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Effects of pulsed electric field treatments on quality of peanut oil

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ABSTRACT

The effects of pulsed electric fields (PEF) treatment on physicochemical properties of peanut oil were investigated in this paper. Compositions of fatty acid, acid value (AV), peroxide value (PV), as well as carbonyl group value (CGV) of various PEF-treated peanut oil samples with different storage time were determined by GC/MS and AOCS standard methods. GC/MS analysis showed that little change of the oil composition was observed after PEF treatment. However, after being treated by various PEF treatments and stored at 40 °C for 100 days, the biggest increment of AV was 0.69 mg g^{-1}, which was lower than that of untreated peanut oil (0.79 mg g^{-1}). The PV significantly increased from 4.8 meq kg^{-1} untreated oil to 11.5 meq kg^{-1} PEF treated oil (50 kV cm^{-1}). And the increase extent of CGV of oil samples during the 100 d' storage period was decreased with increasing electric field strength. During the storage period, the differences of AV, PV, and CGV of PEF-treated sample during storage period were less than that of untreated oil, which implied that the PEF treatment could restrain the speed of lipid oxidation reaction thus extending the shelf-life of oil rich products.

1. Introduction

Lipids are considered as one of the essential nutriments, which play an important role on the physiological function for human beings. However, the quality of lipids is also affected by diverse physical and chemical factors such as oxygen, light, metal ions, external physical field, and so on. Oxidation, saponification, as well as rancidity are main deteriorations of high-lipids content foods, which result in loss of flavor, color and nutritive value and shorten the shelf-life of lipids products (Kanner, 1994). Therefore, the changes of physiochemical properties of lipids under various process and storage condition are of great importance for studying food quality as well as its storage property.

Compared to traditional thermal pasteurization, PEF technology is a non-thermal food preservation method, which inactivates most pathogenic or spoilage micro-organisms and has impact on enzyme activity, and minimizes the loss of taste, color, texture, nutrients, and heat labile functional components of foods (Ade-Omowaye, Angersbach, Taiwo, & Knorr, 2001; Jeyamkondan, Jayas, & Holley, 1999; Knorr & Angersbach, 1998; Knorr, Geulen, Grahl, & Sitzmann, 1994). PEF treatment can be a non-thermal processing alternative to traditional thermal pasteurization (Barbosa-Canovas, Pothakamury, Palou, & Swanson, 1998). Moreover, PEF has been successfully applied to deal with various liquid foods with low viscosity, such as milk, soymilk, pea soup, liquid egg and juices of orange, apple, grape, and carrot (Aguilar-Rosas, Ballinas-Casarrubias, Nevarez-Moorillon, Martin-Belloso, & Ortega-Rivas, 2007; Cortes, Esteve, & Frigola, 2008; Cortes, Esteve, & Rodrigo, 2006; Li, Chen, Liu, & Chen, 2008; Marselles-Fontanet & Martin-Belloso, 2007; Sampedro, Rivas, Rodrigo, Martinez, & Rodrigo, 2007; Torregrosa, Esteve, Frigola, & Cortes, 2006).

A number of published studies have indicated that different processing methods affect the physicochemical properties of lipid products (Chemat et al., 2004; Maranesi et al., 2005). Chemat et al. (2004) investigated that the flavor and composition of sunflower oil was deteriorated by ultrasound wave treatment under 20 kHz, 150 W for 0.5–2 min. After the treatment its peroxide value increased from 5.38 meq kg^{-1} to 6.33 meq kg^{-1}. Maranesi et al. (2005) reported that microwaved cooking modified the concentrations of some fatty acids in the cooked lean slightly but significantly compared to the uncooked samples. Some saturated fatty acids (SFA) increased significantly, namely myristic, pentadecanoic (C15:0) and palmitic acids, as well as the sum of transoctadecenoic acids (Σ C18:1 trans).

However, up to now, few research focusing on the effects of PEF on lipid products have been published. The aim of this study was to investigate the effects of PEF on physicochemical and storage properties of peanut oil.

2. Materials and methods

2.1. Materials

The peanut oil was purchased from a local grocery shop, produced by Jinlongyu Co., Shandong Province, 100% pure, food

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grade. All other reagents in this experiment were of analytical grade, purchased from Hui Shi Biochemical Reagents Co., Ltd. (Shanghai, China).

2.2. PEF system and treatments

The peanut oil was treated in a pilot scale, continuous PEF system (SCUT PEF team, the South China University of Technology, China). Throughout the study, a square-wave pulse was generated with pulse duration (τ) of 40 μs and pulse frequency (f) of 1008 Hz. The main advantage of the square-wave pulse was to deliver electrical energy at the maximum voltage during most of the pulse width. The treatment chamber consisted of two parallel copper plate electrodes and a tubular insulator body made of Teflon. By placing a perforated Teflon parallel to the planar electrode in the volume between the electrodes, it was able to enhance the electric field considerably in the openings of the Teflon. The diameter of the cylindrical treatment zone was 3.00 mm and the flow volume in the treatment chamber was 0.02 mL. The peanut oil samples were pumped (Watson Marlow 323E/D Pump, USA) to the treatment chamber to receive the PEF treatment. The flow rate of the suspension was calculated and controlled by a rotameter (Model FM-01, Ningbo Jiutian Meter Company, China). A digital oscilloscope monitored the voltage and the current of PEF treatments. The type K thermocouples were inserted in the inlet and outlet of each pair of chambers to measure the sample temperature. Throughout all experiments, the flow rate was set at 25 mL min^{-1}.

The peanut oils were pumped through the treatment chamber to subject the PEF treatment at 20 kV cm^{-1}, 30 kV cm^{-1}, 40 kV cm^{-1}, and 50 kV cm^{-1}, respectively. After the PEF treatment, the treated samples ($\leqslant$40 °C) were cooled spontaneously to room temperature, sealed in amber glass bottles (20 mL) and stored in dark room at 40 °C for 0, 1, 15, 30, 45, 60, 80 and 100 d, respectively. The untreated sample was used as reference.

2.3. Fatty acid analysis

Various oil samples were esterified according to the AOAC standard method (AOAC, 1990). Methyl esters of fatty acids (FA) were extracted with hexane and were analyzed by GC–MS (Hewlett–Packard computerized system consisting of a 5890 gas chromatograph coupled to a 5971 A mass spectrometer). GC–MS analyses were conducted under following conditions: carrier gas He; flow rate 1 mL min^{-1}; split 1:20; injection volume 0.1 μL; injection temperature 250 °C; oven temperature programmed from 60 to 220 °C at 4 °C/min and holding at 220 °C for 30 min; ionization mode used was electronic impact at 70 eV. Identification of the components was achieved from their retention indices, determined with reference to a homologous series of alkanes, and by a comparison of their mass spectral fragmentation patterns with those stored in the data bank (Wiley/NBS library) and in literature data.

2.4. Physicochemical properties analysis

Determination of each of the physicochemical parameters of the oil was carried out according to the analytical methods: acid value (GB/T 5530-1998, China), the number of milligrams of potassium hydroxide necessary to neutralize the free acids in 1 g of sample; peroxide value (AOCS Cd 8-53), expressed as mequiv of active oxygen/kg of oil; carbonyl group value (GB/T 5009.37-1996, China), the number of millimole of carbonyl group in 1 kg of oil sample. Analyses were performed at least three times and the mean values were reported.

3. Results and discussion

3.1. Effects of PEF on fatty acid composition

The composition and content of various peanut oil samples were presented in Tables 1 and 2. It was demonstrated that the

Table 1
Influence of PEF treatments on fatty acid composition of peanut oil (mg/100 mg).

	0 kV cm^{-1} 40 °C, 0 d	50 kV cm^{-1} 40 °C, 0 d	0 kV cm^{-1} 40 °C, 100 d	20 kV cm^{-1} 40 °C, 100 d	30 kV cm^{-1} 40 °C, 100 d	40 kV cm^{-1} 40 °C, 100 d	50 kV cm^{-1} 40 °C, 100 d
C16:0	10.0 ± 0.5[a]	10.3 ± 0.6	9.1 ± 0.5	9.2 ± 0.5	9.2 ± 0.5	9.6 ± 0.5	9.7 ± 0.6
C18:0	2.6 ± 0.3	2.8 ± 0.2	2.6 ± 0.2	2.6 ± 0.2	2.5 ± 0.1	2.7 ± 0.2	2.8 ± 0.2
C18:1	39.5 ± 2.1	38.4 ± 2.0	34.7 ± 2.4	34.7 ± 1.8	34.6 ± 2.0	36.7 ± 1.9	37.7 ± 2.0
C18:2	30.0 ± 1.5	29.4 ± 1.6	26.1 ± 1.5	26.1 ± 1.9	26.0 ± 1.5	27.0 ± 1.5	27.9 ± 1.5
C20:0	1.2 ± 0.1	1.2 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.2 ± 0.2	1.3 ± 0.1
C20:1	0.8 ± 0.1	0.7 ± 0.1	0.9 ± 0.1	0.7 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	0.9 ± 0.1
C22:0	2.3 ± 0.1	2.1 ± 0.2	2.1 ± 0.2	2.1 ± 0.1	2.0 ± 0.2	1.9 ± 0.1	2.0 ± 0.1
C24:0	2.0 ± 0.2	1.9 ± 0.2	1.5 ± 0.1	1.7 ± 0.2	2.0 ± 0.1	1.1 ± 0.1	1.2 ± 0.1

[a] All values represent the means ± standard deviation; n = 3.

Table 2
Changes of fatty acid content of peanut oil after PEF treatment (mg/100 mg).

	Saturated fatty acid (n = 0)	Monounsaturated fatty acid (n = 1)	Polyunsaturated fatty acid ($n \geqslant 2$)	(n = 0):(n = 1):($n \geqslant 2$)	Total unsaturated fatty acid content
0 kV cm^{-1} 40 °C, 0 d	18.1	40.3	30.00	1:2.23:1.65	70.3
20 kV cm^{-1} 40 °C, 0 d	18.2	40.2	29.9	1:2.21:1.64	70.1
30 kV cm^{-1} 40 °C, 0 d	18.2	40.2	29.9	1:2.21:1.64	70.1
40 kV cm^{-1} 40 °C, 0 d	18.3	40.0	29.7	1:2.19:1.63	69.7
50 kV cm^{-1} 40 °C, 0 d	18.5	39.2	29.4	1:2.12:1.59	68.6
0 kV cm^{-1} 40 °C, 100 d	16.4	35.6	26.1	1:2.17:1.59	61.7
20 kV cm^{-1} 40 °C, 100 d	16.7	35.4	26.1	1:2.12:1.56	61.5
30 kV cm^{-1} 40 °C, 100 d	16.8	35.4	26.0	1:2.11:1.55	61.4
40 kV cm^{-1} 40 °C, 100 d	16.5	37.5	27.0	1:2.28:1.64	64.5
50 kV cm^{-1} 40 °C, 100 d	16.9	38.5	27.9	1:2.28:1.65	66.4

Values are the means of triplicate.