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Optimizing the extraction process of sesame seed's oil using response surface method on the industrial scale

Mohammad Rostami[a,1], Vahid Farzaneh[b,*,1], Abolfazl Boujmehrani[a], Morteza Mohammadi[c], Hamid Bakhshabadi[d]

[a] Edificio Member of the Board of Khorasan Cotton and Oil Seeds Company, Iran
[b] IBB/CGB, Institute for Biotechnology and Bioengineering/ Center of Genomics and Biotechnology- Faculty of Science and Technology- University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
[c] Department of Food Science and Technology, Azad University, Sabzevar Branch, Iran
[d] Department of Food Science and Technology, University of Agricultural Sciences and Natural Resources, Gorgan, Iran

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ABSTRACT

In the present study, some chemical parameters of remained oil contents of the pressed cakes obtained of local sesame seed's oil extraction and also from different stages of extraction process were determined. To measure these parameters of extracted oil, three diverse heating temperatures (75, 90 and 105 °C) with three states of moisture contents (4.5%, 5.5% and 6.5%) for output seeds were designed. Analysis's results of obtained data by response surface method demonstrated that an increase in given temperature, increases oil content in pressed cakes and also insoluble fine partial content of the final extracted oil, while decreases protein's content in the meals. Increasing moisture content of output seeds of heating cabinet, indicated decrease in oil content of the meals. According to the results of optimizing process, it can be stated, heating process by temperature 75 °C and moisture content of output seeds in confine of 6.3–6.5%, are high yielded combined parameters that may result oils with high quality and byproducts with the minimum remained oil content.

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1. Introduction

Sesame (*Sesamum indicum* L.) from Pedaliaceae, is a very common oil seed crop being cultivated in the tropical and high temperate regions of the world (Biabani and Pakniyat, 2008). This oil is main product of India, Sudan, China and Burma (60% of produced sesame oil in the world) (ElKhier et al., 2008). That is the most traditional edible oil crops which has been using in mankind cases and has widely been cultivated in Asia and Africa (Ali et al., 2007). This healthful product, with annual production of 760,000 million tons in 2003, had 12th rank as largest vegetable oil products used in the world, which is more higher in quantity than olive and safflower oils products (ElKhier et al., 2008). The most significant property of sesame oil is resistance to oxidative deterioration (Manley et al., 1974). Sesame seed oil has been using in a huge spectrum for cooking, bakery process and producing margarine. Also sesame seeds are used mainly for preparing tehina (sesame paste product similar to peanut butter) and Halva (a most public traditional food which is available on Iranian dishes) (Abou-Gharbia et al., 1997; Sankar et al., 2005). The analysis of sesame's composition cited that this worthy product is a very rich source of oil (44–58%), protein (18–25%) and carbohydrates (∼13.5%) (Kamal-Eldin and Appelqvist, 1994; Mohammed et al., 2011). Sesame seeds due to involving oil with high quantity and quality are named queen of the oil seeds for mankind usages (Brar, 2008).

The current mode of sesame seed oil extraction at the traditional level is briefly, (1) pounding the seeds in a mortar and (2) pouring hot water into the mortar causing the oil to float on the surface, from where it is skimmed off. This method of extraction is, however, very slow and low yielded (Majdi et al., 2007). Also oil can be produced by most natural methods, chemical materials or additives which are not used commonly. The finest oil extraction mode of sesame seeds is mechanical cold press (at a low temperature as such lower than 45 °C), which filtration of the fluid will improve the quality. Free fatty acid contents and peroxide values are common parameters for determination of the oils quality (ElKhier et al., 2008). The conventional process for sesame oil extraction includes: (1) cleaning, (2) dehulling, (3) roasting, (4) grinding and (5) oil extraction, respectively (Fukuda and

* Corresponding author. Tel.: +351 969 018 099.
E-mail address: Farzaneh1364@gmail.com (V. Farzaneh).
[1] These authors contributed equally to this work as first authors.

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Namiki, 1988). Roasting is a critical stage which influences color, composition, and organoleptic qualities of the extracted oils as well as oxidative stability (Yen and Shyu, 1989). In one study, observed results demonstrated that with increasing temperature given to canola seeds, non-triglyceride component contents and acidity of the oil were increased (Prior et al., 1991). Other similar study cited that antioxidative activities of defatted sesame meals, increased with an enhance in temperature of roasting (Jeong et al., 2004). Scientists expressed that increasing in stirring temperature, leads to oil with high acidified contents (Boselli et al., 2009). Enhancing in temperature of roasting and moisture content of seeds, diminish oil contents of the meals (Iezadikha et al., 2011). Zhang et al. applied RSM for optimization of Zanthoxylum Bungeanum seed oil transesterification to biodiesel interactions by using canon as a catalyst (Zhang et al., 2010). Optimization of transesterification variables for biodiesel production from cottonseed oil using RSM has also been reported by (Fan et al., 2011). Due to the deficiency of matters in the field of hot-press method for extraction oil of sesame seeds in industrial scale, the main purpose of this investigation is optimization of given temperatures and moisture contents of output seeds of oven, to obtain oil and meal with high quality.

2. Materials and methods

Sesame seeds have bought from Afghanistan for oil extraction operations and chemical experiments, then were transferred to Khorasan cotton and oil seeds factory in north east of Iran.

2.1. Oil extraction mode

Sesame seeds, were stored into Kendo shape silos in dark and room temperature for a while after receiving and extra particles and impurities such as dust, sands, stones, spoiled seeds, small weed seeds and other extra materials were separated by mechanical sieves and were kept by extraction (Ohlson, 1976). Afterward, seeds were transferred into the roasting cabinet and temperature and humidity of the roasting chamber's perimeter were set on 75 °C, 90 °C, 105 °C and 5.5%, 6% and 6.5%, respectively. Roasted seeds were then placed into the screw press apparatus and pressed up to liberate their oil contents. Output pressed cakes were transferred to the next stage for extraction by solvent. After extraction, solvent was separated from micelle (mixture of oil–solvent and meals) by debugger equipment (desolventize-toast).

2.2. Moisture content

Moisture content of the oil at 105 ± 1 °C was determined according to the Eq. (1).

$$\text{Percentage of moisture content} = \frac{W_1 - W_2}{M} \times 100 \quad (1)$$

where W_1 is the initial weight of the vessel with sample before drying, W_2 represents the weight of the vessel and sample after drying and M is the pure sample weight (AOAC, 2008).

2.3. Determination of fat content

Soxhlet apparatus and *n*-hexane (as solvent) were used for oil extraction. Initially, sample with specific weight was put in the thimble and then both were placed inside the apparatus, round bottom flask containing a specific volume of *n*-hexane was fixed, afterward a condenser was tightly connected to the bottom end. The whole set up was heated up by the temperature of 70 °C and oil has been extracted. Additional solvent in the extracted oil was separated by distillation (AOAC, 2008).

2.4. Determination of protein content

Total nitrogen content has been determined by the Kjeldahl assay. Then, protein content was calculated by multiplying obtained total nitrogen content explained previously by 6.25 (GF) (Khalid et al., 2003).

2.5. Determination of insoluble fine partial content

To measure the amount of insoluble fine partial content, 10 ml of the oil was transferred into a eppendorf tube and was centrifuged with 4000 rpm speed for 10 min. Afterward, the percentage of the insoluble fine partial contents was expressed by Eq. (2) (AOAC, 2008).

$$\text{Fine partial percentage} = \text{Mass of the sediment} \times 10 \quad (2)$$

2.6. Experimental design for optimization

RSM (Response Surface Method) was used to optimize the conditions of oil extraction for sesame seeds. A face-centered cube design (FCD) consisting of 13 experimental runs, including three replications at the center point, was selected to evaluate the combined trace of the dependent variables (remained oil, protein and moisture contents in meal, oil insoluble fine partials in obtained oil and oil content in the output cakes). The domain and the center point values of the three independent variables were adjusted on the base of obtained results of moisture contents in the preliminary test for output seeds of toaster (4.5–6.5%) and temperature (75–105 ± 1 °C) before extraction procedure. The tests were performed in random order to diminish the side effects of unexplained variability in the observed responses due to systematic errors. The independent variables involve temperature (x_1, ±1 °C), moisture content of output seeds after roasting and before extraction (x_2, %), while the response (dependent) variables were determined, remained oil (y_1 and y_2, respectively), protein and moisture contents in the meals (y_3 and y_4, respectively), insoluble fine partials in the extracted oil and oil contents in the pressed cakes (y_5). The response functions (y_1–y_5) were involved into linear, quadratic, and interactive components. Experimental data were fitted with quadratic regression according to Eq. (3):

$$y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 \quad (3)$$

where y is the predicted response, b_0 is the intercept; b_1 and b_2 are linear coefficients; b_{11} and b_{22} are squared coefficients; b_{12} is the interaction coefficient; and x_1 and x_2 are the coded levels of variables (X_1 and X_2). The Design-Expert 6.0 (Stat-Ease Inc., Minneapolis, MN, USA) was used to determine the analysis of variance (ANOVA) and the coefficient of determination (R^2 and adjusted R^2) to evaluate the quality of fitness of the model.

3. Results and discussions

3.1. Remained oil content of the pressed cake

The obtained results of oil content of the pressed cakes with constant increase in temperature and moisture content of output seeds of roaster, have obviously demonstrated that an increase in the moisture content of output seeds from 4.5% to 6.5%, can diminish the extracted oil content of the seeds (Fig. 1). Unlikely an increase in temperature showed an enhance in extracted oil of the seeds. Increasing the roasting temperature from 75 to 105 °C and moisture content from 4.5 to 6.5% can result to an increase in the oil content of pressed cakes due to an increase in the temperature with increase of the moisture can be attributed to the destruction of cell walls of the seeds and creating a substance like a sticky plastic material

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