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ScienceDirect
Food Chemistry 101 (2007) 1492–1498
Food Chemistry
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Effect of treatment with electrolyzed NaCl solutions and essential oil compounds on the proximate composition, amino acid and fatty acid composition of carp fillets

Barakat S.M. Mahmoud [a,*], Y. Kawai [b], K. Yamazaki [b], K. Miyashita [a], T. Suzuki [c]

[a] Laboratory of Bioresources Chemistry, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato, Hakodate 041-8611, Japan
[b] Laboratory of Marine Food Science, Graduate School of Fisheries Science, Hokkaido University, 3-1-1, Minato, Hakodate 041-8611, Japan
[c] Laboratory of Photo-biology, Graduate School for Creation of New Photonics Industries, Hamamatsu 431-1202, Japan

Received 8 August 2005; accepted 2 March 2006

Abstract

This investigation was undertaken to evaluate the effect of treatment with electrolyzed NaCl solutions and 1% essential oil (0.5% carvacrol + 0.5% thymol) on the proximate composition and nutritional components (amino acids and fatty acids) of carp fillets at room temperature (25 °C). Carp fillet samples were treated with anodic electrolyzed NaCl solution [EW (+)], cathodic electrolyzed NaCl solution [EW (−)] followed by EW (+) [EW (−)/EW (+)], 1% essential oil (0.5% carvacrol + 0.5% thymol) [1% (Cv + Ty)], EW (+) followed by 1% (Cv + Ty) [EW (+)/1% (Cv + Ty)] and EW (−) followed by EW (+) and finally with 1% (Cv + Ty) [EW (−)/EW (+)/1% (Cv + Ty)]. Proximate composition, SDS–PAGE, amino acid composition, digestibility and fatty acid composition were used to determine the changes in carp fillet composition. Moisture, total lipid, total protein, ash and carbohydrate contents of the carp fillets were approximately 76%, 3.9%, 17.5%, 1.0% and 0.40%, respectively. The dominant amino acid was glutamic acid, and the composition ranged from 14.2 to 14.5 mol%. Protein digestibility of the carp fillets was approximately 85%. Oleic acid was the major monounsaturated acid in the carp fillets (41.0–41.9%). These results show that our method of fish preservation, using electrolyzed NaCl solutions and 1% (Cv + Ty), did not affect the quality (nutritional components) of carp fillets, and could be a good alternative to synthetic preservatives routinely used in the food industry.

Keywords: Amino acids; Anodic solution EW (+); Carvacrol (Cv); Cathodic solution EW (−); Carp protein; Digestibility; Electrolyzed NaCl solutions (EW); Fatty acids; Thymol (Ty)

1. Introduction

Fish is an excellent source of high quality protein that contains sufficient amounts of most of the essential amino acids required in the human diet. Proteins are important in food processing and food products because they possess many functional properties (Sze-Tao & Sathe, 2000). The nutritive value of fish protein is very important in consumer satisfaction (Schwarz, Kirchgessner, & Deuringer, 1998).

Fish is also high in polyunsaturated fatty acids [ω-3 fatty acids, eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids], which play an important role in human health and nutrition. These fatty acids are considered to be essential because they cannot be synthesized in the human body and must be acquired through the diet (Simopoulos, 1991). The polyunsaturated fatty acids in fish have many beneficial effects on health, such as their ability to lower serum cholesterol (Simopoulos, 1991), blood pressure (Dyerberg, 1986), the risk of stroke (Simopoulos, 1991), serum triacylglycerol levels and insulin resistance and they also modulate glucose metabolism (Aro, Larmo, Backman, Kallio, & Tahvonen, 2005; Branden & Carroll,

* Corresponding author. Tel.: + 81 138 40 5565/5564; fax: +81 138 40 5573.
E-mail address: barakatsmm@yahoo.com (B.S.M. Mahmoud).

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doi:10.1016/j.foodchem.2006.03.057

1986; Li, Bode, Drummond, & Sinclair, 2003). In addition, fish oil is an important source of fat-soluble vitamins (Holik & Vitamin, 1994). Consequently, consumption of seafood is encouraged because of the possible health benefits, however, fish is highly susceptible to spoilage, which can be caused by both microbial spoilage and chemical deterioration. Natural and synthetic agents can control the deterioration of fish (Cho, Miyashita, Miyazawa, Fujimoto, & Kaneda, 1987; Gram & Dalgaard, 2002; Lindley, 1998; Shahidi, Wanasundra, & Brunet, 1994).

In the last decade, several investigators have reported using electrolyzed NaCl solutions or essential oil compounds as natural food preservatives. In our previous studies, electrolyzed NaCl solutions and/or 1% (Cv + Ty) had very good antioxidant and antimicrobial effects on carp fillets under many different conditions (Mahmoud et al., 2004a, 2004b; Mahmoud et al., 2005; Mahmoud et al., 2006). However, the nutritive value of fish can be affected by these treatments and this influences the quality of fish. The chemical composition and nutritional components of fish are extremely important because they influence consumer acceptance of food (Morzel, Verrez-Bagnis, Arendt, & Fleurence, 2000; Okland, Stoknes, Remme, Kjerstad, & Synnes, 2005).

Electrolyzed acidic solution EW (+), which contains hypochlorous acid, and electrolyzed alkaline solution EW (−), which contains hypochlorite ion, may denature proteins and affect the fatty acid content (Estrela et al., 2002; Tagawa et al., 2000).

The effect of electrolyzed NaCl solutions and essential oil compounds on the composition of fish materials has never been reported. Thus, the aim of the present study was to evaluate the effect of treatment with electrolyzed NaCl solutions and 1% (carvacrol + thymol) on the proximate composition and nutritional components of carp fillets as a new technology in food preservation.

2. Materials and methods

2.1. Carp fish

Healthy common carp (*Cyprinus carpio*) with an average weight of 2.0 kg were obtained from Miyazaki carp Aquaculture (Hakodate, Japan). Gutting and skinless filleting were performed immediately after the fish arrived in the laboratory. The fillets were subsequently washed with tap water and stored at −70 °C prior to use.

2.2. Chemicals

Carvacrol and thymol (purity 98%, $C_{10}H_{14}O$, FW 150.22) were obtained from KANTO Chemical Reagent Co., Ltd. (Tokyo, Japan).

2.3. Preparation of electrolyzed NaCl solutions

Electrolyzed NaCl solutions were prepared using a two-compartment batch-scale electrolysis apparatus (Super Oxseed Labo, Aoi Electronic Corp., Shizuoka, Japan). A 0.1% concentration of NaCl was dissolved in deionised water. The voltage was automatically maintained between 11 and 12 V of direct current. After 10 min of electrolysis, the anodic solution, EW (+), with a pH of 2.22 ± 0.03, +1137 mV (ORP) and 40.8 ± 0.05 ppm of available chlorine, and cathodic solution, EW (−), with a pH of 11.6 ± 0.07 and −885 mV (ORP), were prepared in the anode and cathode compartments, respectively. Both solutions were prepared immediately before use. The available chlorine concentration was measured by electrotitration using an available-chlorine meter (type HC-30, Central Kagaku Co. Inc., Tokyo, Japan). The oxidation/reduction potential and pH were measured using an ORP tester (ML-300; SUDO, Tokyo, Japan) and a pH meter (D-14; Horiba, Tokyo, Japan), respectively.

2.4. Treatment of carp fillets

Six samples of skinless carp fillets were used to assess the effects of EW solutions and/or 1% (0.5% Cv + 0.5% Ty) compounds on the chemical composition. Skinless carp fillets were prepared from different carp fish. The samples were treated by dipping them for 15 min in one of the following: 1, a 100-fold volume of sterile 0.2% agar solution (as a control); 2, EW (+); 3, EW (−) followed by EW (+) [EW (−)/EW (+)]; 4, 1% (carvacrol + thymol) [1% (Cv + Ty)]; 5, EW (+) followed by 1% (C + T) [EW (+)/1%Cv + Ty]; or 6, EW (−)/EW (+), followed by 1% (Cv + Ty) [EW (−)/EW (+)/1% (Cv + Ty)]. Treatments were carried out in a sterile 3-l flask with gentle shaking (100 rpm) using a multi-shaker (MMS, Tokyo Rikakikai, Co., Ltd., Tokyo, Japan) at room temperature (25 °C). After treatment, samples were left to drip for 1 min before the analyses were performed.

2.5. Proximate composition analysis

Each treated sample was analyzed for its proximate composition (moisture content, crude protein, crude lipid and crude ash) by the standard method of the Association of Official Analytical Chemists (AOAC, 1995), and carbohydrate content was calculated as the difference between 100% and the combined % of moisture, ash, crude protein and total lipid.

2.6. Sodium dodecylsulfate-polyacrylamide gel electrophoresis (SDS–PAGE)

Samples (5 g) of carp fillets were homogenized with 50 ml of distilled water for 2 min. The dispersed samples were then immediately mixed with the sample buffer [1% SDS, 50 mM Tris–HCl buffer, pH 6.8, 20% glycerol and 2% β-mercaptoethanol] at a ratio of 1:1. The mixture was heated at 100 °C for 2 min, cooled in ice and centrifuged at 10,000 rpm for 10 min at 2–5 °C. The clear supernatant

Table 1
Proximate composition of treated carp fillets

Subjects	Control	EW (+)	EW (−)/EW (+)	1% (C + T)	EW (+)/1% (C + T)	EW (−)/EW (+)/1% (C + T)
Moisture (%)	76.63 ± 0.29	76.91 ± 0.37	76.71 ± 0.17	76.24 ± 0.49	76.93 ± 0.12	76.55 ± 0.01
Lipids (%)	3.97 ± 0.13	3.93 ± 0.11	3.97 ± 0.13	3.98 ± 0.13	3.97 ± 0.13	3.94 ± 0.13
Protein (%)	17.9 ± 0.48	17.7 ± 0.44	17.8 ± 0.24	18.1 ± 0.30	17.6 ± 0.85	18.0 ± 1.21
Ash (%)	1.09 ± 0.12	1.00 ± 0.98	1.08 ± 0.29	1.17 ± 0.22	1.03 ± 0.12	1.09 ± 0.20
Carbohydrate (%)	0.41 ± 0.63	0.46 ± 0.19	0.44 ± 0.74	0.51 ± 0.39	0.47 ± 0.56	0.42 ± 1.26

No significant differences between samples were detected ($p > 0.05$).

was collected for analysis by electrophoresis. Protein concentration was determined by the method of Lowry, Rosenbrough, Farr, and Randall (1951).

SDS–PAGE was performed according to the method of Laemmli (1970), using 12.5% polyacrylamide gels and a small gel electrophoresis unit (Mini PAGE Chamber AE-6530M, Atto Co., Tokyo, Japan). After electrophoresis, proteins were stained with Coomassie Brillant Blue R-250.

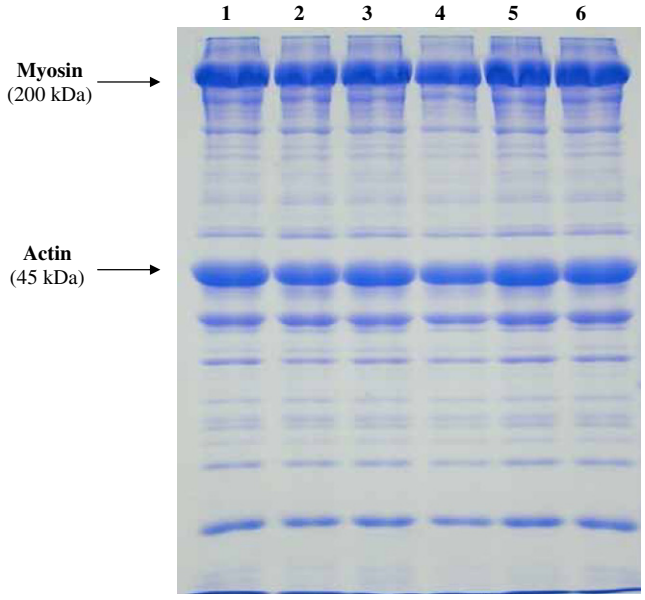

Fig. 1. SDS–PAGE analysis of treated carp fillet proteins with: 1, control; 2, EW (+); 3, EW (−)/EW (+); 4, 1% (Cv + Ty); 5, EW (+)/1% (Cv + Ty); 6, EW (−)/EW (+)/1% (Cv + Ty).

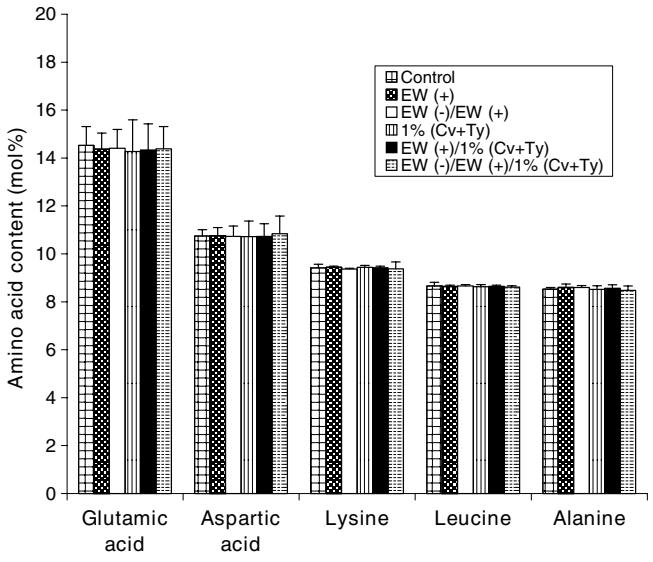

Fig. 2. The dominant amino acid composition of carp fillet proteins.

Table 2
Effect of treatment with electrolyzed NaCl solutions and essential oil compounds on the amino acid composition of carp fillets (mol%)

Amino acid	Control	EW (+)	EW (−)/EW (+)	1% (Cv + Ty)	EW (+)/1% (Cv + Ty)	EW (+)/EW (+)/1% (Cv + Ty)
Ala	8.53 ± 0.07	8.60 ± 0.14	8.60 ± 0.08	8.52 ± 0.05	8.56 ± 0.15	8.48 ± 0.18
Arg	4.95 ± 0.06	4.86 ± 0.03	4.83 ± 0.06	4.87 ± 0.11	4.88 ± 0.10	4.84 ± 0.03
Asp	10.74 ± 0.27	10.75 ± 0.35	10.73 ± 0.43	10.72 ± 0.65	10.73 ± 0.53	10.84 ± 0.74
Cys	0.01 ± 0.02	0.01 ± 0.01	0.01 ± 0.03	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.02
Glu	14.53 ± 0.78	14.37 ± 0.47	14.40 ± 0.49	14.27 ± 1.32	14.33 ± 1.09	14.38 ± 0.92
Gly	6.71 ± 0.45	7.74 ± 0.28	6.71 ± 0.52	6.65 ± 0.69	6.75 ± 0.68	6.78 ± 0.61
His	2.06 ± 0.18	2.11 ± 0.13	2.14 ± 0.13	2.20 ± 0.09	2.13 ± 0.06	2.18 ± 0.01
Ile	4.55 ± 0.05	4.53 ± 0.08	4.47 ± 0.01	4.59 ± 0.14	4.53 ± 0.14	4.51 ± 0.13
Leu	8.66 ± 0.15	8.64 ± 0.05	8.66 ± 0.06	8.63 ± 0.09	8.65 ± 0.05	8.61 ± 0.06
Lys	9.41 ± 0.16	9.44 ± 0.05	9.37 ± 0.03	9.44 ± 0.08	9.42 ± 0.07	9.38 ± 0.28
Met	2.76 ± 0.30	2.74 ± 0.31	2.72 ± 0.34	2.69 ± 0.33	2.73 ± 0.39	2.70 ± 0.37
Phe	3.33 ± 0.21	3.45 ± 0.23	3.44 ± 0.29	3.47 ± 0.35	3.42 ± 0.33	3.40 ± 0.16
Pro	4.49 ± 0.08	4.45 ± 0.30	4.51 ± 0.22	4.56 ± 0.23	4.52 ± 0.42	4.50 ± 0.35
Ser	5.35 ± 0.06	5.38 ± 0.01	5.41 ± 0.04	5.38 ± 0.02	5.38 ± 0.07	5.49 ± 0.18
Thr	5.18 ± 0.05	5.17 ± 0.06	5.18 ± 0.05	5.24 ± 0.04	5.19 ± 0.08	5.18 ± 0.01
Trp	0.72 ± 0.03	0.75 ± 0.04	0.80 ± 0.07	0.75 ± 0.08	0.75 ± 0.09	0.71 ± 0.06
Tyr	2.78 ± 0.02	2.74 ± 0.07	2.75 ± 0.08	2.73 ± 0.10	2.75 ± 0.13	2.77 ± 0.03
Val	5.24 ± 0.19	5.27 ± 0.04	5.27 ± 0.23	5.28 ± 0.25	5.27 ± 0.09	5.21 ± 0.09

No significant differences between samples were detected ($p > 0.05$).

2.7. Amino acid analysis

Treated carp fillets (5 g) were homogenized with 50 ml of ethanol (80%) using an ACF Homogenizer (Nippon Seiki) for 2 min and then filtered under vacuum. This was repeated three times. The residual samples were washed with diethyl ether and dried at room temperature before they were hydrolyzed in 3 N mercaptoethane sulfonic acid at 110 °C for 22 h. The hydrolyzed samples (100 μl) were injected into an amino acid analyzer (JLC/500V, JEOL, LTD, Tokyo, Japan) using *n*-leucine as an internal standard.

2.8. In vitro protein digestibility

Samples were dissolved in distilled water to give a 50 ml aqueous protein mixture (6.25 mg protein/ml). Samples were then adjusted to pH 8.0 with 0.1 N HCl and/or NaOH, while stirring in a water bath maintained at 37 ± 2 °C. A multi-enzyme solution (1.6 mg trypsin, 3.1 mg chymotrypsin and 1.3 mg peptidase/ml, obtained from Sigma–Aldrich, St. Louis, MO) was maintained in an ice bath and adjusted to pH 8.0 with 0.1 N HCl and/or NaOH. Five milliliters of the multienzyme solution were added to 50 ml of the protein suspension, while it was stirred at 37 ± 2 °C. pH was recorded automatically over a 10 min period, using a recording pH meter. In vitro digestibility was calculated using the following regression equation: digestibility (%) = 210.46 − 18.10 × pH (at 10 min) (Hsu, Vaak, Saterlee, & Miller, 1977).

2.9. Fatty acid analysis

Fatty acid methylesters of carp fillet lipids were prepared according to Hosokawa, Shimatani, Kanada, Inoue, and Takahashi (2000). Two to three milligrams of carp extracted oil (extracted using the method of Folch, Lees, & Sloane Stanley, 1957) were dissolved in 1.0 ml of *n*-hexane, before the addition of 0.2 ml of methanolic 2 N NaOH solution. After vortexing for 10 s, the mixture was kept at 50 °C for 30 s, before the addition of 0.2 ml of the solution containing methanolic acid/HCl and mixed again for 60 s. The mixture was then centrifuged at 3000 rpm for 5 min. The *n*-hexane layer was collected and dried using N_2, and a further 100 μl of *n*-hexane were added to the dried sample. One microliter of this solution was analyzed by gas chromatography using a Shimadzu GC-14B (Shimadzu Seisakusho Co., Ltd., Kyoto, Japan) equipped with a flame-ionization detector and a capillary column [Omegawax 320 (30 m × 0.32 mm, i.d.), Supelco Inc., Bellefonte PA, USA].

2.10. Statistical analysis

For each treatment or evaluation, analyses were repeated three times, data were pooled and the mean value and standard deviation were determined. Differences between samples were determined by Student's *t* test and were considered to be significant when $p \leqslant 0.05$ (Steel & Torrie, 1980).

3. Results and discussion

3.1. Proximate composition

The proximate compositions of treated carp fillets with EW (+), EW (−)/EW (+), 1% (Cv + Ty), EW (+)/1% (Cv + Ty) and EW (−)/EW (+)/1% (Cv + Ty) are shown in Table 1. The moisture content was approximately 76% for all samples. The content was similar to those reported by Chatakondi et al. (1995), Geri, Poli, Gualtieri, Lupi, and Parisi (1995) and Stolle et al. (1994) who found that the water content of fresh common carp fillets ranged from 59% to 84%.

The fat content was approximately 3.90% of the percentage wet weight for all samples. These results are in agreement with those reported by Chatakondi et al. (1995), however, they are lower than the results of Schwarz et al. (1998) and higher than the results of Geri et al. (1995). The differences can be explained by the known seasonal and geographical variation of the fat content in fish (Abd-Rahman, Huah, Nassan, & Daud, 1994).

The protein content of the carp fillets ranged between 17.6 and 18.1, which is in good agreement with values obtained by Chatakondi et al. (1995), Geri et al. (1995) and Stolle et al. (1994). The ash content of the carp fillets was about 1.0%, which is within the range reported by Chatakondi et al. (1995) and Geri et al. (1995). The carbohydrate content of the carp fillets ranged from 0.41% to 0.51%.

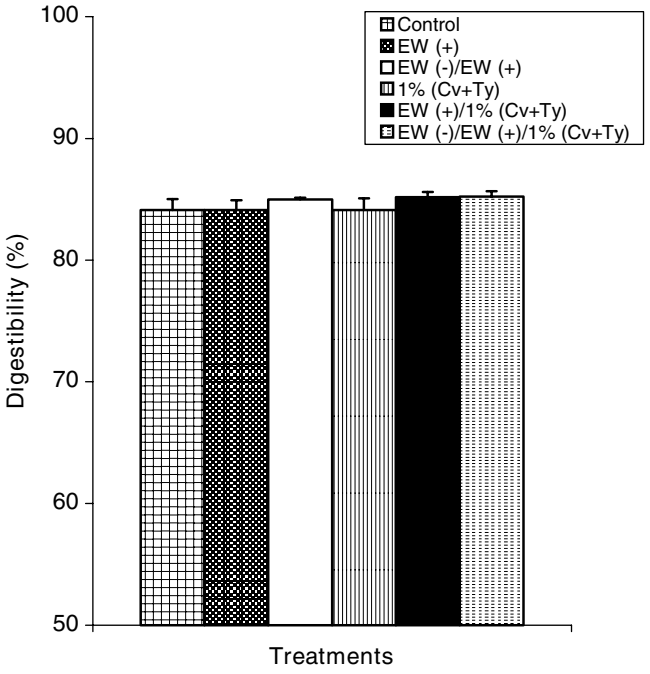

Fig. 3. Effect of treatment with: 1, control; 2, EW (+); 3, EW (−)/EW (+); 4, 1% (Cv + Ty); 5, EW (+)/1% (Cv + Ty); 6, EW (−)/EW (+)/1% (Cv + Ty) on the digestibility of carp fillets.

No significant differences in moisture, lipids, protein, ash and carbohydrate were detected among the samples, indicating that the proximate composition of the carp fillets was not affected by treatment with electrolyzed NaCl solutions and/or 1% (Cv + Ty).

3.2. SDS–PAGE

SDS–PAGE was used to measure the quantity of eluted proteins in the carp fillets, as shown in Fig. 1. Intensities of the myosin heavy chain (200 kDa) and the actin band (45 kDa) were analyzed between the samples and no significant differences were observed. These results indicate that the 15 min dipping in EW (+) (pH 2.22) did not decompose the protein in the carp fillets.

3.3. Amino acid composition

The amino acid profile is very important when considering the nutritive quality of fish (Okland et al., 2005). To ensure that treatments of EW (+), EW (−)/EW (+), 1% (Cv + Ty), EW (+)/1% (Cv + Ty) and EW (−)/EW (+)/1% (Cv + Ty) had no decomposition effect on the carp fillets, the amino acid composition were analyzed. The means and their associated standard deviations are expressed as mol% (Table 2). No significant differences ($p > 0.05$) among the samples were detected. The dominant amino acid (Fig. 2) was glutamic acid, which ranged from 14.2 to 14.5 mol%. Relatively high amounts of aspartic acid (10.7–10.8 mol%), lysine (9.37–9.44 mol%), leucine (8.61–8.66 mol%) and alanine (8.48–8.60 mol%) were observed. These results are in agreement with those reported by Chatakondi et al. (1995).

3.4. Digestibility

The digestibility of protein is the primary determinant of the availability of its amino acids (Hsu et al., 1977). The digestibility of treated carp fillets was approximately 85% (Fig. 3) and there were no significant differences among the samples, including the control sample. Fish muscle is easy to digest (Yanes, Ballester, & Monckeberg, 1976) and the low value of the in vitro digestibility of carp fillets is in agreement with Moughan (1999) who reported that the in vitro digestible protein value is always lower than that obtained from an in vivo assay.

Table 3
Fatty acid composition of the total lipids in treated common carp fillets

Fatty acids	Control	EW (+)	EW (−)/EW (+)	1% (Cv + Ty)	EW (+)/1% (Cv + Ty)	EW (+)/EW (+)/1% (Cv + Ty)
14:0	1.87 ± 0.06	1.76 ± 0.15	1.89 ± 0.40	1.88 ± 0.05	1.92 ± 0.18	1.82 ± 0.07
15:0	0.26 ± 0.01	0.23 ± 0.02	0.25 ± 0.02	0.24 ± 0.03	0.25 ± 0.04	0.25 ± 0.02
16:0	16.32 ± 0.81	16.79 ± 0.74	17.43 ± 0.73	16.66 ± 0.37	16.63 ± 0.56	16.77 ± 0.32
16:1*n* − 7	7.0 ± 1.10	6.74 ± 1.30	6.66 ± 1.40	6.70 ± 1.24	6.83 ± 1.46	6.79 ± 1.48
16:2*n* − 4	0.36 ± 0.06	0.30 ± 0.03	0.36 ± 0.09	0.34 ± 0.07	0.34 ± 0.07	0.36 ± 0.08
16:3*n* − 4	0.44 ± 0.03	0.42 ± 0.06	0.46 ± 0.02	0.44 ± 0.03	0.45 ± 0.04	0.47 ± 0.07
18:0	4.05 ± 0.40	4.37 ± 1.05	3.96 ± 0.32	3.84 ± 0.39	3.76 ± 0.39	3.96 ± 0.71
18:1*n* − 9	41.03 ± 0.17	41.5 ± 0.31	41.02 ± 0.34	41.29 ± 0.34	41.69 ± 0.35	41.92 ± 0.11
18:1*n* − 7	3.45 ± 0.22	3.28 ± 0.23	3.46 ± 0.23	3.26 ± 0.12	3.43 ± 0.12	3.27 ± 0.10
18:1*n* − 5	0.26 ± 0.01	0.25 ± 0.01	0.26 ± 0.01	0.27 ± 0.04	0.26 ± 0.02	0.26 ± 0.06
18:2*n* − 6	9.66 ± 0.72	9.69 ± 0.39	9.33 ± 0.77	9.69 ± 0.94	9.65 ± 0.94	9.15 ± 0.42
19:0	0.13 ± 0.06	0.13 ± 0.07	0.14 ± 0.06	0.14 ± 0.06	0.13 ± 0.07	0.13 ± 0.05
18:3*n* − 3	0.87 ± 0.03	0.85 ± 0.09	0.84 ± 0.14	0.87 ± 0.11	0.87 ± 0.12	0.86 ± 0.08
18:4*n* − 3	0.19 ± 0.01	0.19 ± 0.01	0.19 ± 0.01	0.19 ± 0.01	0.19 ± 0.02	0.19 ± 0.03
20:0	0.11 ± 0.03	0.12 ± 0.09	0.12 ± 0.05	0.12 ± 0.08	0.11 ± 0.07	0.11 ± 0.4
20:1*n* − 11	0.56 ± 0.07	0.51 ± 0.04	0.58 ± 0.08	0.57 ± 0.10	0.59 ± 0.08	0.62 ± 0.05
20:1*n* − 9	2.78 ± 0.49	2.74 ± 0.24	2.55 ± 0.05	2.76 ± 0.24	2.73 ± 0.22	2.89 ± 0.47
20:1*n* − 7	0.18 ± 0.05	0.15 ± 0.05	0.17 ± 0.03	0.17 ± 0.04	0.17 ± 0.04	0.18 ± 0.03
20:2*n* − 6	0.39 ± 0.07	0.37 ± 0.13	0.37 ± 0.07	0.39 ± 0.13	0.38 ± 0.13	0.39 ± 0.11
20:3*n* − 6	0.28 ± 0.11	0.31 ± 0.30	0.29 ± 0.09	0.28 ± 0.21	0.25 ± 0.15	0.27 ± 0.13
20:4*n* − 6	0.50 ± 0.23	0.49 ± 0.02	0.53 ± 0.03	0.48 ± 0.05	0.51 ± 0.03	0.51 ± 0.04
20:3*n* − 3	0.07 ± 0.01	0.08 ± 0.01	0.07 ± 0.02	0.08 ± 0.02	0.09 ± 0.02	0.08 ± 0.01
20:4*n* − 3	0.31 ± 0.02	0.30 ± 0.04	0.30 ± 0.04	0.31 ± 0.07	0.31 ± 0.08	0.30 ± 0.06
20:5*n* − 3	2.09 ± 0.40	2.01 ± 0.89	2.25 ± 0.34	2.10 ± 0.67	2.02 ± 0.69	2.01 ± 0.43
22:1*n* − 11, 13	0.46 ± 0.11	0.42 ± 0.03	0.41 ± 0.10	0.46 ± 0.21	0.45 ± 0.21	0.44 ± 0.18
22:1*n* − 9	0.12 ± 0.02	0.12 ± 0.02	0.11 ± 0.01	0.12 ± 0.05	0.12 ± 0.05	0.12 ± 0.04
21:5*n* − 3	0.09 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.10 ± 0.01	0.09 ± 0.02	0.09 ± 0.01
22:5*n* − 6	0.21 ± 0.08	0.19 ± 0.14	0.19 ± 0.14	0.23 ± 0.07	0.21 ± 0.14	0.20 ± 0.13
22:5*n* − 3	0.85 ± 0.20	0.91 ± 0.59	0.87 ± 0.16	0.97 ± 0.39	0.88 ± 0.51	0.84 ± 0.27
22:6*n* − 3	4.99 ± 0.25	4.58 ± 0.16	4.76 ± 1.10	4.92 ± 0.68	4.60 ± 0.28	4.66 ± 0.18
24:1*n* − 9	0.12 ± 0.01	0.12 ± 0.01	0.10 ± 0.01	0.13 ± 0.03	0.09 ± 0.01	0.09 ± 0.02
Total SFA	22.74 ± 0.12	23.4 ± 0.19	23.79 ± 0.11	22.88 ± 08	22.8 ± 0.01	23.04 ± 0.17
Total UnSFA	77.26 ± 0.09	76.6 ± 0.16	76.21 ± 0.13	77.12 ± 0.15	77.2 ± 0.32	76.96 ± 0.11
Ratio S/UnS	0.29 ± 0.10	0.30 ± 0.12	0.31 ± 0.02	0.29 ± 0.09	0.29 ± 0.04	0.29 ± 0.11

No significant differences between samples were detected ($p > 0.05$).

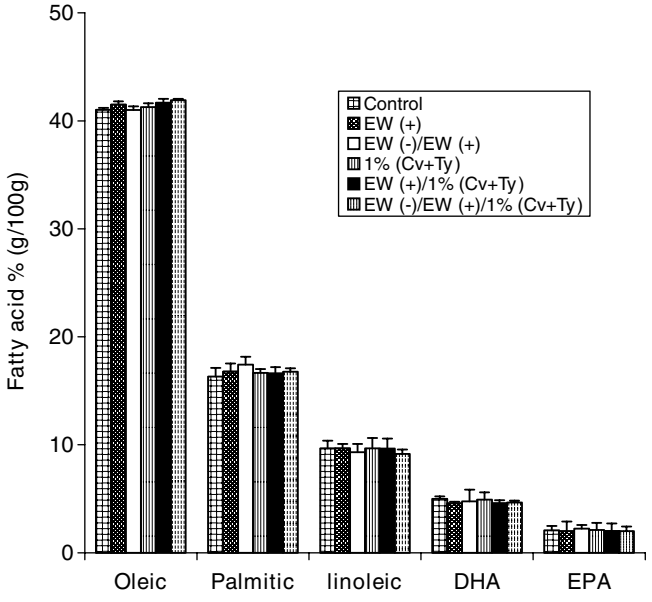

Fig. 4. The dominant fatty acid composition, and DHA and EPA composition of carp fillets.

3.5. Fatty acid content

The fatty acid content g/100 g of the total fatty acids in carp fillet oil are shown in Table 3. There are no significant differences in the fatty acid compositions among the samples after treatment with EW (+), EW (−)/EW (+), 1% (Cv + Ty), EW (+)/1% (Cv + Ty) and EW (−)/EW (+)/1% (Cv + Ty). Oleic acid was the major monounsaturated fatty acid in carp fillet oil, at 41.0–41.9%, followed by linoleic acid at 9.15–9.69%. As seen in Fig. 4, the amounts of DHA and EPA present in carp oil were 4.58–4.99% and 2.01–2.25%, respectively. The total fatty acid content of the carp fillets was 77.3% unsaturated fatty acid and 22.7% saturated fatty acid. The major saturated fatty acid was palmitic acid at 16.3–17.4% of the total fatty acids. These results are in agreement with those obtained by previous studies (Chatakondi et al., 1995; Rasoarahona, Barnathan, Bianchini, & Gaydou, 2004).

4. Conclusion

The proximate composition and nutritional components of carp fillets were not affected by treatment with electrolyzed NaCl solutions and essential oil compounds. These treatments could be used in fish preservation as a good alternative to artificial preservative agents.

Acknowledgement

The first author is grateful to the Ministry of Education, Science and Culture (MONBUKAGAKUSHO) for enabling the opportunity to study in Japan.

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