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Effect of lactic acid and ajwain (*Carum copticum*) on the biogenic amines and quality of refrigerated common carp (*Cyprinus carpio*)

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ABSTRACT

Common carp (*Cyprinus carpio*) samples treated with *Carum copticum* (0.5% and 1%) and lactic acid were examined for a period of 18 days. Samples were analysed for their total viable count (TVC), psychrotrophic count (PTC), pH, thiobarbituric acid reactive substances (TBARS), total volatile base nitrogen (TVN) and biogenic amines (histamine, cadaverine, and putrescine) to evaluate their quality and safety. The TVC, PTC, pH, and TVN values were significantly reduced ($p < 0.05$) by lactic acid treatment, as was the formation of biogenic amines. Lipid oxidation was significantly ($p < 0.05$) delayed in samples treated with *Carum copticum*. Moreover, in these samples, a reduction in the formation of biogenic amines was observed. Therefore, *Carum copticum* and lactic acid can be utilized as food preservatives to extend the shelf-life of fish.

1. Introduction

Seafood provided by aquaculture is one of the main sources of animal protein for human nutrition (FAO, 2012). Although, these foods are highly perishable and preservation of their quality is of challenges in food science. In addition, fish consumption is very important for health due to the essential amino acid content of fish and other beneficial effects, such as reducing the risk of cancer; heart diseases and stroke; type 2 diabetes; arthritis; infant development and mental health (Lund, 2013). Nutritional experts recommend the consumption of two meals of fish per week (Tsuchiya, Hardy, Burbacher, Faustman, & Mariën, 2008). However, rapid autolysis and the microbiological and chemical spoilage of fish products cause 10–12 million tons of food loss (Kulawik, Zogul, Glew & Ö;zogul, 2013).

Common carp (*Cyprinus carpio*) is a major aquaculture fish species that produced approximately 4,159,117 tons in 2014 (FAO, 2016). Common carp, one of the main seafoods produced and distributed in Iran, is an appropriate source of protein that is in demand by consumers. It is prone to rapid spoilage, which makes it difficult to establish distant markets. Although many bacteria, such as *Pseudomonas*, *Flavobacterium*, *Aeromonas*, *Micrococcus*, *Shewanella*, and *Moraxella*, are commonly involved in the spoilage of freshwater fish, the dominant microorganism in the deterioration of common carp is *Pseudomonas* (Zhang, Li, Li, Liu, & Luo, 2015).

Essential oils (EOs) are acquired from different parts of plants, such as seeds, flowers, leaves, barks, roots, fruits and woods (Burt, 2004). Due to antimicrobial and antioxidant proprieties of essential oils, they have been used widely in food models in order to prevent growth of microorganism and oxidation of lipids (Raeisi et al., 2016). Interestingly, researchers have used different EOs (Bensid, Ucar, Bendeddouche, & Özogul, 2014) to extend the shelf-life and ensure the safety of fish. *Carum copticum* (ajwain) is grown in Iran, Pakistan, and India and has brownish seeds and white flowers. Some therapeutic proprieties have been attributed to its seeds (anti-vomiting, analgesic, and anti-asthma) in Persian folk medicine (Oroojalian, Kasra-Kermanshahi, Azizi, & Bassami, 2010). As reported by Raeisi, Sharifi-Rad, Quek, Shabanpour, and Sharifi-Rad (2016), *Carum copticum* had antimicrobial and antioxidant effects on rainbow trout during storage at 4 °C.

Organic acids, which are highly effective food additives, have been used widely to inhibit spoilage and the growth of pathogenic microorganisms. Moreover, since lactic acid has potential for microbial growth suppression, it can be effective to prevent formation of microbial metabolites such as biogenic amines. Since lactic acid is a safe food additive that does not incur acute or chronic toxic effects, it is applied to many different food models, including fish (Sallam, 2007).

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Bacterial metabolism (decarboxylation of amino acids) in fish flesh leads to the production of biogenic amines. Histidine, lysine, and arginine are precursors for the formation of histamine, cadaverine and putrescine, respectively (Buňka et al., 2013). Typically, ingesting BAs in low concentrations does not pose a major risk to a healthy human, but foodborne intoxication can occur if they are present in adequate amounts (Bjornsdottir, Bolton, McClellan-Green, Jaykus, & Green, 2009). Histamine poisoning is one of the most noteworthy foodborne intoxications caused by BAs. When some specific bacteria, such as *Enterobacteriaceae* and *Pseudomonas*, grow in food to a certain extent, BAs such as histamine could cause histamine toxicity (Buňka et al., 2013). While histamine is the key factor, Cadaverine and putrescine are potentiators of this toxicity (del Rio et al., 2017).

Due to potential beneficial application of *Carum copticum* and lactic acid in food models, the current study aimed to compare their effects on microbiological and chemical quality of *Cyprinus carpio* during 18 days of storage at 4 °C. Furthermore, their effect on formation of histamine, putrescine and cadaverin will be evaluated.

2. Materials and methods

2.1. GC/MS analysis of Carum copticum

The GC-MS analyses were performed using an Agilent HP-6890 gas chromatograph (Agilent Technologies, Palo Alto, CA, USA) with a HP-5MS capillary column (30 mm × 0.25 mm, 0.25 μm film thickness) equipped with an HP 5973 mass spectrometer (Agilent Technologies) and electron impact ionization (70 eV). The oven temperature was set at 50 °C for 5 min initially, increased at a rate of 3 °C per min to reach 240 °C, and finally raised to 290 °C at 15 °C per min, where it was held isothermal for 3 min. Helium was used as a carrier gas at a flow rate of 0.80 ml per min, and 1.00 μL samples were injected manually in the split less mode. Peak area percentages were used to obtain quantitative data. Retention indices were calculated for all components using a homologous series of n-alkanes injected in conditions that were identical to those used for the samples. The components of the oil were identified by comparing their retention indices relative to (C8 to C22) n-alkane standards presented in the literature or to authentic compounds available in our laboratory and then confirmed by matching their mass spectra with those of a computer library of the GC-MS data system and other published mass spectra (Adams, 2012).

2.2. Preparation of fish samples

Common carps (C*yprinus carpio*) with a mean weight of 1 kg were purchased from a local store of Ahvaz, Khuzestan province and immediately killed by percussive stunning. Fish were transferred on crushed ice to Food Laboratory in Food Hygiene Department at the Shahid Chamran University of Ahvaz (the ice:fish ratio during transfer was 3:1). They were decapitated, gutted, filleted and washed with tap water within 1 h. Each fish yielded 4 fillets with an average weight of 120 g. The fish were obtained during the period of February–May 2015.

2.3. Treatment of fish fillets

Carum copticum essential oils were purchased from Nader Essential Oil Co., Mashhad, Iran. Fillets were divided into four groups: (i) fillets were placed in sterile 0.85 NaCl solution (C); (ii) fillets were dipped in 1.5% lactic acid (Merck, Darmstadt, Germany; A); (iii and iv) 0.5% and 1% essential oil was used to prepare samples E1 and E2. All fillets were held in the bath for 30 min. Polysorbate 80 was applied to the essential oil groups to dissolve them in water. The samples were packed in polyethylene containers and stored at 4 °C for 18 days. The analysis was done at 0, 3, 6, 9, 12, 15 and 18 days of storage. Each group was replicated three times, and the mean values were used.

2.4. Microbiological analysis

Ten grams of fish fillets was taken, transferred aseptically into sterile bags containing 90 ml of 0.85% NaCl solution, and stomached for 60 s using a stomacher (Interscience, France). To obtain a microbial count, other decimal dilutions were made with 0.85% NaCl, and 0.1 ml of the appropriate dilutions was transferred onto plates of count agar (Merck, Darmstadt, Germany). Incubation at 37 °C for 36 h or 7 °C for 7 days was used to obtain the total viable count (TVC) and psychrotrophic count (PTC), respectively. Microbial enumeration data were expressed as $\log_{10}$ cfu/g (Ojagh Rezaei, Razavi, Hosseini, 2010).

2.5. Biochemical analysis

2.5.1. Determination of pH values

Ten grams of fish sample was added to 100 ml of distilled water, homogenized, and filtered by Whatman filter paper (No. 1) (Maidstone, England). The filtrate pH was recorded with a digital pH meter (Sartorius, USA) according to the method of Fan et al. (2009).

2.5.2. Determination of thiobarbituric acid reactive substances (TBARS)

A TBARS assay was performed to evaluate lipid oxidation as described by Tsironi, Dermesonlouoglou, Giannakourou, and Taoukis (2009). Five grams of the sample was added to 15 ml of distilled water and homogenized. Subsequently, 1 ml of homogenized sample and 2 ml of thiobarbituric acid (TBA) solution (0.375 g TBA, 82.9 ml H_2O_2, 15 g trichloroacetic acid, 1.76 ml HCl 12 N) were transferred to a glass tube. The tube was placed in a 90 °C water bath for 1 h. After cooling to room temperature, the tube was centrifuged at 2000 g for 15 min. Absorbance (AS) against water blank was measured at 532 nm with a spectrophotometer (Cecil, England). A blank reagent was measured, and absorbance (AB) recorded. TBARS value (mg of malonaldehyde equivalents/kg of tissue) was calculated with the following formula:

$$TBA = \frac{50 \times (AS - Ab)}{200}$$

2.5.3. Determination of total volatile base nitrogen (TVN)

Ten grams of fish sample and 50 ml of distilled water were mixed with a blending device (Moulinex, France). The mixture was transferred to a round bottom flask containing 2 g of MgO and 2–3 drops of silicon. Forty millilitres of 3% aqueous solution of boric acid, 0.1 g of methyl red and 0.1 g of methylene blue were added to a 250 ml Erlenmeyer flask as the distillate receiver. The distillation process continued for 18 min until the total TVN was distilled and the boric acid solution turned green. Subsequently, an aqueous 0.1 N sulfuric acid solution was used to titrate the receiver flask. The TVN value was expressed as mg N per 100 g of fish sample, and it was calculated according to the consumption of sulfuric acid.

2.5.4. Biogenic amines (BAs)

The quantification of BAs was performed as previously described by Dawood, Karkalas, Roy, and Williams (1988). Briefly, 10 g of each sample was blended with trichloroacetic acid (TCA, 75 ml, 5 g/100 ml) in a blender for 2 min and then centrifuged at 2000 g for 10 min. Whatman filter paper (No. 1) was utilized to filter the supernatant. 5% TCA was added to filtrate to obtain a 100-ml final volume. Glass tubes with a 25-ml capacity containing 2 ml of the filtrate solution, 10 μl of benzoyl chloride (Merck, Germany) and 1 ml of NaOH (2N, Merck, Germany) were dipped in 30 °C water. Three millilitres of diethyl ether and 2 ml of saturated NaCl were added to the tubes and centrifuged at 3000 g for 10 min.

Another glass tube was used to collect the supernatant organic phase, and this tube was placed in a 70 °C oven with an air current to evaporate the extracts.

Two hundred microlitres of methanol (HPLC grade) was used to

dissolve the residue, and a Millipore filter (0.45 µl pore size) was used to filter the solution. Twenty microlitres of solution was injected for HPLC.

Standard amine solutions were prepared by dissolving putrescine (75 mg), cadaverine (60 mg) and histamine (60 mg) in 1 ml of mobile phase (methanol/water; 70/30 v/v). The standards were diluted with mobile phase to lower the concentrations to 50, 30, 15, 10 and 5 mg/ml for each amine. These concentrations were used to achieve a standard curve and its corresponding equation.

Determination of BAs was performed using an HPLC (Shimadzu, Japan) equipped with a UV detector. A mixture of methanol:water (70:30 by volume) was used as the isocratic mobile phase, with a flow rate of 1 ml/min at room temperature. The absorption at 254 nm was used to detect peaks.

2.6. Statistical analysis

The determination of microbiological, chemical, and BAs were replicated three times for each group, and average values were used for statistical analysis in SPSS 16 (SPSS Chicago, IL, USA). Data were subjected to a ANOVA, Bonferroni and Dunnett T3 post hoc tests. A significance level of 5% was used.

3. Results and discussion

3.1. GC-MS analysis

The components of oil were determined by GC-MS analysis. The constituents of *Carum copticum* essential oil, accompanied by retention time and percent, are outlined in Table 1. The GC-MS analysis resulted in the identification of 16 components, representing 98.88% of the total components. The main constituents were thymol (57.18%), ρ-cymene (22.55%) and γ-terpinene (13.07%), in accordance with the results of Oroojalian et al. (2010).

3.2. Microbiological analysis

Changes in the total viable counts (TVC) of common carp samples in four groups are shown in Fig. 1. The initial TVC of samples varied from 2.82 $\log_{10}$ cfu/g in the acid group to 4.68 $\log_{10}$ cfu/g in the control group. An increasing trend of TVC in fish fillets was observed, in agreement with the results of Wang, Chen, Chen, Fan, and Luo (2016). Common carp samples exceeded the value of 7 $\log_{10}$ cfu/g for TVC, which is considered the upper acceptability limit for fish (International Commission on Microbiological Specifications for Foods, 1978), on day 6 for C, EO1, and EO2. However, lactic acid extended the shelf-life of the fish until day 12, similar to the results of Metin, Erkan, Varlik, and Aran (2001). Compared with the C, EO1 and EO2 samples, lactic acid treatment resulted in the extension of microbiological shelf-life by at least 3 days.

Table 1
Essential oil composition of *Carum copticum* identified by gas chromatography-mass spectrometry.

Phytochemicals	Percent	Retention index
α -Pinene	0.29	11.35
β -Pinene	0.43	13.45
β -Myrcene	0.34	14.28
α -Phellandrene	0.06	14.89
α -Terpinene	0.31	15.54
ρ -Cymene	22.55	16.21
β -Phellandrene	0.54	16.29
γ -Terpinene	13.07	17.93
α -Terpinolene	0.09	19.18
α -Terpineol	0.15	24.92
L-Carvone	0.90	27.97
Trans-Anethole	1.70	28.68
Thymol	57.18	29.73
Carvacrol	0.52	29.84
3-Dodecen-1-Al 0.16	0.16	36.51
Apiol	0.56	42.73
Total	98.85	–

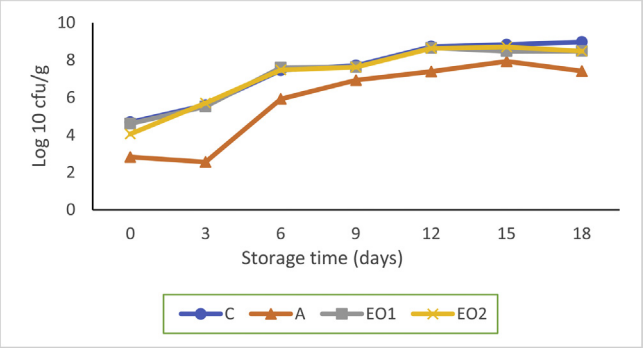

Fig. 1. Changes in total viable counts (TVC) of common carps stored for 18 days (C: control, A: lactic acid, EO1: essential oil 0.5%, EO2: essential oil 1%).

The results of the psychrotrophic counts (PTC) are presented in Fig. 2. In this study, the PTC on day 0 ranged from 2.42 $\log_{10}$ cfu/g in samples from group A to 4.69 $\log_{10}$ cfu/g in EO1. Moreover, the growth trend of psychrotrophic bacteria was similar to TVC. The PTC values of group A were significantly lower ($p < 0.05$) than were those of groups C and EO1.

Although the antimicrobial properties of *Carum copticum* have been reported in the literature (Oroojalian el al., 2010), few studies have evaluated its antimicrobial effects in fish. These results were in disagreement with other reports that mentioned this effect for *Carum copticum*. However, it should be emphasized that antimicrobial effect of essential oils depends on their concentration. In addition, antibacterial properties of *Carum copticum* on *Bacillus subtilis*, *E. coli*, *Proteus vulgaris*, *Salmonella typhimurium*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* were not observed by Ahmad, Mehmood, and Mohammad (1998).

3.3. Biochemical analysis

3.3.1. pH values

Fig. 3 shows the average values for pH on each day of analysis. The pH value for the control samples (C) was 6.6 at day 0, and it increased significantly during storage, reaching 7.04 after 18 days. The accumulation of alkaline compounds such as ammonia due to bacterial activity and metabolism led to a progressive increase in pH during the storage of common carp fillets (Schormuller, 1968, pp. 1561–1584). Comparing all of the treatment groups indicated that group A had significantly lower ($p < 0.05$) pH values than did groups C and EO1. This finding

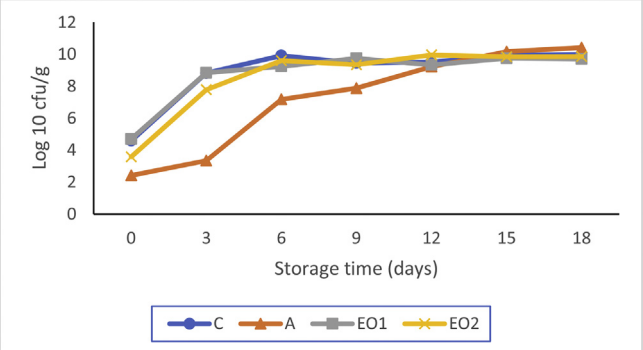

Fig. 2. Changes in psychrotrophic counts (PTC) of common carps stored for 18 days (C: control, A: lactic acid, EO1: essential oil 0.5%, EO2: essential oil 1%).

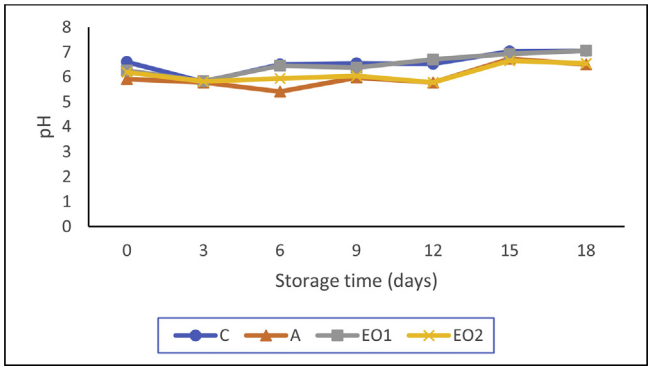

Fig. 3. Changes in pH values of common carps stored for 18 days (C: control, A: lactic acid, EO1: essential oil 0.5%, EO2: essential oil 1%).

may be attributed to the bacterial growth inhibition of lactic acid.

3.3.2. Thiobarbituric acid reactive substances (TBARS)

TBARS analysis is utilized to assess the lipid oxidation and antioxidant activity in food. It is also considered a quality indicator for fish (Sallam, 2007). The effects of different treatments on the changes of TBARS are presented in Fig. 4. By day 0, TBARS values varied from 0.008 mg of malonaldehyde equivalents/kg of tissue in EO1 to 0.78 mg of malonaldehyde equivalents/kg of tissue in samples treated with lactic acid. Increasing amounts of TBARS values were observed during the 18 days of storage. An increasing trend of TBARS could be attributed to the accumulation of secondary lipid oxidation products, whereas the reduction of TBARS values in A samples was due to malonaldehyde decomposition (Bensid et al., 2014).

The TBARS values in group A were significantly higher ($p < 0.05$) than were those in groups C, EO1, and EO2, which was expected due to the lower pH values. Higher amounts of antioxidant activity were observed with higher pH values for mint by Arabshahi, Devi, and Urooj (2007). The results showed lower TBARS values in EO1 and EO2 compared with C ($p < 0.05$), suggesting that *Carum copticum* had antioxidant activity in *Cyprinus carpio* fillets, in agreement with Raeisi, Hashemi, et al. (2016) and Raeisi, Sharifi-Rad, et al. (2016). High amounts of phenolic compound observed in *Carum copticum* essential oil constituents (such as thymol and ρ-cymene) can contribute to the reduction of free radicals or dedicated hydrogen atoms (Ojagh, Rezaei, Razavi, & Hosseini, 2010). Five milligrams of malonaldehyde equivalents/kg of tissue TBARS was considered a limit for high-quality chilled fish. However, none of the samples exceeded this value throughout the storage period.

3.3.3. Total volatile base nitrogen (TVN)

The changes in the TVN values for control and treatment groups are

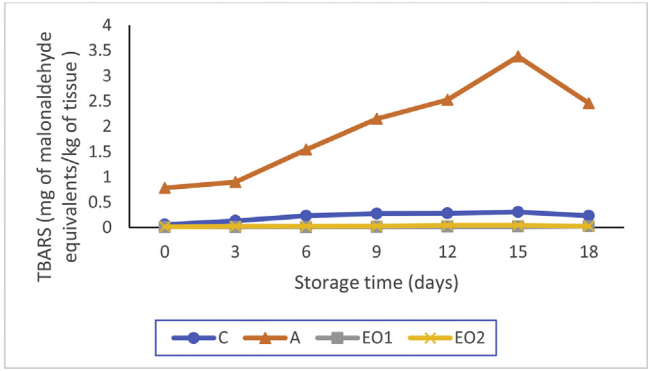

Fig. 4. Changes in TBA values of common carps stored for 18 days (C: control, A: lactic acid, EO1: essential oil 0.5%, EO2: essential oil 1%).

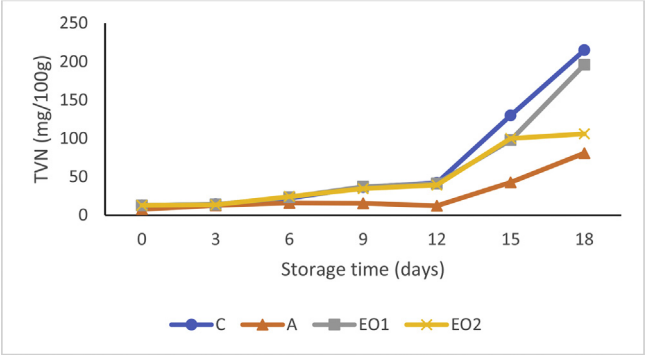

Fig. 5. Changes in TVN values of common carps stored for 18 days (C: control, A: lactic acid, EO1: essential oil 0.5%, EO2: essential oil 1%).

outlined in Fig. 5. The TVN values varied from 7.65 mg N per 100 g in A to 12.8 mg N per 100 g in EO2 on the initial day. The values of TVN increased during the 18 days of storage at 4 °C and reached 214.86 mg N per 100 g, 80.73 mg N per 100 g, 196 mg N per 100 g and 105.93 mg N per 100 g in groups C, A, EO1, and EO2, respectively. Furthermore, the average of TVN values in samples treated with lactic acid was significantly lower than those in samples in groups C and EO1 ($p < 0.05$).

Harpaz, Glatman, Drabkin, and Gelman (2003) reported 25–30 mg N per 100 g of flesh as an acceptable limit for fresh fish. The results of the current study showed that samples of C, EO1, and EO2 exceeded the acceptability limit on day 9 of storage, while lactic acid treatment preserved common carp fillets for at least 12 days. Sallam (2007) reported at least 3 days of shelf-life extension in sliced salmon that were treated with sodium acetate, sodium lactate and sodium citrate. Lower amounts of TVN in chub mackerel treated with 2% and 4% lactic acid have also been reported (Metin et al., 2001), similar to the findings of our study. Abdeldaiem, Ali, and Ramadan (2017) treated common carps with rosemary essential oil and reported a significant reduction in TVN values compared with those of the control samples.

Regardless of the endogenous enzymes of fish, bacterial growth plays an important role in increasing the TVN values, followed by an off-odour and off-flavour, which is a consequence of the breakdown of proteins and formation of volatile nitrogen compounds (Orban et al., 2011). Therefore, a retardation of the increasing trend of TVN in fish during storage is correlated with the growth inhibition of bacteria in fish flesh. High amounts of TVN were demonstrated in this study, as *Carum copticum* failed to prevent bacterial growth. However, it should be noted that the sex, season, harvesting area, age, species of fish (Kilinc & Cakli, 2005), and concentration and constituents of essential oils (Burt, 2004) all have an impact on the TVN values.

3.3.4. Biogenic amines (BAs)

The average values of BAs during 18 days of storage are presented in Table 2. The results are expressed as the mean ± standard deviation (SD) of mg of BA/kg. Histamine was undetectable at the early stages of common carp storage at 4 °C, which resembled the findings of Hosseini et al. (2013). The highest amount of histamine was 3.59 mg/kg, which was much lower than the limit of histamine concentration (50 mg/kg) recommended for Scombridae and tuna by the FDA (2011, pp. 73–93). This result is consistent with the results obtained in a previous study on *Cyprinus carpio* (Křížek, Vácha, & Pelikánová, 2011). The overall low formation of histamine in common carp fillets in this study may refer to its initial amino acid composition or alteration during treatment and/or storage (Rabie, Simon-Sarkadi, Siliha, El-seedy, & El Badawy, 2009).

The cadaverine and putrescine contents of *Cyprinus carpio* fillets increased significantly during storage in groups C, EO1, and EO2, in agreement with the results of Özogul and Özogul (2006) study. On day 0, cadaverine in C samples had the highest concentration among the

Table 2
Changes in biogenic amines (BAs) concentration (mg/kg) of refrigerated *Cyprinus carpio* treated with lactic acid and *Carum copticum* for 18 days (C control, A lactic acid, EO1 essential oil 0.5%, EO2 essential oil 1%).

BAs	Treatment	Storage days						
		0	3	6	9	12	15	18
HIM	C	ND^{a}	ND^{a}	0.50^{a} ± 0.30	0.22^{a} ± 0.06	ND^{a}	0.59^{a} ± 0.41	3.59^{a} ± 0.15
	A	ND^{a}	ND^{a}	ND^{ab}	0.08^{b} ± 0.05	ND^{a}	ND^{ab}	0.39^{b} ± 0.08
	EO1	ND^{a}	ND^{a}	0.15^{ac} ± 0.01	0.17^{ab} ± 0.09	0.52^{a} ± 0.24	0.53^{ac} ± 0.14	2.09^{c} ± 0.31
	EO2	ND^{a}	ND^{a}	1.32^{ad} ± 0.15	1.56^{c} ± 0.22	1.42^{b} ± 0.30	1.85^{c} ± 0.68	2.75^{ac} ± 0.40
CAD	C	22.05^{a} ± 3.56	34.06^{a} ± 5.03	50.24^{a} ± 8.09	70.72^{a} ± 6.75	91.82^{a} ± 6.09	262.40^{a} ± 17.90	348.11^{a} ± 19.94
	A	ND^{b}	ND^{b}	ND^{b}	ND^{b}	ND^{b}	ND^{b}	ND^{b}
	EO1	20.05^{a} ± 3.69	33.13^{a} ± 4.57	45.08^{a} ± 2.95	51.71^{c} ± 7.26	91.63^{a} ± 3.51	159.31^{c} ± 25.39	227.29^{c} ± 11.16
	EO2	17.04^{a} ± 1.85	29.59^{a} ± 5.27	44.97^{a} ± 5.99	45.06^{c} ± 6.88	87.59^{a} ± 7.30	125.70^{c} ± 10.18	131.29^{d} ± 13.00
PUT	C	21.71^{a} ± 3.06	22.85^{a} ± 3.98	25.37^{a} ± 4.83	62.14^{a} ± 4.95	86.68^{a} ± 7.66	111.69^{a} ± 5.97	166.51^{a} ± 11.26
	A	13.02^{b} ± 1.43	14.81^{b} ± 1.54	19.83^{b} ± 0.95	22.09^{b} ± 2.76	23.59^{b} ± 2.27	33.27^{b} ± 4.48	29.04^{b} ± 2.30
	EO1	19.39^{ac} ± 2.07	24.25^{a} ± 4.74	22.94^{ab} ± 3.31	43.44^{c} ± 7.05	88.20^{c} ± 3.89	97.50^{c} ± 6.88	134.52^{c} ± 13.67
	EO2	16.03^{c} ± 3.80	21.84^{a} ± 3.19	22.98^{ab} ± 3.10	38.57^{c} ± 3.18	71.34^{d} ± 7.45	88.87^{d} ± 4.40	109.70^{d} ± 12.98

Means ± S.D.; n = 3; ND = not detected. Values are the mean of three replications ± standard deviation. Means in same column with different letters are significantly different ($p < 0.05$).

other biogenic amines. The highest content of putrescine (mg/kg) was 21.71, which increased to 166.51, 29.04, 134.52 and 109.70 in samples from groups C, A, EO1 and EO2, respectively, after 18 days of storage at 4 °C. The mean values of cadaverine and putrescine were highest in control samples throughout the 18 days, followed by EO1 and EO2 ($p < 0.05$). For case of samples from group A, cadaverine remained undetectable until the last day of storage. The data indicate that *Carum copticum* (0.5% and 1%) decreased the formation of biogenic amines, even though its antimicrobial effects were not observed at these concentrations. Özogul, Öztekin, and Kulawik (2017) treated anchovy with 1% lavender and lemon balm ethanol extract and reported the same results found by Houicher, Kuley, Özogul, and Bendeddouche (2015), who treated sardine with 1% mint and artemisia extract. This may be attributed to the presence of high concentrations of phenolic compounds in *Carum copticum,* e.g. thymol, ρ-cymene and γ-terpinene (Oroojalian et al., 2010). Hosseini et al. (2013) suggested a maximum average value of 20 mg/kg cadaverine for acceptability of fish flesh. Therefore, the putrescine values in A samples reached the maximum level after 9 days, but this phenomenon occurred on day 3 for EO1 and EO2, and C exceeded the set limit at the beginning of storage period (day 0).

4. Conclusions

Microbiological and biochemical analyses of common carp fillets stored at 4 °C under four different conditions were conducted, and the outcomes showed that a retardation of microbial growth was possible with lactic acid treatment. Although such treatment extended the shelf-life of samples from group A, it promoted lipid oxidation, whereas samples from groups EO1 and EO2 demonstrated an inhibition effect on the increase in TBARS values. Samples from EO1 and EO2 had no significant antimicrobial proprieties, but they had a significantly reduced formation of biogenic amines and lactic acid. Histamine production in common carp fillets stored at 4 °C was low in all groups, and it does not present a major risk for public health. The present study was limited to comparing *Carum copticum* and lactic acid treatment of common carp fillets and we suggest that the combined effect of *Carum copticum* and organic acids (such as lactic acid, citric acid) should be evaluated in future studies.

Declarations of interest

None.

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