Thermal Science and Engineering (2018) Volume 1
doi:10.24294/tse.v1i2.424

Effects of Roasting and Boiling on the Yield, Quality and Oxidative Stability of Extracted Soya Bean Oil

Samuel Kofi Tulashie[1*], Francis Kotoka, Amponsah Preko Appiah[1], Philip Awuah[2], Bright K.A. Baiden[3]

[1]Industrial Chemistry Unit, Department of Chemistry, University of Cape Coast, Cape Coast, Ghana.Email:stulashie@ucc.edu.gh

[2] Ghana Nuts Company Limited, Techiman, Brong Ahafo Region , Ghana.

[3] Chemical and Paper Engineering Department, Western Michigan University, Michigan, USA.

ABSTRACT

In this study, the effect of roasting and boiling on the yield and oxidative stability of soya bean oil was investigated. The oil was soxhlet extracted and the oxidative stability was determined by the free fatty acid value, acid value and peroxide value. The results showed that the oil yield, free fatty acid value, acid value and peroxide value were significantly affected by roasting, boiling, and the thermal treatment time. The percentage oil yield in the control oil sample was 18.51%, which increased to 20.24% and 20.73% after boiling and roasting respectively, at 40mins. The corresponding free fatty acid and the peroxide value of the control oil sample were 0.14% and 2.04 meqO_2/kg, which increased to 0.82% and 6.60 meqO_2/kg by roasting, and 0.47% and 5.62 meqO_2/kg by boiling respectively. Thus the oil yield, free fatty acid value, peroxide value, and acid value increased with increasing roasting and boiling time.

The results indicate that roasting provides a higher oil yield than boiling, but boiled oil has higher oxidative stability than roasted oil.

Keywords**:** Roasting; Boiling; Soya bean; Oil Extraction; Oxidative stability

1. Introduction

Oils obtained from oilseeds provide the calories, vitamins and essential fatty acids in the human diet in an easily digested form. The rate of vegetable oil consumption is increasing compared with animal fat due to its low sterol [1]. The largest sources of vegetable oil are annual plants, which include soybean (**Figure 1**), corn, cottonseed, groundnut, sunflower, rapeseed, melon and sesame seed[2]. Other sources are oil bearing perennial plants such as olive, coconut, shea,cashew and palm.

Separation of oil from oil seeds is an important processing operation. The process employed has a direct effect on the quality and quantity of oil obtained from the oil seeds[4]. There are three (3) major methods used in the extraction of oil from various agricultural seeds. These are the mechanical/hydraulic pressing method, solvent extraction method and rendering method[5]. Soybean oil as shown in **Figure 2** is extracted from the seeds either by a solvent, mechanical pressing or aqueous enzymatic extraction. However, the common processing methods used to prepare the oilseeds for human consumption are roasting and boiling, followed by solvent extraction.

Roasting refers to the use of heat treatment to induce the development of the typical colour, taste and flavor. It alsochanges the chemical composition, modifying nutritional value and shelf life[7], therefore, roasting is considered as the key step in making condiment oil[8]. Similarly, boiling is one of the commonest processing methods used to prepare oilseeds and also the most difficult process due to the difficulty in removing any traces of water that were used for boiling.It also affects the moisture content of the seed which in turn affects the extraction process. The solvent extraction method involves the leaching out of the insoluble solid structure of the oil seeds by the use of volatile organic solvent, e.g. n –Hexane Isopropanol, Buthanol, and Acetane[9]. Solvent extraction is the most widely used oil-recovery method for soybeans, but it also requires considerable capital and large scale to compete.

Figure 1; Soya bean seeds.[3]

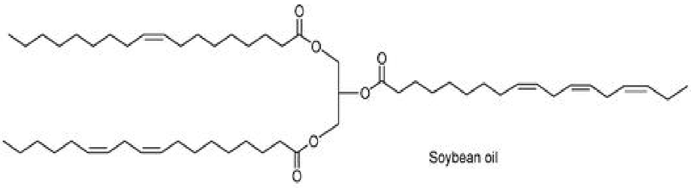

Figure 2; Structure of Soya bean Oil[6]

Several studies have been done on extraction of vegetable oils as well as the effects of moisture content, heating temperature, and heating time on oil yield and oil oxidative stability. For instance, it was reported that the oil yield from castor beans at any pressure was dependent on the moisture content, with higher yield obtained at 8-10% moisture content after heating[10]. It was also reported that the total amount of oil extracted from jatropha kernels, and other vegetable oils depended mainly on the extraction time and temperature, moisture content and particle size of the oil bearing material, with the oil extracted during the first 20 minutes of extraction [1,11]. Conversely, the effects of roasting and boiling on oil yield and stability had also been investigated. Roasting and boiling processes were reported to have increased oil yield but changed the chemical composition, amino acid and oxidative stability of the oil from soya bean seeds, safflower seeds, orange seeds, and coconut[12,13]. Furthermore, the oxidative stability, peroxide value, and acid value of soya bean oil had been stated to have increased via roasting and boiling[8,14,15].

Indeed, several studies have been done on soya bean oil extraction but little exploration had been done on the effects of boiling and roasting on the oil yield, and oxidative stability. This present study investigated the effects of roasting and boiling on the yield, quality, and oxidative stability of extracted soya bean oil.

2. Materials and Methods

2.1 Chemicals and reagents

0.1 N sodium hydroxide solution, phenolphthalein indicator solution, acetic acid isooctane, potassium iodide, 0.01 N sodium thiosulfate, ethanol and n-hexane were obtained from Ghana Nut Company Limited laboratory. All other chemicals used were of analytical grade and were obtained from standard chemical suppliers.

2.2 Sample collection

Soybeans samples were purchased from a local market in Techiman in the Brong Ahafo region of Ghana.

2.3 Thermal treatment of samples

The soybean seeds were first cleaned of dirt and foreign particles such as sand, stones, wood and metal particles. The samples were then rid of insects by sun drying for three days, after which they were then sorted and divided into two equal portions for the thermal treatment processes. The first portion of the Soybean samples was boiled whereas the other portion was roasted; all in a stainless steel container on a hot plate at 100 ºC for 20 mins and 40 mins respectively. The samples were cooled, dried and ground into fine powder using an electric blender and then stored in clean containers in a fridge.

2.4 Determination of Moisture and Volatile Matter

An empty dish was dried and weighed and the mass was recorded as W_1. 10g of the sample was placed into the dish and the new weight was recorded as W_2. It was then brought to drying in a preheated oven set at 105±1ºC for 3 hrs. The sample was removed and cooled in desiccators for 30mins. It was then weighed and record final weight as W_3. The procedure was repeated for all the treatments.

$$\% \text{ Moisture and volatile matter} = \frac{W3-W1}{W2-W1} \times 100 \quad (1)$$

Where, W_1= Weight of empty dish

W_2= Weight of dish + sample

W_3= Weight dried sample

2.5 Oil Extraction Using Soxhlet Method

Oil extraction was done using the Soxhlet method with n-hexane as solvent, and the oil yield in the initial sample was then calculated as follows:

$$\%\ \text{oil yield} = \frac{W_0}{W} \times 100 \tag{2}$$

Where

W_0 =weight of oil extracted

W = weight of the sample

2.6 Determination of Free Fatty Acid

50ml of hot, neutral ethanol and a few drops of phenolphthalein were added to 5g of the oil sample in Erlenmeyer flask, and shaken vigorously. The resulting solution was titrated with 0.1 N $NaOH_{(aq)}$ with constant shaking until the pink colour remained constant. From the quantity of 0.1 N $NaOH_{(aq)}$ used, the percent free acid was calculated shown in equation (3), stating the result in terms of oleic acid[16].

$$\text{Free fatty acids as oleic acid} = \frac{28.2 \times V \times N}{W} \tag{3}$$

Where V = Volume in ml sodium hydroxide used

N = Normality of the Sodium hydroxide solution; and

W = Weight in g of the sample

2.2.6 Determination of Acid value

50 ml freshly neutralized hot ethanol and one drop of phenolphthalein indicator solution were added to 5 g of the cooled soybean oil in a 250 ml Erlenmeyer flask. The resulting hot mixture was boiled for about 5mins and titrated against standard alkali solution, shaking vigorously during the titration until the pink colour remained constant. The acid value was calculated as follows:

$$\text{Acid value} = \frac{56.1 \times V \times N}{W} \tag{4}$$

Where V = Volume in ml sodium hydroxide used

N = Normality of the $NaOH_{(aq)}$; and

W = Weight in g of the sample

2.7 Determination of Peroxide value

30 ml of the acetic acid-isooctane solution (3:2) was added to 5 g of the sample in a 250 ml Erlenmeyer flask, follow by swirling to dissolve the oil. 0.5 ml of the saturated $KI_{(aq)}$ was then added and allowed to stand with occasional shaking for 1min, follow by the addition of 30 ml of distilled water. The solution was slowly titrated with 0.01 N $Na_2S_2O_3$ (sodium thiosulfate) with vigorous shaking until the yellow color was almost disappeared. As the titration continued, 0.5 ml of starch was added while shaking vigorously to release all the iodine from the isooctane layer, until the blue color disappeared. The peroxide value was calculated as shown in equation (5)

$$\text{Peroxide value} = \frac{S - B \times N \times 1000}{W} \tag{5}$$

Where

S = volume of $Na_2S_2O_3$ used for sampling

B = volume of $Na_2S_2O_3$used for blank

N = normality $Na_2S_2O_3$

W = weight of the sample (g)

2.8 Statistical analysis

All measurements were in triplicates and the results presented as a mean value ± standard deviation (SD) were analyzed using statistical package for social science (SPSS) research version 16. Statistically significant difference between roasting and boiling times were calculated at the level of confidence $\alpha = 0.05$. In order to find out if the difference in the mean values estimated were statistically significant, the one –way analysis of variance was applied.

3. Results and Discussions

3.1 Percentage Moisture Content

Table 1 indicates the moisture content of the raw, boiled, and roasted soya beans. The raw beans moisture content determined to be 4.92%. It was observed that the beans roasted for 40 mins exhibited the lowest moisture content of 2.04%, followed by the roasted soya beans for 20 mins with a moisture content of 3.99%. The boiled beans at 40 mins obtained the highest moisture content of 7.22%, followed by those boiled at 20 mins (6.47%).

Samples	%Moisture Content
Raw Beans	4.92
Roasted Beans /20mins	3.99
Boiled Beans /20mins	6.47
Roasted Beans /40mins	2.04
Boiled Beans /40mins	7.22

Table 1. Percentage Moisture content of the roasted and boiled soya beans

Thus, the moisture content in the roasted beans at 40 mins and 20 mins was reduced by 2.89% and 0.93%, respectively, while that of the boiled beans was increased by 2.3% and 1.55% at 40 mins, and 20 mins, respectively. The differences in moisture content of the two thermal treatments processes may be as a result of water absorption, and evaporation during boiling, and roasting respectively. The result is consistent with other literatures that reported that boiled beans have higher moisture content than roasted beans[1,17].

3.2 Effect of roasting on oil yield and stability of oil

The oxidative stability of the oil was determined by investigating the effects of roasting time on the free fatty acid, peroxide value and acid value as these properties are strong indicators of the stability of the oil. Table 2 depicts the effects of roasting on oil yield and oxidative stability of the soya bean oil.

Treatment	Time/mins	%Fat/oil	%FFA	PV meO_2/kg	AVmg/NAOH/g
Raw	0	18.51±0.500^a	0.14±0.0577^a	2.04±0.1012^a	0.27±0.1732^a
Roasting	20	19.72±0.500^b	0.54±0.0361^c	3.37±0.2080^b	1.05±0.0723^b
	40	20.73±0.255^b	0.82±0.0305^b	6.60±0.0416^{ab}	1.60±0.0665^{ab}

Table 2. Effects of roasting on oil yield and chemical properties of the soya beans

Values are means ± standard deviation of the means of three measurements. Values followed by the same superscript in a column indicates significant difference between these values at a $p<0.05$.

The fat content/oil content, free fatty acid, peroxide value and the acid value of the raw bean sample at time zero (0 min) were determined to be 18.51 ± 0.500%, 0.14 ± 0.0577%, 2.04 ± 0.1012 meO_2/kg, and 0.27 ± 0.1732 mg/NAOH/g, respectively. It was observed that all these determined properties increased with the roasting time. At 20 mins of roasting, the fat content, free fatty acid, peroxide value, and the acid value increased to 19.72 ± 0.500%, 0.54 ± 0.0361%, 3.37± 0.2080 meO_2/kg, and 1.05 ± 0.0723 mg/NAOH/g respectively. They respectively increased further to 20.73 ± 0.255%, 0.82 ± 0.0305%, 6.60± 0.0416 meO_2/kg, and 1.60 ± 0.0665 mg/NAOH/g at 40 mins. The increment in the aforementioned properties during roasting may be due to the breaking down of the oil cells and cell walls, protein coagulation, moisture content adjustment, increase in hydrolysis of the oil cells, which enhanced the movement of the fats and other compounds from the cells to the ambience. The results obtained is similar to other studies which reported increment in fats/oil content and other compounds during roasting[1]

3.3 Effect of boiling on oil yield and stability of oil

The effects of boiling on oil yield and oxidative stability of oil of soybeans was also investigated. As shown in **Table 3**, there was consistent increment in the oil yield and all the other investigated properties with increasing boiling time.

Treatment	Time/mins	% fat	% FFA	PV/meO$_2$/kg	AVmg/NAOH/g
Raw	0	18.51±0.0500[a]	0.14±0.0057[a]	2.04±0.1012[a]	0.27±0.1732[b]
Boiling	20	19.36± 0.0550[c]	0.43±0.0577[b]	2.77±0.1528[b]	0.83±0.0577[a]
	40	20.24± 0.0800[b]	0.47±0.0361[b]	5.62±0.1442[ab]	0.92±0.5568[a]

Table 3. Effects of boiling on oil yield and chemical properties of the soya beans

Values are means ± standard deviation of the means of three measurements. Values followed by the same superscript in a column indicates significant difference between these values at a $p<0.05$.

The highest properties were recorded at 40 mins of boiling. Thus, the fat content, free fatty acid, peroxide value, and acid value increased correspondently from 18.51 ± 0.500%, 0.14 ± 0.0577%, 2.04 ± 0.1012 meO$_2$/kg, and 0.27 ± 0.1732 mg/NAOH/g to 20.24± 0.0800%, 0.47±0.0361%, 5.62± 0.1442 meO$_2$/kg, and 0.92 ± 0.5568 mg/NAOH/g. Like roasting, the increment in the investigated properties may also be due the breaking down of the oil cells and cell walls, protein coagulation, moisture content adjustment, increase in hydrolysis of the oil cells The overall effects of the oil yield, free fatty acid, peroxide value, and acid value of the soya beans are clearly depicted in **Figure 3.** The results indicate a remarkable influence of roasting and boiling soya beans oil and its properties. Heating of oil broke down the oil cells, coagulated protein and adjusted the moisture content of meal to optimize value for extraction whiles reducing oil viscosity. All these effects allowed easy extraction of the oil. As the temperature increased, the hydrolysis of the oil cells also increased.

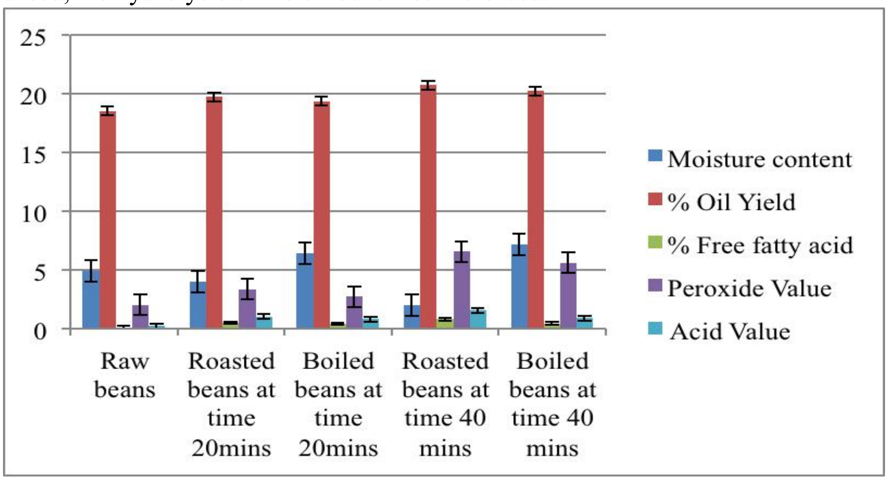

Figure 3; The effects of roasting and boiling on the moisture content, oil yield, free fatty acid, peroxide value, and acid value ofthe soya beans with respect to time**.**

It was observed that except the moisture content, the roasting process produced higher values of the investigated properties than boiling throughout the treatment period. Both treatments led to significant difference ($p<0.05$) in the oil content. The results showed that the oil content of the soya bean seeds obtained via roasting, and boiling at 40 mins increased from 18.51% in raw samples to more than 20.00%. However, at 40 mins, the highest oil yield was obtained via roasting (2.22%) than boiling (1.73% increment). This implies that oil yield increases with time, and roasting produces higher oil yield than boiling. These results are similar to other literature which reported oil yield with roasting and boiling time[12].

It was also observed that the investigated properties increased in both thermal treatments. However, the roasting process increased the free fatty acid, the peroxide value, and the acid value appreciably than the boiling process. There were significant changes in free fatty acid value, and the acid value during boiling and roasting ($p<0.05$). However, there were no significant difference between the 20 mins and 40 mins of boiling though roasting exhibited significant difference between the 0, 20 and 40 mins. The results, therefore, suggest that since the free fatty acid value and peroxide value respectively measures the extent to which the glycerides in the oil have been decomposed by lipase action, and gives the initial evidence of rancidity in unsaturated oils, both the boiling and roasting processes may enhance the hydrolytic rancidity of the soy bean oil, hence, affecting the oxidative stability of the oil. However, the results generally showed that oil extracted from roasted soya beans seed at 100^{o}C had greater oil yield but relatively lower oxidative stability, hence, may have a reduced shelf life than oil extracted from boiled soya beans. The results are consistent with other studies which indicated that roasted soya bean oil has higher yield but lower oxidative stability[15,16,18,19].

4. Conclusion

The results obtained in the present work have showed the yield, roasting and boiling processes affected quality and oxidative stability of extracted soya bean oil. Thus; roasting is preferred when higher yield is required but may however decrease the quality and shelf life of the oil as it produced higher free fatty acid value, acid value and peroxide value which significantly account for the oxidative rancidity and consequently affects the oils oxidative stability. Boiling as a heat treatment on the other hand may not give higher yields as expected, but may increase the quality and shelf life of the soya bean oil produced. However, the results indicate that boiling can potentially induce oxidative rancidity since the acid values, peroxide values, and free fatty acid values were also appreciable.

It is therefore recommended that further studies be carried out on the optimization of these heat treatment techniques or better still develop a new treatment method that will not only ensure a high oil yield but will also significantly improve the oil quality, oxidative stability and shelf life generally.

Conflict of interest

The authors have no conflicts of interest regarding the publication of this paper.

Acknowledgement

We thank the University of Cape Coast-Ghana and Ghana Nut Company Limited for their laboratory assistance.

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