

Bleaching of vegetable oils using press mud obtained from sugar industry

**Peymaneh Ghasemi Afshar¹, Masoud Honarvar^{1*}, Maryam Gharachorloo¹, Parvin Eshratabadi²
and Behzad Bazayr³**

¹*Department of Food Science and Technology, College of Food Science and Technology, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran*

²*Institute of Standard and Industrial Research, Karaj, Iran*

³*Department of Agriculture and Natural Resources, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran*

ABSTRACT

The management of waste such as "Filter Mud", the sugar industry residue is becoming one of the major areas of concern for Iran. Treatment of this material and its conversion to the forms that might have applications in vegetable oil industries helps in cost effectiveness and efficient recycling of this industrial by-product. In this study the possibility of the bleaching of vegetable oils with two different filter muds obtained from sugar industry was investigated and compared with commercial activated bleaching earth. After the activation of the ash of filter muds by HCl and H₂SO₄, bleaching process was carried out on the oils under vacuum at the constant temperature of 110°C using 1 and 2 % adsorbents. Beta-carotene content, color, peroxide value and acidity of the neutralized and bleached oils were determined. The results indicated that the bleaching efficiency varied depending on some experimental parameters namely the type of adsorbent used, adsorbent activation method and adsorbent dosage. The results revealed that acid activated ash of sugar industry filter muds significantly decreased all the subjected characteristics apart from the acidity and despite the differences in composition and particle sizes, the efficiency of these adsorbents particularly the HCl activated ash of sugar beet filter mud for removal of Beta-carotene and reduction of oil color was comparable to bentonite, the commercial activated bleaching earth. Therefore the activated ash of sugar industry filter mud might be employed as an alternative to the commercial bleaching agent in edible oils refining due to its effectiveness.

Keywords: Activation; Adsorbent; *Beta*-carotene; Filter mud; oil

INTRODUCTION

Bleaching is a critical step in oil refining due to the reduction of impurities such as color and oxidation products namely hydroperoxides [1, 2]. Removal of these substances is essential in the refining of oils as it improves the stability and the sensory quality of the oils [1]. Improvement in color is due to the removal of organic compounds such as carotenoids, especially *beta*-carotene, and their derivatives, xanthophylls, chlorophyll, pheophytin, gossypol, and their degradation products, that impart undesirable color to the oils [1]. This removal is usually achieved by adsorption of these color pigments on to an adsorbent such as activated bleaching earths, a clay that have been widely used in the oil industry. The natural bleaching earth, fuller's earth, a hydrated aluminum silicate, mostly has been replaced by acid activated clays, which are sulfuric or hydrochloric acid treated bentonites or montmorillonites [3]. Though activated clays are efficient and effective adsorbents for bleaching, attention is currently directed at agro waste ash as an alternative adsorbent [4].

Industrial wastes are generated in large quantities all over the world and if not properly handled or treated, might cause detrimental effects on the environment, therefore the management and processing of these substances is particularly important [5].

Sugar industry is one of the industries that produces considerable amount of recyclable organic materials. One of the main by-products from any sugar factory is "Filter cake" or "Filter mud", the compressed sugar industry residue produced from the filtration of the sugar juice [6].

Although filter mud is fairly rich in organic matter, there is a major disposal problem concerned with this waste. Some quantities of the filter mud are used as fertilizer and soil conditioner. However, this approach is not a desirable practice in view of the foul odor from biological degradation [7], insoluble and imbalanced nature of the nutrient content in it, generation of intense heat (65°C), and duration for natural decomposition [6].

According to the statistical figures, sugar factories in Iran produce about 1 million tons of filter mud every year as a waste product. Disposal of the waste is becoming one of the major areas of concern for a developing country like Iran. Usually the press mud is either disposed of in open fields or sold as immature compost to farmers [6].

Several waste materials have been identified as potential candidates to substitute bleaching earth or bentonite and some attempts have been made to convert a variety of materials using different methods and conditions [6]. However, little effort has been given to the proper treatment of filter mud emerging out of sugar industries.

Treatment of filter cake and its conversion to the forms that might have applications in edible oil industries helps in cost effectiveness and efficient recycling of this industrial residue.

Therefore, the aim of this work is to study the effect of bleaching with acid activated ash from sugar industry filter mud on color, *beta*-carotene concentration, acidity and peroxide value of soybean, canola and sunflower seed oils and compare the results with the commercial bleaching earth.

MATERIALS AND METHODS

Materials

The neutralized soybean, canola and sunflower seed oils were obtained from Nosh Azar Oil Company of Tehran.

Two types of filter mud (resultant from sugar beet and cane refining lines) were obtained from Hekmatan Sugar Factory (Hamedan, Iran).

The commercial activated bleaching earth, Bentonit Type KF, was purchased from Kanysaz Jam Industries Ltd., (Tehran, Iran).

All the chemicals used were of analytical grade, purchased from the Merck Chemical Company of Germany.

Methods

Preparation of Activated Ash of Filter mud

Fresh filter mud samples from sugar beet and cane refining lines were air-dried in the shade in an open field until the moisture content reached to less than 4%. Dried filter mud samples were grounded in the mill (Triplex, France), passed through a sieve of 200 mesh and the obtained powders were stored in plastic bags.

The ground filter cake samples were carbonized in an air atmosphere and then heated in muffle furnace for 2h at 800°C for ashing. The ash samples were cooled in a desiccator at room temperature, and stored in amber glass bottles.

The ash was mixed with 12N HCl and 12N H₂SO₄ in the ratio of 1:3 (w/v) separately, and the slurry was agitated at 750 r/min at 80 ± 2°C for 2 h. After activation, the slurry was filtered. The filtered ash was washed with distilled water several times until the pH of the supernatant was 4-4.5. The ash was dried at 105°C for 24 h. Activated ash was grounded and passed through a 200 mesh sieve.

Determination of Physico-chemical Characteristics of Activated Ash

Chemical composition of the activated ash samples and commercial bleaching earth were determined using X-ray fluorescence (XRF), Philips Magix Pro XRF spectrometer [8].

Particle size analysis of activated ash samples and commercial bleaching earth were done using particle size analyzer, Fritsch Particle Sizer Analysette 22[9].

Bleaching of Vegetable Oils

The bleaching experiments were performed under vacuum in a two-necked flask equipped with a stirrer and contact thermometer. 100 g of neutralized oil was mixed with 1 or 2 g of activated ash samples. The bleaching process was carried out under a vacuum (9 mmHg) at the constant temperature of 110°C for 30 min. The bleached oil was cooled under vacuum to 70°C and then filtered through a Whatman No. 41 filter paper to remove the adsorbent.

Physical and Chemical Analysis of Bleached Oils

A series of physical and chemical tests were carried out on the neutralized and bleached oils according to the British Standard and AOCS Official Methods.

Total carotene content expressed as *beta*-carotene equivalents in the neutralized and bleached oils was measured with a TG 60 spectrophotometer (PG Instruments T60U UV/Vis Spectrophotometer). The oil was dissolved in isooctane and the absorbance was measured at 450 nm [10]. The experiment was conducted in triplicate order to determine the bleaching capacity of the activated filter cake accurately by comparison with a commercial bleaching earth.

Color measurement was carried out by Lovibond Tintometer apparatus in 5.25 inch cell according to AOCS standard method, Cc13e-92 [11].

The free fatty acid contents were determined according to AOCS method, Cd 3d-63[11].

Peroxide value determinations were carried out according to AOCS method, Cd 8-53 by dissolving the oil in acetic acid-chloroform (3:2) solution and titration with 0.01 N sodium thiosulfate solution in the presence of potassium iodide and starch indicator [11].

Statistical Analysis

All the experiments and measurements were carried out in triplicate order and the mean values were reported. The data were statistically analyzed using the Statistical Analysis System software package on replicated test data. Analyses of variance were performed by the application of ANOVA procedure. Significant differences between the means were determined using Duncan multiple range test.

RESULTS AND DISCUSSION

In this study the effectiveness of four different adsorbents namely ashes of sugar beet and cane refining lines filter mud activated with HCl or H₂SO₄ were compared with the commercial activated bleaching earth in bleaching of soybean, canola and sunflower seed oils and process efficiency and the quality of bleached oils were evaluated.

Table 1 shows the quantities of carotenoids in soybean, canola and sunflower seed oils that were bleached with 1 and 2 % of adsorbents.

Although in all oil samples *beta*-carotene contents significantly ($p < 0.05$) decreased after bleaching with 1 and 2% of adsorbents, bleaching efficiency varied depending on the experimental parameters; namely adsorbents type, activation method and dosage.

In all three oils, bentonite adsorbed the maximum amount of *beta*-carotene and after that the ash of sugar beet filter cake reduced *beta*-carotene content more than the ash of cane filter cake at the same dosage. Although the concentrations of acids for activation of both ashes were the same (12N), ashes activated with HCl performed better than those activated with H₂SO₄ under the same experimental conditions. It was also found that by increasing the adsorbent dosage from 1 to 2 %, the percentage of carotenoid removal was increased that is the result of increase in active sites available for adsorption.

Regardless of bentonite, the highest reduction in carotenoid content was obtained by using 2% of ash of sugar beet filter mud activated with HCl (Table1) as the reduction percentage in *beta*-carotene for soybean, canola and sunflower seed oils reached 76.1, 65.5 and 63.2% respectively. At the 1% bentonite level the bleaching efficiency was comparable to 2% addition of ash from sugar beet filter mud activated with HCl.

Differences in bleaching power might be depended on the adsorbents particle size and their compositions. Acid activation modifies the chemical composition of clay minerals. It has been shown that acid activation causes an exchange of the octahedral cations; Al^{3+} , Fe^{3+} , and Mg^{2+} with H^+ ions which leads to the modification of the clay crystalline structure. The surface areas of the modified samples were observed to increase to more than three times that of the raw sample [12].

Our XRF results showed that the all adsorbents are composed of metal oxides particularly CaO, MgO, SiO_2 and Al_2O_3 (Tab. 2). The major component in bentonite, the commercial bleaching earth is silica while the main composition in activated ashes of sugar beet and cane filter muds is CaO.

Addition of MgO can increase the bleaching activity of earths [13]. It has been also observed that smectites with greater MgO contents in their structure are more activated by mineral acids than those smectites with minor MgO content [2].

According to the results given in Tab. 2, ash of sugar beet filter cakes consist of the highest content of MgO and SiO_2 as compared with other adsorbents except bentonite. Bleaching efficiency increases proportionally to the removal of octahedral cations from the ash structure.

On the other hand, the results indicated that ashes of sugar beet and cane filter cakes activated with HCl that adsorbed higher amounts of *beta*-carotene have smaller particle size than ashes activated with H_2SO_4 (Table 2). The results indicated that the smaller particles enhanced the adsorption of *beta*-carotene, which is in agreement with the previous investigations by Richardson [14]; Morgan et al. [15]; Henderson [16]; Chen et al. [17] and Agatemor [1].

From the view point of diffusion, small particles may shorten the diffusion path of *beta*-carotene to the pore surface for adsorption, thus enhancing adsorption of *beta*-carotene or it is as a result of increase in surface area, pore volume, and pore size of the particles [1].

Al-Zahrani et al. [18] reported that acid treatment of clays changes the clay structure by creating new pores resulting in an increase in surface acidity through the replacement of cations like Al^{3+} , Fe^{3+} and Ca^{2+} from the structure with H^+ . Two basic reactions occur during clay activation with mineral acids. The acid first dissolves part of Al_2O_3 as well as CaO, MgO, etc., from the lattice. This causes an opening of the crystal lattice and an increase in internal surface area. The second reaction is the gradual exchange of the Ca and Mg ions, located at the surface of the crystal against hydrogen ions from the mineral acid. Therefore acid activated clay is almost saturated with H^+ and exhibits strong acidic character [18].

Based on previous studies, it seems that activation of filter cakes with acid increases the surface area and in this aspect HCl has been more effective than H_2SO_4 .

We speculate reduction of particle size in the case of HCl treated filter cake provides more adsorption sites and present better bleaching results. It should be noted that the positive effect of reduction in particle size might create difficulty in filtration due to the increased oil retention by the adsorbent as has been noted by Valenzuela et al. [19] in the case of bleaching clays.

Increased amount of used adsorbent will provide more surface area for the adsorption and removal of *beta*-carotene. Some previous investigators working with other agro waste ash and clays, as adsorbent, reported an enhanced removal of *beta*-carotene and a reduction in peroxide value and anisidine value as the result of increasing adsorbent/oil ratio [1, 20]. For instance, Chen et al. [17] reported that increasing the amount of activated rice husk ash enhances the removal of *beta*-carotene from soybean oil.

In this research the evaluation of bleaching efficiency was based on the Lovibond color indices (Table3). As expected indices for yellow and red colors decreased in all the bleached oils, confirming thereby the high efficiency of the bleaching process using activated ashes of sugar industry filter cakes. The results indicated that there are no significant differences between red and yellow color intensities of oils bleached with 1% of bentonite and 2% of the HCl activated ash of sugar beet filter mud ($p < 0.05$).

Table 1: Amount of carotenoids (mg β -carotene/Kg oil) in soybean, canola and sunflower seed oils bleached with 1 and 2 % of different adsorbents¹

Oil Samples	Neutralized oils (Blank)	Bleaching agent											
		Ash of sugar beet filter cake activated with					Ash of cane filter cake activated with					Commercial bentonite	
		HCl		H ₂ SO ₄			HCl		H ₂ SO ₄				
		1%	2%	1%	2%	1%	2%	1%	2%	1%	2%		
Soybean	30.95±0.02 ^a	15.14± 0.03 ^h	7.38±0.02 ^j	19.17±0.03 ^e	16.98±0.02 ^g	19.67±0.03 ^d	17.26±0.03 ^f	26.95±0.02 ^b	22.18±0.04 ^c	7.92±0.04 ⁱ	0.43±0.04 ^k		
Canola	32.09±0.02 ^a	19.02±0.04 ^h	11.06±0.05 ⁱ	26.41±0.03 ^d	22.89±0.02 ^f	27.23±0.04 ^c	22.06±0.08 ^g	29.04±0.03 ^b	25.98±0.05 ^e	6.96±0.02 ^j	2.69±0.06 ^k		
Sunflower	7.14±0.06 ^a	3.51±0.02 ^h	2.63±0.03 ⁱ	5.55±0.03 ^d	4.58±0.05 ^f	5.33±0.03 ^e	4.41±0.06 ^g	6.97±0.02 ^b	5.78±0.05 ^c	2.26±0.03 ^j	1.39±0.02 ^k		

¹Note: The values are expressed as means ± standard deviation.

^{a-k}There is no significant difference between similar letters in each column ($p < 0.05$).

Table 2: Composition and particle size of used adsorbents

Adsorbents properties	Ash of sugar beet filter cake activated with			Ash of cane filter cake activated with		Commercial bentonite																													
	HCl		H ₂ SO ₄	HCl	H ₂ SO ₄																														
	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃		Na ₂ O	K ₂ O	L.O.I																										
Chemical Composition (%) ¹	46.80 ± 0.20	1.30 ± 0.05	2.98 ± 0.04	0.34 ± 0.04	0.07 ± 0.01	0.06 ± 0.03	<100 ppm	47.83±0.03	43.70 ± 0.20	1.10 ± 0.01	2.30 ± 0.03	0.29 ± 0.00	0.05 ± 0.00	0.05 ± 0.02	<100 ppm	48.95±0.06	46.70 ± 0.20	0.92 ± 0.05	1.85 ± 0.04	1.35 ± 0.04	0.24 ± 0.04	0.22 ± 0.01	0.07 ± 0.01	0.05 ± 0.00	0.03 ± 0.02	<100 ppm	44.40 ± 0.20	1.35 ± 0.04	1.49 ± 0.05	73.36 ± 0.20	7.39 ± 0.02	0.61 ± 0.03	0.13 ± 0.01	0.51 ± 0.03	13.98±0.02
Average particle size (µm)	8.16	16.18	8.92	16.94	9.63																														

¹:Note: The values are expressed as means ± standard deviation.

Direct correlations were observed between changes in color and *beta*-carotene concentrations as *beta*-carotene was major color compound in the oils.

The free fatty acid content of bleached oil samples is presented in Table 4. The acidity of soybean, canola and sunflower seed oils bleached with activated ash of filter cake samples and commercial bentonite are increased slightly that might be due to the treatment with acid activated earths. There is no significant differences between free fatty acid contents of oils bleached with bentonite and other used adsorbents ($p < 0.05$). These results agree with Morgan et al.[15] and Hoffmann[21] who reported increases in the free fatty acids in the bleached oils .

It is well accepted that partial hydrolysis of the oil takes place during bleaching, thus increasing free fatty acid content. The extent of oil hydrolysis during bleaching depends on the acidic properties of the bleaching clays. Acid activation results in acidic surfaces that will more readily split the oil into free fatty acids [22]. Another factor that promotes oil hydrolysis during bleaching is the presence of moisture. Since the neutralized oils in this work were dried over anhydrous sodium sulphate before bleaching under vacuum, the effect of moisture is minimal and might be excluded from the discussion.

Table 5 shows the peroxide values of oil samples bleached with activated ashes of sugar beet and cane filter cakes as well as bentonite.

The peroxide values of neutralized soybean, canola and sunflower seed oils were 2.38, 2.98 and 2.81 meq/kg respectively. By bleaching the oils with 2% HCl activated ash of sugar beet filter cake these values were reduced to 2.11, 2.32 and 1.98 meq/kg respectively. Although greater reductions in the peroxide values were obtained by using commercial activated bleaching earth, HCl treated ash of sugar beet filter cake did reduce the peroxide value of bleached oils demonstrating the effectiveness of this material in the bleaching process.

Young [23] and Boki et al.[24] reported that oxidation levels are reduced by the breakdown of hydroperoxides; the primary oxidation products on the adsorbent surfaces such as bleaching earth. Also Boki et al. [25] suggested that a decrease in peroxide value might be due to the decomposition of peroxides by the strongest acid on the surface of bleaching earth.

The results indicated that peroxide value of the oil samples bleached with 2% activated ash of filter cake samples are similar to those obtained using 1% dosage of bentonite.

The lower adsorption might be due to the competition from other minor oil compounds or pigments present in the edible oil that are more selectively adsorbed onto the activated samples [22,25].

Proctor et al. [26] and Gnanasamandam et al.[27] reported a reduction in peroxide value of bleached soybean oil when using carbonized soy hulls as bleaching agents, while Aly et al.[28] Girgis [29] reported an increase in peroxide value during bleaching of refined cottonseed oil when using acid activated ashes of apricot stones, and the results were higher when Tonsil clay was employed for the bleaching process.

Table 3: Color of soybean, canola and sunflower seed oils bleached with 1 and 2 % of different adsorbents (Lovibond)¹

Oil Samples	Color (Lovibond)	Neutralized oils (Blank)	Bleaching agent											
			Ash of sugar beet filter cake activated with					Ash of cane filter cake activated with					Commercial bentonite	
			HCl		H ₂ SO ₄			HCl		H ₂ SO ₄				
			1%	2%	1%	2%	1%	2%	1%	2%	1%	2%		
Soybean	Yellow	68±0.17 ^a	37.3±0.17 ^h	26.2±0.10 ⁱ	48.6±0.26 ^d	39.1±0.10 ^f	49.6±0.17 ^e	37.8±0.15 ^g	55.0±0.10 ^b	47.5±0.10 ^e	24.3±0.26 ^j	14±0.10 ^k		
	Red	9 ±0.26 ^a	6.3 ±0.17 ^d	5.1 ±0.17 ^e	7.2±0.20 ^c	6.1±0.17 ^d	7.9±0.10 ^b	6.1±0.11 ^d	9.0±0.34 ^a	7.9±0.10 ^b	4.9±0.17 ^e	3.1±0.26 ^f		
Canola	Yellow	24±0.06 ^a	16.8±0.17 ^d	10.1±0.10 ^g	19.2±0.15 ^c	14.1±0.10 ^f	21.8±0.17 ^b	16.2±0.17 ^e	22.1±0.10 ^b	17.6±0.26 ^d	9.8±0.10 ^g	6.8±0.17 ^h		
	Red	6.9±0.17 ^a	5.8±0.20 ^c	4.9±0.11 ^e	6.5±0.26 ^b	5.2±0.11 ^d	6.7±0.10 ^{ab}	5.8±0.26 ^c	6.8±0.23 ^{ab}	5.1±0.26 ^{de}	4.8±0.17 ^e	2.9±0.23 ^f		
Sunflower	Yellow	42±0.32 ^a	26.8±0.17 ^d	17.3±0.26 ^{gh}	29.3±0.26 ^d	8.9±0.10 ^g	31.5±0.34 ^c	22.1±0.11 ^f	33.4±0.17 ^b	23.8±0.11 ^e	16.9±0.17 ^h	8.9±0.10 ^j		
	Red	4.8±0.26 ^a	3.9±0.10 ^c	3.1±0.17 ^{de}	4.1±0.10 ^{bc}	2±0.34 ^{de}	4.5±0.36 ^{ab}	3.6±0.43 ^{cd}	4.7±0.17 ^a	3.6±0.10 ^{cd}	2.9±0.26 ^e	2.0±0.17 ^f		

¹: Note: The values are expressed as means ± standard deviation.
^{a-k} There is no significant difference between similar letters in each column (p<0.05).

Table 4: Free fatty acid contents of soybean, canola and sunflower seed oils bleached with 1 and 2 % of different adsorbents (%)

Oil Samples	Neutralized Oils (Blank)	Bleaching agent											
		Ash of sugar beet filter cake activated with					Ash of cane filter cake activated with					Commercial bentonite	
		HCl		H ₂ SO ₄			HCl		H ₂ SO ₄				
		1%	2%	1%	2%	1%	2%	1%	2%	1%	2%		
Soybean	0.38±0.05 ^c	0.41±0.02 ^{ab}	0.42±0.03 ^{ab}	0.42±0.03 ^{ab}	0.42±0.02 ^{ab}	0.41±0.04 ^{ab}	0.42±0.04 ^{ab}	0.41±0.02 ^{ab}	0.43±0.03 ^a	0.40±0.01 ^{cb}	0.43±0.04 ^a		
Canola	0.42±0.03 ^a	0.42±0.01 ^a	0.45±0.02 ^a	0.44±0.03 ^a	0.45±0.04 ^a	0.43±0.02 ^a	0.45±0.02 ^a	0.44±0.01 ^a	0.46±0.02 ^a	0.43±0.02 ^a	0.44±0.01 ^a		
Sunflower	0.31±0.02 ^a	0.33±0.02 ^a	0.34±0.02 ^a	0.34±0.01 ^a	0.35±0.02 ^a	0.35±0.05 ^a	0.36±0.03 ^a	0.37±0.03 ^a	0.37±0.05 ^a	0.32±0.09 ^a	0.35±0.04 ^a		

¹: Note: The values are expressed as means ± standard deviation.
^{a-c} There is no significant difference between similar letters in each column (p < 0.05).

Table 5: Peroxide value of soybean, canola and sunflower seed oils bleached with 1 and 2 % of different adsorbents (meq/kg)

Oil Samples	Neutralized Oils (Blank)	Bleaching agent											
		Ash of sugar beet filter cake activated with					Ash of cane filter cake activated with					Commercial bentonite	
		HCl		H ₂ SO ₄			HCl		H ₂ SO ₄				
		1%	2%	1%	2%	1%	2%	1%	2%	1%	2%		
Soybean	2.38±0.03 ^a	2.23±0.04 ^c	2.11±0.03 ^d	2.35±0.04 ^{ab}	2.31±0.02 ^b	2.36±0.04 ^{ab}	2.34±0.04 ^{ab}	2.35±0.06 ^{ab}	2.34±0.04 ^{ab}	1.98±0.03 ^e	0.92±0.03 ^f		
Canola	2.98±0.03 ^a	2.53±0.02 ^e	2.32±0.04 ^g	2.85±0.06 ^{cd}	2.84±0.03 ^d	2.90±0.05 ^{bcd}	2.86±0.02 ^{cd}	2.94±0.05 ^{ab}	2.91±0.04 ^{bc}	2.46±0.03 ^f	1.18±0.06 ^h		
Sunflower	2.81±0.06 ^a	2.10±0.02 ^f	1.98±0.02 ^g	2.20±0.04 ^e	2.19±0.02 ^e	2.58±0.02 ^c	2.44±0.04 ^d	2.75±0.04 ^{ab}	2.70±0.05 ^b	2.38±0.03 ^d	1.13±0.02 ^h		

¹: Note: The values are expressed as means ± standard deviation.
^{a-h} There is no significant difference between similar letters in each column (p<0.05).

CONCLUSION

The results indicated that the efficiency of acid activated ash of sugar industry filter cakes particularly the HCl activated ash of sugar beet filter cake for removal of *beta*-carotene and reduction of oil color was comparable to bentonite. Therefore the activated ash of sugar industry filter cake might be employed as a bleaching agent in edible oils refining due to its effectiveness.

Acknowledgments

Authors gratefully express their sincere thanks to the Department of Food Science and Technology, College of Food Science and Technology, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran and Institute of Standard and Industrial Research, Karaj, Iran (ISIRI), Department of Food Research for supporting this research.

REFERENCES

- [1] Agatemor Ch, *Food Sci and Technol Res.*, **2008**, 14(3), 301-305.
- [2] Foletto EL, Colazzo GC, Volzone C, Porto LM, *Brazilian J Chem Eng.*, **2011**, 28,169-174.
- [3] Taylor DR, *Bailey's industrial oil and fat products*, John Wiley & Sons, New York, **2005**.
- [4] Proctor A, Clark PK, Parker CA, *J Am Oil Chem Soc.*, **1995**, 72,459-462.
- [5] Aziz BK, Abdullah MA, Jubrael KJ, *Asian J Chem.* ,**2011**,23.
- [6] Khwairakpam M, Bhargava R, *Bioresource Technol.*,**2009**, 100,5846-5852.
- [7] Tsai WT, Chen HP, Lai CW, Husien KJ, Lee MS ,Yang JM, *Anal Appl Pyrolysis*,**2003**, 70,399-411.
- [8] ISO, 12677, International Organization for Standardization, Geneva, Switzerland,**2011**.
- [9] ISO, 13320-1, International Organization for Standardization, Geneva, Switzerland, **1999**.
- [10] BS 684, British Standard Institution. London, England, **1993**.
- [11] Firestone D, *Official methods and recommended practices of the American Oil Chemists' Society*, AOCS Press, Champaign, Illinois,**1994**.
- [12] Ajemba RO, Onukwuli OD, *J Basic Appl Sci Res.*, **2012**, 9, 9438-9445.
- [13] De BK, Patel JD, Patel JB, Patel VK, Patel VR, *J Oleo Sci.* , **2009**,58,57-63.
- [14] Richardson LC, *J Am Oil Chem Soc.*,**1978**,55, 777
- [15] Morgan D, Shaw D, Sidebottom M, Soon T, Taylor R, *J Am Oil Chem Soc.* ,**1985**,62, 292-299.
- [16] Henderson JH, *J Am Oil Chem Soc.*,**1993**, 70, 831.
- [17] Chen CY, Lin CI, Chen HK, *J Chem Eng Japan*,**2003**, 36, 265-270.
- [18] AL-Zahrani AA, AL-Shahrani SS, AL-Tawil YA,*J King Saud Univ.*,**2000**,13,193-203.
- [19] Valenzuela Díaz FR, Santos PS, *Quim Nova*, **2001**, 24,345-353.
- [20] Liew KY, Yee AH, Nordin MR, *J Am Oil Chem Soc.*, 1993, 70,539-541.
- [21] Hoffmann G, *The chemistry and technology of edible oils and fats and their high fat products*, Academic Press Inc., London,**1989**.
- [22] Omar S, Girgis B, Taha F, *Food Res. Inter.*,**2003**,36,11-17.
- [23] Young F, In: Gunston F (Ed) *Palm oil*, John Wiley and Sons Inc., New York, **1987**, pp47- 51.
- [24] Boki K, Shinoda S, Ohno S, *J Food Sci.*, **1989**, 54,1601-1603.
- [25] Boki K, Wada T, Ohno S,*J Am Oil Chem Soc.*,**1991**, 68,561-565.
- [26] Proctor A, Gnanasambandam R, *J Am Oil Chem Soc.*, **1997**, 74, 1549-1552.
- [27] Gnanasambandam R, Mathias M, Proctor A, *J Am Oil Chem Soc.*, **1998**, 75, 615-621.
- [28] Aly SM, Girgis B, *Modeling Measurement and Control (AMSE)*, **2000**, 61(1), 35-42.
- [29] Girgis AY, *Grasas Aceites*,**2005**,34,34-45.