koja je sadržavala različite koncentracije FEO (0 (kontrola-voda), 25, 125 i 250 mg L-1), zatim su ocijeđeni, pakirani u vakuumu i pohranjeni pri 8 °C tijekom 12 dana. Određivan je broj aerobnih mezofilnih bakterija (AMB) sirovog FCP te su analizirani CIELAB parametri boje i senzorske karakteristike sirovih, kuhanih i prženih uzoraka. S povećanjem koncentracije FEO AMB se smanjio, a taj se trend uglavnom zadržao i tijekom skladištenja. S povećanjem koncentracije FEO i s vremenom skladištenja uočene su blage, ali negativne promjene boje. U sirovom i kuhanom krumpiru svojstva okusa i mirisa komorača povećavale su se s povećanjem udjela FEO, dok je miris FEO nakon prženja bio tek neznatno izražen i to u FEO-250 0-tog dana. Unatoč antimikrobnom djelovanju FEO, kvarenje FCP-a tijekom skladištenja nije spriječeno. Općenito, nakon 6 dana, najbolji rezultati s obzirom na boju i odsutnost neugodnog mirisa sirovog te neugodnog i kiselkastog okusa kuhanog i prženog FCP postignuti su tretmanom s 25 mg L-1 FEO.

Ključne rječi: *"fresh-cut" krumpir, eterično ulje komorača, aerobne mezofilne bakterije, senzorske karakteristike, kuhani i prženi krumpir*

Prispjelo/Received: 17.11.2022. Prihvaćeno/Accepted: 02.12.2022.