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The influence of laurel essential oil treatment on the shelf-life and sensory characteristics of fresh-cut apples during storage

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Abstract

Fresh-cut apples provide consumers convenient, fresh, ready-to-eat product. However such products are susceptible to browning and microbiological spoilage which occurs very quickly after processing. Due to their antimicrobial properties, essential oils have a potential stabilizing effect on fresh-cut products, but could have undesirable effects on their color or taste. The aim of this study was to investigate the effect of laurel essential oil (LEO) treatment at different concentrations (25, 75, 125 and 175 mg L^{-1}) on the shelf-life (aerobic mesophilic bacteria count) and physical (soluble dry metter, pH, color, texture) and sensory characteristics of fresh-cut apples during 10 days of storage at 8 °C. Number of aerobic mesophilic bacteria decreased with the increase of LEO concentration and it slightly increased with the increase of storage time. In general, samples treated with 75 mg L^{-1} LEO had the lowest and samples treated with 175 mg L^{-1} LEO the highest soluble dry matter, while pH trend was vice versa. Soluble dry matter, pH, and firmness increased during storage. Apples treated with 75 mg L^{-1} LEO after 10 days of storage showed the least color change. This study showed that LEO can be used to preserve and enrich sensory characteristics of fresh-cut apples, especially at a concentration of 75 mg L^{-1}. Generally, this LEO concentration can be recommended regarding the results of microbiological and sensory analysis as well as results of soluble dry matter, pH, color parameters and firmness.

Keywords: minimally processed apple, laurel essential oil, color, texture, microbiological analysis

Introduction

Apples (*Malus domestica*) are one of the most commonly consumed fruits in the world, along with bananas and grapes. The richness of vitamins (A, B1, B2, B6, C, E and K), minerals (potassium, manganese and copper), fiber, pectin, and phenolic compounds (quercetin, kaempferol and catechin) (Feliciano et al., 2010) contributes to numerous health benefits often associated with apples. Apples have the potential to protect against cancer, heart disease, and diabetes, lower cholesterol, improve bone health, and enhance brain function (Feliciano et al., 2010), supporting the saying "An apple a day keeps the doctor away." Although apples are already a convenient on-the-go snack, the demand for pre-cut, individually packaged, minimally processed (fresh-cut) apples has increased in the marketplace. Such products are particularly popular with children, who are more likely to eat apples when they are sliced (Wansink et al., 2013). Although fresh-cut apples (FCA) are quite convenient, minimal processing can lead to quality deterioration associated with water loss, softening, microbial contamination, increased respiration and ethylene, and browning of the cut surface (Qi et al., 2001). Therefore, in addition to selecting appropriate cultivars, various physical and chemical approaches are being investigated to extend shelf-life. These include antimicrobial and browning inhibitors (e.g., ascorbic acid, citric acid and some sulfur-containing amino acids), edible coatings, packaging materials and conditions (e.g., vacuum or modified atmosphere) (Lee et al., 2003), storage conditions (Dite-Hunjek et al., 2020a), and non-thermal technologies (e.g., UV-C light) (Pelaić et al., 2022). In addition, the use of natural essential oils derived from various plant species as an alternative to chemical antimicrobial and anti-browning agents (antioxidants or enzyme inhibitors) is receiving considerable attention in the scientific community (Ayala-Zavala et al., 2009; Liu et al., 2019). Essential oils are complex, concentrated mixtures of various volatile chemical compounds extracted from plants that possess antioxidant and antimicrobial properties in addition to their highly aromatic nature (Luo et al., 2019). Short hydrocarbon chains supplemented by oxygen, nitrogen, and sulfur atoms bonded at different positions in the chain molecules are usually components of such mixtures. They have highly reactive atoms that give the essential oils different functional properties. Due to the distinctive taste of the original plant, their use has enabled the production of innovative, biologically and aromatically enriched fresh-cut products (Ayala-Zavala et al., 2009). However, apart from their promising stabilizing effect on fresh-cut products, they may have undesirable effects on taste or color (Luo et al., 2019) due to their composition and very strong and intense aroma. Therefore, the optimal selection of aromatic plants (essential oil and its concentration) and fresh-cut products is crucial to achieve improved and harmonized flavor, as well as product quality and safety. For FCA, the use of cinnamon, clove, citrus, and peppermint essential oils is recommended (Ayala-Zavala et al., 2009). Due to the widespread use of aromatic herb laurel (*Laurus nobilis* L.) not only in culinary and food industry, but also in folk medicine, as a stomach and carminative remedies, and for the treatment of digestive problems (Cazzola and Cestaro, 2014), it is interesting to consider its use in fresh-cut products contributing to the biological value of the products (Chahal et al., 2017). The medicinal properties are associated with the chemical composition of laurel, which includes various polyphenols and volatile compounds (e.g., 1,8-cineole, α-pinene, linalool and α-terpineol) (Chahal et al., 2017). Although the antimicrobial activity of laurel essential oil (LEO) against certain microorganisms is well documented in the scientific literature (Chmit et al., 2014; da Silveira et al., 2014; Merghni et al., 2016), there are still no data on its application in the processing of FCA. For the success of the applied treatment in terms of absence of browning or microorganisms, as well as sensory characteristics during storage, an adequate concentration of essential oils is also important. The aim of this study was to investigate the effects of treatment with different LEO concentrations on the shelf-life of FCA and on their physical and sensory characteristics.

Materials and methods

Plant material

Apples (*Malus domestica* cv. Cripps Pink) were purchased from the local supermarket, while LEO was purchased from Ireks Aroma Ltd. (Jastrebarsko, Croatia).

Sample preparation

Washed and dried unpeeled apples were cored and sliced into 8 slices using a manual apple slicer. Solutions of LEO (25, 75, 125, and 175 mg L^{-1}, i.e., LEO-25, LEO 75, LEO-125, and LEO-175, respectively) were prepared by mixing a given amount of LEO with distilled water. The sliced apples were immediately dipped into the LEO solutions (solution:sample=1:1, v/m) and kept for 15 min with gentle shaking. The control samples (LEO-0) were prepared in the same way, but the slices were dipped in distilled water. After draining, the slices (150 g) were vacuum packaged (SmartVac SV 750, Status, Metlika, Slovenia) in a double-layer (100 and 130 μm) polyamide/polyethylene vacuum bag (PA/PE) (Status, Metlika, Slovenia) and stored at 8 °C for 10 days. Samples were analyzed on the day of preparation (day 0) and on the 1st, 3rd, 7th and 10th day of storage.

Microbiological analysis

Analysis of aerobic mesophilic bacteria count (AMB) was performed by the horizontal colony count method at 30 °C (HRN EN ISO 4833:2008) on the 1st, 3rd, 7th and 10th day of storage. Peptone water (0.1%, m/V) was used for dilutions and 1 mL was used to inoculate plate counter agar (Biolife, Milan, Italy). The incubation time and temperature in the drying oven (FN -500, Nueve, Ankara, Turkey) were 30±1°C and 72±3 h, respectively. Analyses were performed in duplicate and results were expressed as mean values of log CFU g^{-1} (Pelaić at al., 2022).

Soluble dry matter and pH

Soluble dry matter (SDM) and the pH values were determined using a refractometer (Pal-3, Attago Tokyo, Japan) and a pH meter (SevenEasy, Mettler Toledo, USA) respectively, in juice separated after grinding (Philips ProMix, 650W) several apple slices. Two measurements were performed for each sample.

Color analysis

CIELAB color parameters (L^*-lightness, a^*-red/green, and b^*-yellow/blue) were measured using a colorimeter (CR-5, Konica Minolta, Tokyo, Japan) equipped with a D65 light source with 2° angle observers with 8 mm diameter hole measuring plate and black cylinder cover (Dite Hunjek et al., 2020a; Levaj et al., 2020). Measurements were carried out on three slices per sample (randomly selected from bag) on the 0th, 1st, 3rd, 7th, and 10th storage days. The 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 LEO-0 on day 0.

Texture analysis

The firmness analysis was performed on apple slices using a texture analyzer (Fruit Texture Analyzer, Agrosta, Serqueux, France) with 5 kg load cell and 4-mm cylinder penetration probe. High speed was set to 2 mm s^{-1}, low speed to 1 mm s^{-1} and stroke after contact to 4 mm. For each sample the measurements were performed on two slices with 4 punctures and the results are expressed as mean value±standard error.

Sensory monitoring

Sensory evaluation of samples was done by Quantitative Descriptive Analysis (QDA) by a panel of 5 experienced and trained (to ensure consistency) sensory analysts. The evaluation was performed in a sensory laboratory [equipped according to the guidelines of the International Organization for Standardization guidelines (ISO, 2007)] at room temperature. On the day of the analysis samples were coded immediately after removal from the bags and evaluated according to Dite Hunjek et al. (2020b) and Levaj et al. (2020) with some modifications. Attributes suitable for assessing the sensory quality of the samples were previously selected and intensity was assessed using a standardized five-point scale with a score of 1 indicated the absence of a particular attribute and a score of 5 indicated a very pronounced attribute. Color was rated as browning intensity as follows: 1-no browning (white or cream), 2-no browning (yellow), 3-light browning, 4-medium browning and 5-complete browning. Apple, laurel and off- odor and taste, moistness, crispness-juiciness, firmness to the touch and taste, sweetness, acidity, harmonious taste, and overall acceptability were evaluated.

Statistical analysis

The influence of LEO concentration and storage time on AMB, color parameters, pH, SDM, texture, and sensory characteristics were statistically analyzed by analysis of variance (ANOVA) and Tukey HSD post-hoc test at a significant level of $p \leq 0.05$ using Statistica ver. 8.0 software (Statsoft Inc., Tulsa, USA).

Results and discussion

FCA samples were treated with LEO at various concentrations, stored for 10 days, and analyzed every few days (AMB count, color parameters, pH, soluble dry matter, texture and sensory characterostics).

Microbiological analysis

From the results presented in Figure 1, it can be seen that in all samples, including LEO-0, the maximum mean value of AMB count was 2.68 log CFU g^{-1}, which is under the limit set in the Croatian legislation (NN 83/2022) and Guidance for microbiological criteria for foodstuffs (2011) what is 5 log CFU g^{-1}. LEO concentration and length of storage had a significant effect on the AMB count (Table 1). As the concentration of LEO increased, the AMB count decreased, while it increased with longer storage. Up to 3 days of storage, the AMB count was similar to the first day, but after 7 days of storage, the AMB count increased significantly, however it remained unchanged at the 10th day. Due to the lower AMB count on day 0 in samples with higher LEO concentration, the AMB count at the end of storage was also lower.

Similar findings are already published, e.g., in FCA treated with alginate-based edible coating with thyme essential oil (0.5, 3.5 and 6.5 mL L^{-1}) microbial growth was also slower with higher concentration of thyme oil, and even 0.5 mL L^{-1} thyme oil was sufficiently effective in inhibiting microorganisms (Sarengaowa et al. 2018). In addition, initial AMB in FCA treated with pectin-based edible coatings with 0.15% lemon and sweet orange essential oils were 1.24 and 1.24 log CFU g^{-1}, respectively, while control sample had 1.35 log CFU g^{-1} (Sumonsiri et al., 2020). Furthermore, after 9 days of storage control sample had 4.46 log CFU g^{-1}, while AMB count was only 2.61 and 2.36 log CFU g^{-1} in samples treated with 0.15% lemon and orange essential oils, respectively. In muskmelons (*Cucumis melo* L.) treated with LEO total AMB count increased from the initial 2.8 log CFU g^{-1} to 5.14 log CFU g^{-1} after 8 days of storage, while in the control group total AMB count increased from the initial 2.8 log CFU g^{-1} to 9.42 log CFU g^{-1} (Ru et al., 2022). All those results supported thesis of anti-microbial properties of LEO.

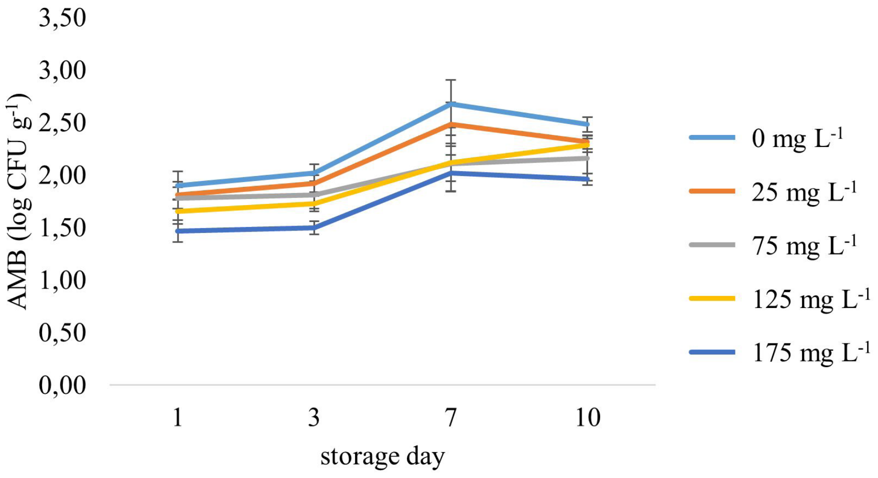

Figure 1. Aerobic mesophilic bacteria count (AMB) of fresh-cut apples during 10 days of storage (results are expressed as avegarge±standard deviation)

Table 1. Influence of laurel essential oil concentration and storage time on aerobic mesophilic bacteria count (AMB) of fresh-cut apple

Source of variation	N	AMB (log CFU g^{-1})
Concentration (mg L^{-1})		$p \leq 0.05$*
0	8	2.27±0.05^{c}
25	8	2.13±0.05^{b,c}
75	8	1.97±0.05^{b}
125	8	1.95±0.05^{a,b}
175	8	1.74±0.05^{a}
Storage time (day)		$p \leq 0.05$*
1	10	1.72±0.04^{a}
3	10	1.79±0.04^{a}
7	10	2.28±0.04^{b}
10	10	2.24±0.04^{b}
Grand Mean	40	2.01±1.39

Results are expressed as mean±standard error.
*Statistically significant variable at $p \leq 0.05$.
Values with different letters are statistically different at $p \leq 0.05$.

Soluble dry matter and pH

SDM is an important parameter when determining the freshness and quality of the fruit, since it dictates the taste, i.e., the sweetness of the fruit (Kusumiyati et al., 2020). Both sources of variation had a significant impact on SDM (Table 2). During storage samples experienced a slight decrease in SDM values up to the 3rd day and a subsequent increase with prolonged storage (Table 2). SDM of minimally processed apples treated with ascorbic and citric acid solutions for seven days slightly increased and ranged from 12.1 to 14.1 °Brix (Levaj et al., 2020) which is similar to the values measured in this study in which the values ranged from 12 to 14.6 °Brix (data not shown). SDM of minimally processed apples treated with combinations of essential oils as edible films, slightly increased during seven days of storage (Chiabrando and Giacalone, 2015). Similar results were also observed for muskmelon treated with LEO (Ru et al., 2022).

Due to the high content of malic acid the pH of all samples varied between 3.51 and 4.18 (data not shown) which is very similar to 3.64 reported in the literature (Putnik et al., 2017). In addition, pH can affect the taste and solubility of carbohydrates and proteins (Hou et al., 2018). Both sources of variation had a significant impact on pH (Table 3). In general, LEO-75 samples had the highest and LEO-175 the lowest pH. A longer storage time resulted in higher pH values, which can be attributed to the fact that organic acids are substrates for enzymatic reactions of respiration (Yaman and Bayoindirli, 2002). However, respiration could also lead to a decrease in pH during storage (Soliva-Fortuny et al., 2002; Putnik et. al, 2018; Dite-Hunjek et al., 2020). Possibly, pH changes could be influenced by certain interactions between the essential oils and the

Table 2. Influence of laurel essential oil concentration and storage time on soluble dry matter (SDM), pH and color parameters (L, a* and b*) of fresh-cut apple*

Source of variation	N	SDM (°Brix)	pH	*L**	*a**	*b**
Concentration (mg L^{-1})		p≤0.05*	p≤0.05*	p≤0.05*	p≤0.05*	p=0.96
0	15	13.72±0.09^{b}	3.77±0.01^{b}	74.80±0.35^{a}	0.97±0.09^{b}	15.71±0.53^{a}
25	15	13.24±0.09^{a}	3.82±0.01^{b,c}	76.59±0.35^{b}	0.74±0.09^{a,b}	15.55±0.53^{a}
75	15	12.89±0.09^{a}	3.85±0.01^{c}	76.37±0.35^{b}	0.72±0.09^{a,b}	15.19±0.53^{a}
125	15	13.07±0.09^{a}	3.77±0.01^{b}	76.55±0.35^{b}	0.58±0.09^{a}	15.39±0.53^{a}
175	15	13.88±0.09^{b}	3.63±0.01^{a}	75.87±0.35^{a,b}	0.88±0.09^{a,b}	15.54±0.53^{a}
Storage time (day)		p≤0.05*	p≤0.05*	p≤0.05*	p≤0.05*	p=0.06
0	15	13.43±0.09^{b,c}	3.65±0.01^{a}	74.91±0.35^{a}	0.55±0.09^{a,b}	14.70±0.53^{a}
1	15	13.50±0.09^{b,c}	3.68±0.01^{a}	75.92±0.35^{a,b}	1.00±0.09^{c}	16.65±0.53^{a}
3	15	12.84±0.09^{a}	3.70±0.01^{a}	76.26±0.35^{a,b}	0.39±0.09^{a}	15.98±0.53^{a}
7	15	13.25±0.09^{b}	3.87±0.01^{b}	76.18±0.35^{a,b}	1.08±0.09^{c}	14.92±0.53^{a}
10	15	13.78±0.09^{c}	3.95±0.01^{c}	76.91±0.35^{b}	0.87±0.09^{b,c}	15.13±0.53^{a}
Grand Mean	75	13.36±0.64	3.77±0.17	76.04+1.63	0.77+0.66	15.48+2.19

Results are expressed as mean±standard error.
*Statistically significant variable at p≤0.05.
Values with different letters are statistically different at p≤0.05.

fruit, which could also depend on the nature of the essential oils and the fruit (Shahbazi, 2018; Mohammadi et al., 2021). The pH of apples (Cripps Pink and Golden Delicious) decreased from 4.069 to 3.787 after 14 days of storage (Putnik et al., 2017). After 12 days of storage, the pH of minimally processed strawberries treated with peppermint essential oil, in the form of an edible coating decreased, while in control group pH value increased (Shahbazi, 2018). Similarly, pH was increased after storage in the control group while there was no significant difference in pH in strawberries treated with basil essential oil (Mohammadi et al., 2021).

Color analysis

Influence of LEO concentration and storage time on color parameters (*L**, *a** and *b**) is shown in Table 2 and total color change (*ΔE**) is shown in Figure 2. LEO concentration and storage time had a significant influence on the *L** and *a** values, while the *b** value was not significantly influenced. The control samples were the darkest, while all samples treated with LEO had similar lightness regardless of the applied concentration. Furthermore, by increasing of storage time samples became brighter. All this indicates that browning of the samples was successfully prevented and controlled by the application of LEO. All samples had a positive value of *a** parameter which means that red tones were present and could be an indicator of the first stage of browning. However, these values were very low, mostly around 1 and below, and do not differ significantly from the samples measured initially. As expected, the natural yellow tone of apples contributed to positive *b** values. Obtained values are generally consistent with the literature data for apple Cripps Pink with some variation, *L** was most similar (72.32), while *a** and *b** were higher in literature (3.64 and 29.70, respectively) (Putnik et al., 2017).
In order to better observe the color difference between samples, *ΔE** values were calculated and the LEO-0 on the day of preparation was used as a reference sample (Figure 2). In the literature *ΔE** values between 1.5 and 3 are described as already visible color change, while values between 3 and 6 are described as still "appreciable" (Yang et al., 2012). Since all samples were in those ranges, this means that the

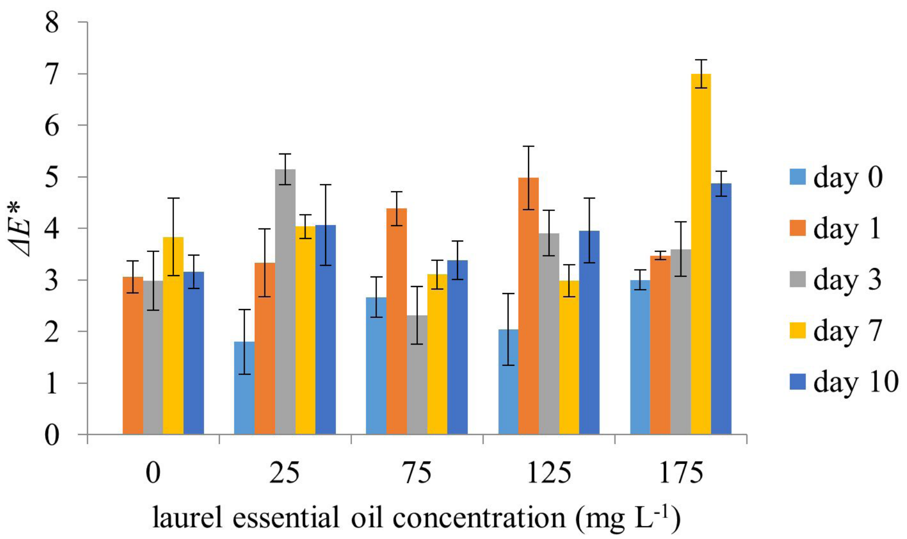

Figure 2. Total color change (ΔE*) of fresh-cut apple treated with laurel essential oil during 10 days of storage (results are expressed as avegarge±standard deviation)

application of LEO resulted in a noticeable, but still appreciable, color change. During the entire storage period, *ΔE** of LEO-0 was the lowest followed by the LEO-75, while the color change was more pronounced in all other samples. In general, *ΔE** showed an increasing trend during 10 days of storage and with increasing concentration of LEO, although it was not completely uniform. Each group of samples experienced a sharp increase on the first day of storage. Similarly, Putnik et al. (2017) found the sharpest *L** decrease in the first 60 min after cutting. This observation where the color change increases with a higher concentration of essential oils is consistent with the results in the literature (Sumonsiri et al. 2020; Sarengaowa et al., 2017).

Texture analysis

Firmness of apples treated with LEO and stored for 10 days ranged from 6.1 to 12.2 N (data not shown). LEO concentration and storage time had a significant influence on FCA firmness (Table 3). Samples treated with 25 mg mL^{-1} LEO had the highest firmness, and all others were similar to LEO-0. The firmness increased during storage between the 3rd an 7th day, but it remained the same on 7th and 10th day.

Relationship between firmness and essential oil concentration was reported by Sarengaowa et al. (2017), who studied the impact of an alginate-based edible coating in combination with 0.5, 3.5, and 6.5 mL L^{-1} thyme oil on FCA. The lower concentration (0.5 mL L^{-1}) of thyme oil maintained the highest firmness during 16 days of storage, while higher concentrations significantly reduced firmness. Possibly, higher concentrations of essential oils could penetrate more into the cellular tissue of the fruit, which could lead to structural changes and consequently softening (Sánchez-González et al., 2011). In this study, much higher concentrations of LEO were used, but still, the firmness was not reduced during storage and it even increased and was significantly higher on the 7th and 10th days of storage. Sumonsiri et al. (2020) reported significantly higher firmness of FCA treated with 0.15% essential oils of sweet oranges or lemons (in edible pectin coatings) after 7 days of storage compared to control samples and samples with 0.10% essential oils. It seems that not only the concentration but also nature of the essential oils (their composition) plays an important role in texture modification. LEO among many biological activities, has also showen the ability to scavenge hydrogen peroxide or have metal chelating effect (Elmastaş et al., 2006) and could possibly inhibit some enzymes or otherwise prevent texture degradation.

Sensory monitoring

Sensory characteristics of apples were evaluated by trained panelists using a standard five-point scale and results are showed at Figure 3 and statistical analysis of the results in Table 4. Expectedly, immediately after the applied treatments (day 0) samples were rated with the best scores. All samples retained the characteristic odor of apple, and sample treated with the highest concentration of LEO had the most profound laurel odor and taste. All samples were quite firm and crispy, and their taste was rated positively. High concentrations of LEO did not harm the taste as samples were highly rated for harmony, quite sweet and slightly acidic taste. But with higher LEO concentration harmonious taste showed slight decreasing trend.

Between day 0 and day 1, there was no remarkable change in overall ratings except for browning, what is in accordance with color measurements. The texture remained unchanged and apples continue to be rated very highly for all characteristics and overall acceptance. Influence of LEO concentration is not noticeable. After 3 days of storage, all parameters were mostly similar to those evaluated on the first day, however samples started to show very slight drop in acidity which can be attributed to the beginning of respiration reactions (Yaman and Bayoindirli, 2002). Apple odor and taste was still profound and no off-odor and off-taste developed during first three days of storage. The overall acceptability of the samples was lower by only 0.4-0.5 depending on the LEO concentration what was caused by the more intense laurel aroma in LEO-175 and lower harmonious taste especially in LEO-0 and LEO-175.

After 7 days of storage, browning of the samples was more evident but no off-odor and off-taste appeared. Browning was more pronounced in LEO-0, LEO-125 and LEO-175, but less pronounced in LEO-25 and LEO-75. Such results are in accordance with instrumentally measured color and with literature data (Sarengaowa, 2020). Each sample experienced an increase in moistness between the 3rd and 7th day, and the trend of enhanced laurel aroma continued. Overall acceptance fell below 4 and varied between 3.6 and 4.1.

Table 3. Influence of laurel essential oil concentration and storage time on fresh-cut apple firmness

Source of variation	N	Firmness (N)
Concentration (mg L^{-1})		p≤0.05*
0	32	8.68±0.18[a]
25	32	9.57±0.18[b]
75	32	8.92±0.18[a,b]
125	32	8.66±0.18[a]
175	32	9.11±0.18[a,b]
Storage time (day)		p≤0.05*
1	40	8.11±0.16[a]
3	40	8.15±0.16[a]
7	40	10.03±0.16[b]
10	40	9.67±0.16[b]
Grand Mean	160	8.99±1.42

Results are expressed as mean±standard error.
*Statistically significant variable at p≤0.05.
Values with different letters are statistically different at p≤0.05.

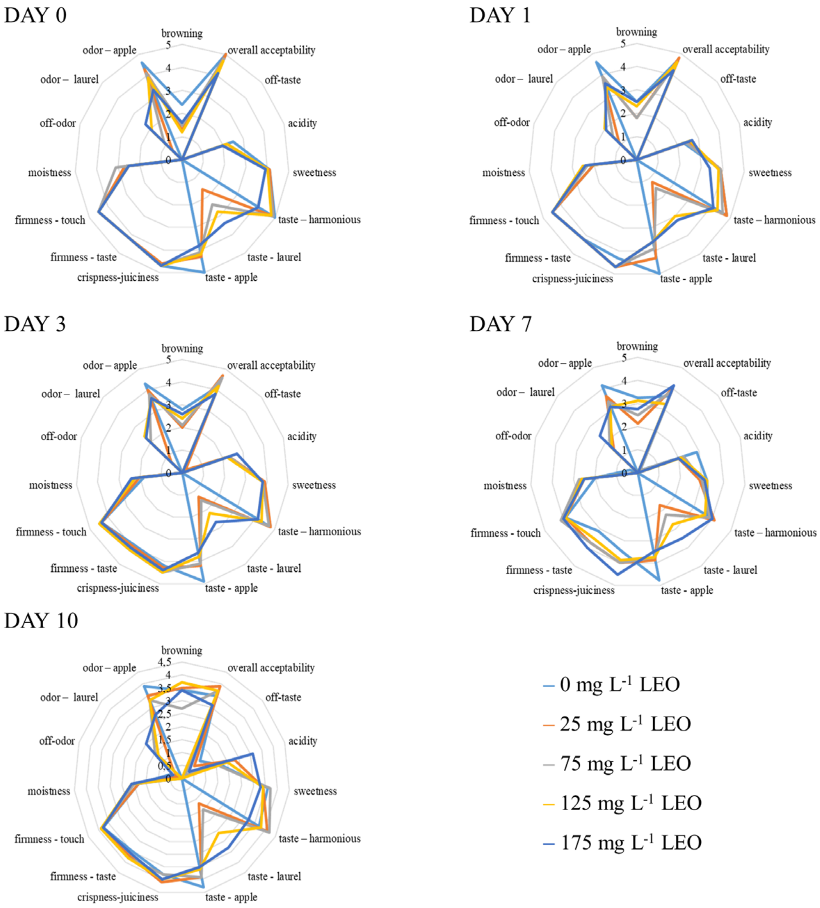

Figure 3. Sensory characteristics of fresh-cut apples treated with different concentrations of laurel essential oil during storage

Table 4. Influence of laurel essential oil concentration and storage time on sensory characteristics of fresh-cut apple

Source of variation	N	Browning	Apple- odor	Laurel- odor	Off-odor	Moistness	Firmness- touch
Concentration (mg L^{-1})		p≤0.05*	p≤0.05*	p≤0.05*	p≤0.05*	p=0.74	p=0.99
0	25	2.94±0.20^{b}	4.34±0.22^{b}	0.00±0.21^{a}	0.20±0.04^{b}	2.04±0.24^{a}	4.24±0.14^{a}
25	25	2.10±0.20^{a}	3.82±0.22^{a,b}	0.86±0.21^{b}	0.04±0.04^{a}	2.18±0.24^{a}	4.22±0.14^{a}
75	25	2.10±0.20^{a}	3.68±0.22^{a,b}	1.54±0.21^{b,c}	0.00±0.04^{a}	2.46±0.24^{a}	4.30±0.14^{a}
125	25	2.52±0.20^{a,b}	3.46±0.22^{a,b}	1.82±0.21^{c}	0.00±0.04^{a}	2.36±0.24^{a}	4.26±0.14^{a}
175	25	2.60±0.20^{a,b}	3.26±0.22^{a}	2.16±0.21^{c}	0.08±0.04^{a,b}	2.36±0.24^{a}	4.24±0.14^{a}
Storage time (day)		p≤0.05*	p=0.13	p=0.68	p≤0.05*	p=0.29	p≤0.05*
0	25	1.60±0.20^{a}	4.04±0.22^{a}	1.18±0.21^{a}	0.00±0.04^{a}	2.68±0.24^{a}	4.50±0.14^{b}
1	25	2.18±0.20^{a,b}	3.88±0.22^{a}	1.30±0.21^{a}	0.00±0.04^{a}	2.24±0.24^{a}	4.50±0.14^{b}
3	25	2.38±0.20^{a,b}	3.86±0.22^{a}	1.48±0.21^{a}	0.00±0.04^{a}	2.14±0.24^{a}	4.44±0.14^{b}
7	25	2.76±0.20^{b,c}	3.44±0.22^{a}	1.36±0.21^{a}	0.10±0.04^{a,b}	2.38±0.24^{a}	3.96±0.14^{a,b}
10	25	3.34±0.20^{c}	3.34±0.22^{a}	1.06±0.21^{a}	0.22±0.04^{b}	1.96±0.24^{a}	3.86±0.14^{a}
Grand Mean	125	2.45±1.15	3.71±1.11	1.28±1.26	0.06±0.24	2.28±1.12	4.25±0.71

Table 4. Continuous

Source of variation	N	Firmness-taste	Crispness-juiciness	Apple- taste	Laurel- taste	Harmonious taste	Sweetness	Acidity	Off-taste	Overall acceptability
Concentration (mg L^{-1})		p=0.92	p=0.53	p≤0.05*	p≤0.05*	p≤0.05*	p=0.94	p=0.56	p=0.38	p=0.74
0	25	3.82±0.16^{a}	4.08±0.15^{a}	4.80±0.21^{b}	0.00±0.19^{a}	4.42±0.14^{a,b}	3.76±0.18^{a}	2.40±0.18^{a}	0.22±0.09^{a}	4.18±0.13^{a}
25	25	3.94±0.16^{a}	4.36±0.15^{a}	4.06±0.21^{a,b}	1.42±0.19^{b}	4.56±0.14^{a}	3.66±0.18^{a}	2.18±0.18^{a}	0.18±0.09^{a}	4.48±0.13^{a}
75	25	4.00±0.16^{a}	4.30±0.15^{a}	3.96±0.21^{a}	1.82±0.19^{b}	4.42±0.14^{a,b}	3.68±0.18^{a}	2.10±0.18^{a}	0.06±0.09^{a}	4.28±0.13^{a}
125	25	3.96±0.16^{a}	4.32±0.15^{a}	3.80±0.21^{a}	2.64±0.19^{c}	4.14±0.14^{a,b}	3.64±0.18^{a}	2.18±0.18^{a}	0.00±0.09^{a}	4.08±0.13^{a}
175	25	4.02±0.16^{a}	4.44±0.15^{a}	3.62±0.21^{a}	3.20±0.19^{c}	3.90±0.14^{a}	3.54±0.18^{a}	2.46±0.18^{a}	0.08±0.09^{a}	3.86±0.13^{a}
Storage time (day)		p≤0.05*	p≤0.05*	p=0.62	p=0.33	p≤0.05*	p≤0.05*	p=0.54	p≤0.05*	p=0.29
0	25	4.20±0.16^{a}	4.68±0.15^{b}	4.28±0.21^{a}	2.04±0.19^{a}	4.74±0.14^{b}	4.02±0.18^{b}	2.18±0.18^{a}	0.00±0.09^{a}	4.72±0.13^{a}
1	25	4.20±0.16^{a}	4.62±0.15^{b}	4.08±0.21^{a}	1.78±0.19^{a}	4.52±0.14^{b}	3.78±0.18^{a,b}	2.50±0.18^{a}	0.00±0.09^{a}	4.58±0.13^{a}
3	25	4.08±0.16^{a}	4.38±0.15^{a,b}	4.12±0.21^{a}	1.54±0.19^{a}	4.54±0.14^{b}	3.82±0.18^{a,b}	2.36±0.18^{a}	0.04±0.09^{a}	4.30±0.13^{a}
7	25	3.58±0.16^{a}	3.88±0.15^{a}	3.92±0.21^{a}	2.00±0.19^{a}	3.84±0.14^{a}	3.18±0.18^{a}	2.14±0.18^{a}	0.04±0.09^{a}	3.70±0.13^{a}
10	25	3.68±0.16^{a}	3.94±0.15^{a}	3.84±0.21^{a}	1.72±0.19^{a}	3.80±0.14^{a}	3.48±0.18^{a,b}	2.14±0.18^{a}	0.46±0.09^{b}	3.58±0.13^{a}
Grand Mean	125	3.95±0.79	4.30±0.78	4.05±1.06	1.82±1.42	4.29±0.78	3.66±0.86	2.26±0.90	0.11±0.46	4.18±0.81

Results are expressed as mean±standard error.
*Statistically significant variable at p≤0.05.
Values with different letters are statistically different at p≤0.05.

On the 10th day of storage, the biggest changes in the samples were observed. Color of LEO-75 was rated remarkably better than the other samples. The best-rated samples according to overall acceptance are LEO-25, LEO-75 and LEO-125, which did not develop off-odor or off-taste, and did not have a very intense laurel taste. The firmness and crispness were retained relatively well in all samples. Overall, LEO didn't show negative trend on texture, even slight positive.

In general, treatment with LEO helped to retain the original texture, and the samples did not experience a noticeable browning. The loss of acidity was minimal, which indicates a good inhibition of enzymes and the reactions for which acids are substrates. The decrease in sweetness was also not remarkable and corresponds to the change in SDM value. With longer storage, apple odor and taste were less intense while laurel odor and taste become more intense in all samples until the 7th day of storage, and after 10 days of storage they experienced a sharp decline.

Results of statistical analysis supported most mentioned observation about obtained results, showed that LEO concentration had significant impact on browning, odor-apple, odor-laurel, off-odor, apple, laurel and harmonious taste. In addition, storage time had significant impact on browning, off-odor, firmness by touching and by taste, crispness-juiciness, harmonious taste, sweetness and off-taste. Although, without statistical significance overall acceptability had decreasing trend during storage, and mean values of LEO-25 and LEO-75 were the highest (Table 4).

In the literature it could be found different results related to essential oils' influence on FCA. Most studies, dealt with the FCA, are related with essential oils incorporated into edible coatings (Sumonsiri et al., 2020; Sarengaowa et al., 2020). It seems that type of essential oil as well as its concentration could have positive or negative impact on particular sensory characteristics' but mostly slight (Sumonsiri et al., 2020). Sarengaowa et al. (2020) found negative impact on FCA color by higher concentration of thyme oil incorporated with alginate-based edible coating.

The color, texture, taste and acidity of the apples treated with lemongrass, clove and cinnamon essential oils, were rated better than the control group on day 0. After 15 days of storage, the color of the control group was evaluated worse compared to the treated samples. The use of essential oils significantly affected the taste and odor of the samples. The samples treated with clove essential oil received the lowest score for taste while samples treated with lemongrass essential oil were rated as the best after storage (Raybaudi et al., 2008) what is in accordance to Ayala-Zavala et al. (2009) who pointed out importance of optimal combination fruit and essential oil.

Conclusions

Our study showed that microbial growth was suppressed by all tested LEO concentrations and regardless of the increasing trend during storage, samples with higher LEO concentration showed lower increase. Moreover, LEO at concentrations between 25-125 mg L^{-1} and especially 75 mg L^{-1} could be the recommended combinations for FCA for 7 days' storage at 8 °C. This is due to the pleasant and enriched sensory properties of FCA as well as the results of AMB, soluble dry matter, pH, color parameters and firmness.

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