



Designing of high voltage electric field for soybean and sunflower oil bleaching



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ABSTRACT

To the best of our knowledge, this work for the first time in the world carried out at the Tarbiat Modares University. In the present research, high voltage electric field (HVEF) method was utilized for bleaching of soybean and sunflower oil. For optimization of the bleaching process, the effect of different independent variables such as clay percentage (0.5–2%), voltage (0–24 kV), distance (8–12 mm), different numbers of cathode–anode (4–8) and inert-electrolyte (HCl; 0–50 mM) was studied. In order to compare the properties of the bleached samples using HVEF and control (industrial condition) bleaching methods, the indexes of Lovibond, Hunter lab, carotenoid, chlorophyll, bleaching efficiency (BE), peroxide (PV), tiobarbituric acid (TBA), free fatty acid (FFA), tocopherol, sterol and fatty acid composition were measured. According to the results, the BE value of HVEF technique in bleached soybean (88.35%) and sunflower oil (75.41%) were higher in comparison with the soybean (85.80%) and sunflower (58.14%) oils bleached using control method. Consequently, the HVEF bleaching method seems to be an alternative to the industrial method as it reduced clay percentage (50 and 66%), temperature (28% and 28%) and process time (35% and 35%) in soybean and sunflower oil bleaching, respectively.

Industrial relevance: High voltage electric field (HVEF) method for bleaching of soybean and sunflower oil was done, for the first time in the world to the based of our knowledge, and was optimized under different conditions including clay percentage (0.5–2%), voltage (0–24 kV), distance (8–12 mm) with different numbers of cathode–anode (0–8), inert electrolyte (HCl; 0–50 mM). HVEF could be an alternative for bleaching method in the oil industry; HVEF could reduce %clay, temperature and time consumption in oil industry with low energy consumption; HVEF could produce micro and Nano clay by pulsed corona and pulsed spark type systems.

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1. Introduction

A variety of activated clays are used for bleaching process. Acid activation of the bleaching clay was performed to enhance the clay mineral surface. It was used almost at the concentration of 2–5% at high temperatures (80–120 °C) for 20–40 min for bleaching process (Valenzuela Diaz & Souza Santos, 2001), which caused some disadvantages: formation of cyclic polymer, breakage of oxidation products, color fixation, and free fatty acid enhancement (Didi, Makhoukhi, Azzouz, & Villemin, 2009; Proctor & Brooks, 2005).

Generally, using of bleaching clay for refining of vegetable oils has led to several problems including: a) separation of the clay from oil is time consuming (Morgan, Shaw, Sidebottom, Soon, & Taylor, 1985), b) oil retention property of bleaching clay causes oil loss (Hussin, Aroua, & Wan Daud, 2011), c) environmental problems appears and in the land-fill disposal costs increases (Gunawan et al., 2010), d) residual acid in activated

bleaching clays can convert triacylglycerols to free fatty acid that leads to an increase in the acidity of oil (Taylor & Ungermann, 1991) and e) the clay cost is high. Therefore, numerous researches are attempting to reduce the bleaching clay because of the mentioned reasons (Hussin et al., 2011).

Bleaching is known as mass transfer process that involves the partial removal of the oil-soluble, non-triglyceride components and solids from the oil stream by filtration. Specifically, the non-triglyceride components in a liquid state are changed to a solid state by adsorption onto the surface of the solid bleaching earth particles which added to the oil stream (Proctor & Brooks, 2005).

The aims of this study were to use HVEF method for separation of pigments and other impurities of oil on the electrode surfaces in order to reduce clay, temperature and time in oil industry. In this research, HVEF method was used for the first time in the world for oil bleaching. Functional groups of oils including pigments (carotenoids, chlorophylls and pheophytin a, b, trace element, free fatty acid, peroxide and hydroperoxide compounds were polarized under HVEF condition which can migrate toward electrode surfaces. Different physico-chemical

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properties including color value, bleaching efficiency, carotenoid and chlorophyll concentration were evaluated to study the influence of HVEF bleaching of soybean and sunflower oil in comparison to the common industrial bleaching (control bleaching) method.

2. Material and methods

2.1. High voltage electric field treatment

HVEF treatments were performed using a continuous flow bench scale system (International Power Silicon Company, Iran). The treatment chamber is consisted of 4, 6 and 8 carbon electrodes (number of cathode–anode) which are connected as a parallel cathode plates and parallel anode plates (Fig. 1). Then, oil (100 ml in each chamber) was stirred using a magnetic stirrer at 65 °C. Dimension of each plate was $10 \times 2.5 \times 1 \text{ cm}^3$ which was separated by a space gap of 10 mm. Electrical current of 5 mA was applied as monopolar (DC). Industrial bleaching was accomplished at activated bentonite bleaching clay (2% for soybean oil and 1.5% for sunflower oil), temperature (90 °C), and time (30 min).

2.2. Color measurement

Color of oil sample was measured by a Lovibond 51/4 Tintometer model F using a glass cell with an optical path length of 10 mm. Also, Colorflex (Virginia, USA) was used to measure the color of the oil sample in the Hunter lab system by a 20-mm tube as the sample cell.

2.3. Determination of total chlorophyll and total carotenoid

The described method by Mínguez-Mosquera, Rejano-Navarro, Gandul-Rojas, Sánchez-Gómez, and Garrido-Fernández (1991) was used (with some modifications) to measure total chlorophyll and total carotenoid. Briefly, 7.5 g oil was dissolved in cyclohexane up to the final volume of 25 ml. Then, the chlorophyll and carotenoid concentration of the oil sample was spectrophotometrically measured by a UV–VIS Spectrophotometer (UV S-2100, Scinco, Seoul, South Korea) at 670 nm and 470 nm, respectively, according to the following equations:

$$\text{Chlorophyll } (\mu\text{g/kg}) = A_{670} \times 10^9 / 613 \times 100 \times d \quad (1)$$

$$\text{Carotenoid } (\text{mg/kg}) = A_{470} \times 10^6 / 2000 \times 100 \times d \quad (2)$$

A: absorbance.

d: spectrophotometric cell diameter (1 cm).

2.4. Identification of carotenoid profile

According to Breithaupt method, all types of carotenoids in the soybean and sunflower oil were identified by a UV–VIS Spectrophotometer (UV S-2100, Scinco, Seoul, South Korea) at the range of 300–800 nm (Breithaupt, 2004).

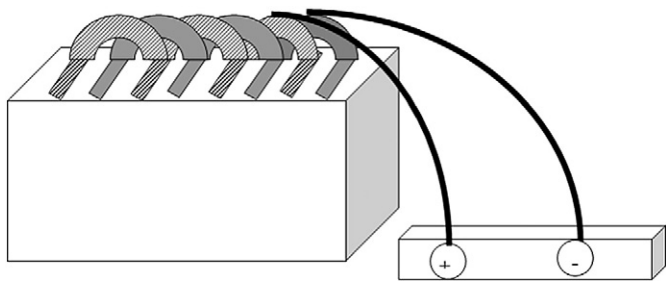


Fig. 1. The treatment chamber consists of carbon electrodes which are connected as a parallel cathode plates and parallel anode plates. 5 mA electrical current was applied as monopolar (DC).

2.5. Bleaching efficiency

The bleaching efficiency (BE) was determined by measuring the absorption of the bleached oil samples at 450 nm using UV–VIS Spectrophotometer (UV S-2100, Scinco, Seoul, South Korea), and the calculation was performed according to the following equation (Ajemba & Onukwuli, 2013):

$$\text{BE } (\%) = (A_{\text{unbleached}} - A_{\text{bleached}} / A_{\text{unbleached}}) \times 100 \quad (3)$$

where A is the absorbance of unbleached and bleached soybean oil at 450 nm.

2.6. Physico-chemical properties

Tiobarbituric acid (TBA) was assessed by the method described by Ali Rehab and El Anany (2012). Besides, free fatty acid (FFA) and peroxide value (PV) were determined by AOCS method, Ca 5a-40 and Cd 8-53, respectively (AOCS, 1996).

2.7. Determination of sterols

Sterols were measured using AOCS method Ce 7-87 (AOCS, 1996). The trimethylsilyl (TMS) derivatives of the sterols were prepared by mixing 100 μl each of bis (trimethylsilyl)-trifluoro-acetamide (BSTFA) + 1% trimethylchlorosilane (TMCS) and pyridine, and heating at 60 °C for 30–60 min. GC analysis was carried out on Agilent (Little Falls, DE, USA) gas chromatograph equipped with an FID, a split-splitless injector and a Supelco SPB-5 (30 m \times 0.25 mm i.d., 0.25 μm of film thickness), with a stationary phase of SPB-5 (Supelco, Inc. Bellefonte, PA). The velocity of the helium, as a carrier gas, was 20 cm/s. The chromatographic conditions were employed with injection in the split mode with a split flow: 25 ml/min, split ratio: 1:22; pressure at column head: 200 kPa; injector temperature: 295 °C; detector temperature: 300 °C; initial oven temperature: 265 °C; initial time: 35 min; final temperature: 300 °C; final time: 5 min; and injection volume: 1.0 μl . Peaks were identified by comparing the retention times of sterols with those of the standards. Quantification of all sterols was based on an internal standard method, using α -cholestanol with (5–750 mg).

2.8. Determination of tocopherols

The tocopherol composition of oil was measured based on the AOCS method Ce 8-89 (AOCS, 1996). Tocopherols were determined by HPLC Agilent Technologies L1200, normal phase silica column YMC-Pack SIL, (250 \times 46 mm i.d. and 5 μm particle size). The chromatographic system included a UV–Vis detector with detection at 292 nm. Separation of all tocopherols was based on isocratic elution when the solvent flow rate was maintained at 1 ml/min. The solvent system selected for tocopherol elution was acetonitrile/methanol/water (5:47.5:47.5 v/v). Prior to HPLC analysis, 2 g oil was diluted with 100 ml of hexane, filtered (0.45 mm nylon syringe filter) and 20 μl samples were injected. The isomers were identified by retention time, co-chromatography and UV–Vis absorption spectrum as compared to standards (α , β , γ and δ -tocopherol from, Calbiochem (purity $\geq 95\%$) was analyzed in the same conditions. The quantification was carried out by external calibration curves for α , β , γ and δ -tocopherol.

2.9. Determination of fatty acid composition

The fatty acid methyl esters (FAME) of soybean and sunflower oil were analyzed by gas chromatography. FAME was prepared by methylation of triacylglycerol, as described by Abedi, Sahari, Barzegar, and Azizi (2015). The FAME was analyzed using a Shimadzu 17 A (Kyoto, Japan) gas chromatograph equipped with a flame ionization detector and a fused silica capillary column (50 m \times 0.25 mm and 0.20 mm of

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