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Influence of Roasting Techniques on Chemical Composition and Physico-chemical Properties of Sesame (*Sesamum indicum*) Seed Flour and Oil

Makinde, F.M.[1]*, Adetutu, A.O.[2] and Olorunyomi, G.O.[2]

Department of Food Science and Technology, Bowen University, Iwo, Osun State, Nigeria.
*Corresponding author: Email: sademakinde@yahoo.com

ABSTRACT

The most common form of utilization of sesame seed is its roasting, which supplies nutrients to the diet. The objective of this study was to determine the effect of different roasting techniques (using open pan and microwave) on the chemical composition of sesame seed flour and physico-chemical properties of its oil. The raw sesame flour (RSF), open pan roasted sesame flour (ORSF) and microwave roasted sesame flour (MRSF) were analysed for proximate composition, minerals, vitamins, anti-nutritional factors and colour, and the seed oils were analyzed for peroxide and iodine values. The ranges of proximate composition of the flours were: protein 24.3-27.5 g/100g, fat 52.4-59.0 g/100g, crude fiber 3.86- 6.13 g/100g, ash 2.88-3.67 g/100g, carbohydrate 5.4-13.2 g/100g and energy value 552.5 -576.6 kcal/100g. Crude fat, ash, fiber and energy values were significantly higher in MRSF and ORSF compared to RSF. However, protein and carbohydrate values were significantly lower in roasted seeds compared to RSF. Calcium, potassium, phosphorus and magnesium ranged from 439.25-445.02, 342.14-346.77, 427.81-434.77 and 357.38-364.03 mg/100g respectively with the RSF having the least value. Whereas micro elements such as iron, manganese and zinc ranged from 3.06-6.42, 0.76-1.50 and 2.78-3.62 mg/100g. Thiamine values for RSF, ORSF and MRSF were 40.23, 20.56 and 4.52 mg/Kg respectively; riboflavin values were 21.08, 15.33 and 2.60 mg/Kg respectively while niacin values were and 28.28, 17.30, 2.01 mg/Kg respectively. Roasting in open pan caused significant reduction in phytate and oxalate contents in sesame than roasting in microwave oven. Colour values (L) of seed flour significantly decreased, whereas a* and b* values increased ($P \leq 0.05$) in ORSF and MRSF compared to RSF. The peroxide values of RSF, ORSF and MRSF were 1.43, 11.21 and 10.02 mEq O2/kg oil respectively while the iodine values were 118.65, 106.44 and 109.71 g I/100g oil for RSF, ORSF and MRSF respectively. The effect of roasting techniques with regard to loss and retention of the nutrients differed significantly ($P \leq 0.05$).*

Keywords: chemical composition; microwave irradiation; open pan roasting

INTRODUCTION

There has been immense expansion in oil seeds production as a result of increasing demand for food applications. Sesame seeds are small, the size, form and colour vary with the thousands of varieties known (Oplinger *et al*., 1990). Sesame seeds occur in many colours depending on the cultivar (Langham, 2008). The most traded variety of sesame is off-white coloured. Other common colours are buff, tan, gold, brown, reddish, gray, and black. Through the ages, sesame seeds have been a source of food and oil. Sesame is also grown for its leaves that are used in stews, and the dried stems may be burnt as fuel with the ash used for local soap making, but such uses are entirely subordinate to seed production. Sesame seeds contain 47-50% fat, 25-27% protein, 10-12% carbohydrate, 3.7-6.4% fiber and 3.7-4.6% ash (Makinde and Akinoso, 2013). The seeds are rich in mono-unsaturated fatty acid (oleic acid) and equally rich sources of many minerals such as calcium, phosphorus, manganese, zinc, magnesium and potassium which play vital roles in the body (Makinde and Akinoso, 2014). The seeds also contain B complex vitamins such as niacin, folic acid, thiamine, riboflavin and pyridoxine with some health benefiting compounds such as sesamol, sesamolin and sesamin (Nakai *et al*., 2003). Phillips *et al*. (2005) however reported that the seeds contain phytic and oxalic acids, which are anti- nutrients.

The effects of various processing methods in the preparation of oilseeds for human consumption are of utmost importance. Roasting is the most important practice for sesame seed processing in Nigeria and is commonly carried out in open pan over fire with continuous stirring, however, such roasting process takes about 20 min or more, which may adversely affect sesame constituents such as lipids, protein, vitamins and other essential nutrients. Meanwhile, social changes and rapid lifestyle make the working women search for a rapid method for preparing food with microwave oven especially those needed a long time for cooking or roasting. Microwave operation have been applied with increasing success in oil extraction, pasteurization, sterilization, baking, blanching, roasting, cooking, drying, and thawing of different food products (Tan *et al*., 2001; Mariod *et al*., 2013) and it is accomplished by means of electromagnetic waves, which penetrate deeply and heat rapidly (Schlegel, 1992). Electromagnetic waves are of electrical and magnetic energy moving together through space. They include gamma rays, x-rays, ultraviolet radiation, visible light, infrared radiation, microwaves and the less energetic radio waves. Although there is no formal definition of the frequency range for microwave radiation, these electromagnetic waves occur in the 300MHz - 300GHz region. Nevertheless, and in accordance with the industrial, scientific and medical (ISM) frequency bands for non- communication purposes, only 915 MHz and 2.45MHz are used for food applications, especially the second due to its worldwide availability (Malheiro *et al*., 2011). Numerous advantages boosted the use of microwave heating making it in many cases a technique preferred in the processing of food. These advantages include precise timing, rapidity, and energy saving. Moreover, it has been found to be safe; there was no toxicity or adverse effects on microwave treated foods (Miller *et al*., 1989).

Many researchers have been concerned with the evaluation of the effect of roasting on sesame seeds; these include: anti oxidative activity of roasted sesame seed oil and the effect of using the oil for frying (Fukuda *et al*., 1986), influence of seed roasting process on the changes in composition and quality of sesame oil (Yen, 1990), oxidative stability of sesame oil prepared from sesame seed with different roasting temperatures (Yen and Shyu, 1989) and microwave roasting effects on the composition and oxidative stability of sesame oil (Yoshida and Kajimoto,1994). However, there is paucity of information on the effect of roasting techniques on chemical composition of sesame seeds. This study was designed to determine the effect of open pan and microwave roasting on the chemical composition of sesame flour and physico-chemical properties of its oil.

MATERIALS AND METHOD

Sample materials
White sesame seeds (*Sesamum indicum* L.) were purchased from a local market in Oyo state, Nigeria and transported to the laboratory in airtight polythene bags and stored under cool dry storage (4°C) condition until needed. All the chemicals and reagents used in the study were of analytical grade.

Sample preparation
Figure 1 shows the flow diagram for the preparation of the raw and roasted sesame seeds. The seeds were first cleaned by removing extraneous materials such as chaff and stone, after which the unwholesome grains were removed by sorting.

Raw Sesame Flour (RSF)
Whole sesame seeds were dehulled by soaking in water (1: 5 w/v) for 4 h at 29 ± 2°C according to the method reported by Mohamed *et al.* (2007). The ruptured seed coats were then removed by rubbing with palms and washed with water. The dehulled seeds were spread on trays and sundried for 4 h. The dried seeds were milled (Wiley mill, 30 mesh) to obtain raw sesame flour (RSF) and stored in glass container.

Open pan Roasted Sesame Flour (ORSF)
The dried dehulled sesame seeds (200g) were roasted in an open iron pan at a temperature of 75 – 85°C with continuous stirring for 20 min until the seeds turned golden brown. After roasting, the seeds were allowed to cool to ambient temperature, milled (Wiley mill, 30 mesh) to obtain open pan roasted sesame flour (ORSF) and stored in glass container.

Microwave Roasted Sesame Flour (MRSF)
The dried seeds (200g) were spread on the glass plate of a domestic-size Beko microwave oven (BKMD 1550) capable of generating 1330 watt powers at 2450 MHz. The microwave oven used operates at a frequency of 2450 MHz, with 1330, 931, 665 and 399 watts of output with power levels of high, medium high, medium and defrost, respectively. Samples were microwave treated at medium power level (665W) for 10 min. Each time the plate of the microwave oven contained 200 grams of seeds with a depth of 1 cm. After roasting, the seeds were allowed to cool to ambient temperature, milled (Wiley mill, 30 mesh) to obtain microwave roasted sesame flour (MRSF) and stored in glass container.

Proximate Analysis
Proximate analysis was determined following the standard methods of the Association of Official Analytical Chemists (AOAC, 2005). Different samples were analysed in triplicate and the results were reported as means. Total carbohydrate content was calculated from the difference. The energy value was estimated (kcal/100g) following the method as described by Ekanayake *et al*. (1999).

Determination of mineral contents
Analysis of potassium content of the samples was carried out using flame photometry, while phosphorus was determined by the phosphovanado-molybdate (yellow) method (AOAC, 2005). The other elements (Ca, Mg, Fe, Zn and Mn) were determined, after wet digestion of sample ash with an Atomic Absorption Spectrophotometer (AAS, Hitachi Z6100, Tokyo, Japan). All the determinations were carried out in triplicates.

Determination of vitamin content
Thiamine (vitamin B1) and riboflavin (vitamin B2) were determined by using spectrophotometric method (AOAC, 2005). Niacin content was determined by high performance liquid chromatography (HPLC) according to the method of Ward and Trenerry (1997).

Determination of anti-nutritional compounds
Phytate content of each sample was determined according to the method described by Maga (1982). The titration method was used to determine the oxalate content according to Day and Underwood (1986).

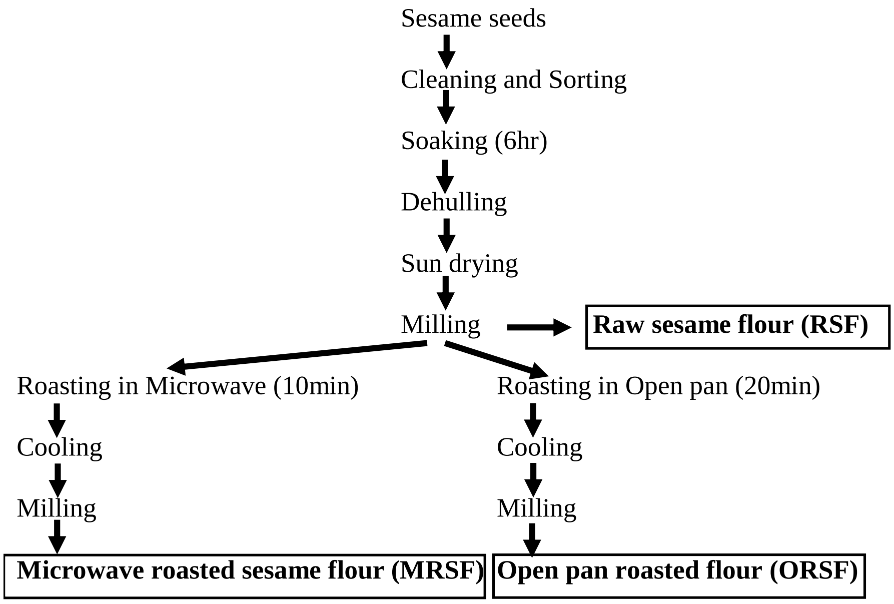

Figure 1. Flow diagram for preparation of raw and roasted sesame flour

Colour value measurement

The colour of raw and roasted sesame flour was measured using the Konica Minolta Spectrophotometer (CR- 410, Japan). The flour samples (30g) were placed in the sample holder and the surface colour was measured at three different positions. The colour readings were displayed as L* a* b* values where L (100 = white; 0 = black) is an indication of lightness; *a** measures chromaticity, with positive values indicating redness and negative values indicating greenness; while *b** also measures chromaticity, with positive values indicating yellowness and negative values indicating blueness. Each sample was analyzed in triplicate.

Determination of seed oil characteristics

The seed oils of the samples were extracted using Soxhlet apparatus and the rancidity indices (peroxide value and iodine value) were determined according to Official American Oil Chemist's Society methods (AOCS, 1985). The peroxide values were expressed as milliequivalents of peroxide oxygen per kg of sample ($mEqO_2$/kg oil) while iodine values were expressed in g I_2/100 g oil.

Statistical analysis

Determinations were carried out in triplicates and the error reported as standard deviation from the mean. Analysis of Variance (ANOVA) was performed and the least significant differences were calculated with the SPSS software for window release 16.00; SPSS Inc., Chicago IL, USA. Significance was accepted at $p \leq 0.05$ levels.

RESULTS AND DISCUSSION

Effect of roasting on chemical composition

The proximate compositions of raw and roasted sesame (*Sesamum indicum* L.) flours are presented in Table 1. Crude fat content increased from 52.37g/100g in RSF to 58.9g /100g in ORSF which is about 13% increase, however in MRSF about 11% increase was observed. The crude fibre also increased by 80% and 59% in ORSF and MRSF respectively compared to RSF. The increase in fat and fiber content in roasted sesame flour is the direct result of the concentration of the constituents during roasting brought about by loss of moisture. Dietary fiber has a number of beneficial effects related to its non-digestibility in the digestive tract (Asp, 1996). Also, fat is important in diets because it promotes fat soluble vitamin absorption and as such sesame seed can be considered as a potential source of vegetable oil for domestic and industrial purposes. The increase in fat content was in good agreement with those indicated by different authors (Damame *et al.,* 1990; El-Badrawy *et al*., 2007) on roasted peanut.

Similarly the ash content increased from 2.88 g/100g in RSF to 3.11 g/100g and 3.67 g/100g in ORSF and MRSF respectively. Statistical results indicated that the protein of sesame is in the order of RSF > MRSF> ORSF. The roasting process accelerates the Maillard reactions and subsequently making the protein and its amino acids significantly unavailable for digestion which explains the observed decrease in the protein content of roasted flours (Makinde and Akinoso, 2014). The raw sample is higher in protein than reported values in the literature for other oilseeds, e.g. cashew nuts (22.8%) and cottonseed (21.9%), and that of animal proteins (16.0-18.0%) such as lamb, fish, and beef (Ajayi *et al.,* 2006). Likewise, the protein content of 23.6 g/100g in sesame seed suggests that it can contribute to the recommended daily protein need of adults (Ajayi *et al.,* 2006). This protein value also falls within the recommended daily allowance for children (23.0-36.0g/100g) as provided by NRC (1989).

Table 1: Chemical composition of sesame seeds flour (g/ 100g dry weight).

Parameter	RSF	ORSF	MVRF
Ash	2.88±0.03[a]	3.11±0.04[b]	3.67±0.03[c]
Protein	27.53±0.02[c]	24.35±0.06[a]	26.31±0.04[b]
Fat	52.37 ±0.04[a]	58.97±0.06[b]	58.54±0.02[b]
Crude fiber	3.86 ±0.05[a]	6.94 ±0.03[c]	6.13±0.03[b]
Carbohydrate	13.18±0.02[c]	6.61±0.04[b]	5.38 ±0.05[a]
Energy (kcal/100g)	552.51[a]	576.61[c]	573.40[b]

Values are means ± standard deviation of triplicate determinations. Means within a row not followed by the same superscript are significantly different ($p \leq 0.05$). RSF- Raw sesame flour; ORSF- Open pan roasted sesame flour; MRSF- Microwave roasted sesame flour.

The carbohydrate values of MRSF and ORSF were significantly lower than RSF. The loss in carbohydrate due to roasting may be attributed to the role of sugar as a precursor in the production of roasted sesame flavour, where it provide a source of carbon for the production of flavour compounds as a result of Maillard reaction (Koehler *et al.,* 1969). The significant differences recorded in calculated energy values of raw and roasted flours reflect differences in the observed values of other proximate composition as discussed above. The energy values of 552.5, 576.6 and 573.4 kcal/100g for RSF, ORSF and MRSF indicate that 497.7g, 476.9g and 479.6g of these samples would, respectively, provide 2750 kilocalories – an energy value which falls within the range of the daily calorie requirement of 2500 to 3000 kilocalories for adults (Onyeike and Oguike, 2003).

The differences in the mineral composition between raw and roasted sesame samples are presented in Table 2. The predominant mineral was calcium followed by phosphorus, magnesium and potassium. Concentrations of major elements such as calcium, magnesium and potassium in RSF (439.25, 357.38, 342.14 mg/100g) were significantly ($P \leq 0.05$) lower than ORSF (445.02, 365.95 and 345.98 mg/100g) and MRSF (442.27, 364.03 and 346.77mg/100g). Digestibility of nuts and oilseed are reported to increase by roasting, this might be responsible for the release and increment in some mineral content (Mohini and Eram, 2005). In contrast, roasting affected the iron and manganese contents of the sesame seeds in varying proportions.

The results also showed that iron content of RSF was 6.42 mg/100g while it reduced to 4.98 and 3.06 mg/100g in ORSF and MRSF respectively. Similarly, the manganese content of RSF was 1.50 mg/100g while 0.87 and 0.76 mg/100g were recorded for ORSF and MRSF respectively. The ratio of Ca/P of the flour samples range between 1.01 for RSF, 1.04 for ORSF and 1.03 for MRSF respectively. The ratio of Ca/P indicated that raw and roasted sesame were good sources of these essential mineral elements as food products containing Ca/P ratio of greater than 1.0 is rated good, while less than 0.5 is rated poor (Nieman *et al*., 1992). The same value (0.43) was recorded for [K/ (Ca+Mg)] ratio of RSF, ORSF and MRSF. The ratio is of great concern for the prevention of disease known as hypomagnesaemia. The milliequivalent of [K/ (Ca+Mg)] of less than 2.2 is recommended in food sample (Marten *et al*., 1987); hence consumption of raw and roasted sesame flour may not lead to hypomagnesaemia.

There was significant reduction in vitamin content of sesame when subjected to roasting as presented in Table 3. Riboflavin level decreased by almost 25.40%, thiamine by 47.60% and niacin by 42.4% respectively in ORSF compared to RSF. Similarly, 15.86% riboflavin, 29.70% thiamine and 31.42% niacin were lost in MRSF. Results showed that roasting significantly affected vitamin content of sesame seed. Nutritional substances, such as vitamins and amino acids, may be destroyed or they can be blocked by reactions with other ingredients during roasting.

Table 2. Mineral composition of sesame seeds flour samples (mg/ 100g dry weight)

Sample	RSF	ORSF	MRSF
Ca	439.25±1.00[a]	445.02±0.58[c]	442.27±0.43[b]
Mg	357.38±0.54[a]	365.95±0.51[c]	364.03±0.63[b]
K	342.14±0.69[a]	345.98±0.47[b]	346.77±0.52[c]
P	434.77±0.97[c]	428.46±0.64[b]	427.81±0.72[a]
Fe	6.42±0.02[c]	4.98±0.04[b]	3.06±0.03[a]
Mn	1.50±0.02[c]	0.87±0.03[b]	0.76±0.01[a]
Zn	2.79±0.04[a]	3.07±0.04[b]	3.62±0.05[c]
Ca/P	1.01[a]	1.04[a]	1.03[a]
K/(Ca+Mg)	0.43[a]	0.43[a]	0.43[a]

Values are means ± standard deviation of triplicate determinations.
Means within a row not followed by the same superscript are significantly different ($p \leq 0.05$).
RSF- Raw sesame flour; ORSF- Open pan roasted sesame flour; MRSF- Microwave roasted sesame flour

Table 3. Vitamin content of sesame seed flours (mg/Kg dry weight)

Sample	RSF	ORSF	MRSF
Thiamine	40.23±0.18^{c}	21.08±0.15^{a}	28.28±0.20^{b}
Riboflavin	20.56±0.24^{c}	15.33±0.07^{a}	17.30±0.12^{b}
Niacin	4.52±0.03^{c}	2.60±0.01^{a}	3.10±0.02^{b}

Values are means ± standard deviation of triplicate determinations
Means within a row not followed by the same superscript are significantly different ($p \leq 0.05$).
RSF- Raw sesame flour; ORSF- Open pan roasted sesame flour; MRSF- Microwave roasted sesame flour

Table 4. Anti-nutrient concentration of sesame seed flour (mg/ 100g dry weight)

Sample	RSF	ORSF	MRSF
Phytate	25.64±0.42^{c}	5.07±0.03^{a}	8.02±0.04^{b}
Oxalate	63.70±0.11^{c}	15.16±0.03^{a}	17.50±0.05^{b}

Values are means ± standard deviation of triplicate determinations
Means within a row not followed by the same superscript are significantly different ($p \leq 0.05$).
RSF- Raw sesame flour; ORSF- Open pan roasted sesame flour; MRSF- Microwave roasted sesame flour

The anti-nutritional factors of raw and roasted sesame flours are presented in Table 4. The values of oxalate were 63.70, 15.16 and 17.50mg/100g for RSF, ORSF and MRSF respectively. Microwave roasting reduced the oxalate content by 72.5% with open pan roasting causing further decrease (76.30%) in the activity of this anti nutrient. The significant loss of oxalate in ORSF and MRSF could be attributed to the destruction of the oxalate at high temperature as oxalates were heat labile. Similar to oxalate reduction activity, roasting process caused significant decrease in phytate level. It was reduced up to 80.23% in ORSF and 68.72% in MRSF. The reduction of phytate concentration is an indication of chemical degradation of phytate to lower inositol phosphates and inositol or cleavage of the phytate ring itself during roasting (Chen and Betty, 2003). The reduction in phytate and oxalate levels could be interpreted as the main reason for the observed increase in the concentrations of some of the minerals during roasting.

Effect of roasting on colour

Roasting had a significant effect on colour values of sesame flour as presented in Table 5. The colour of sesame flour showed a significant decrease ($p \leq 0.05$) in L values of ORSF and MRSF while there was significant increase in a (redness) and b (yellowness) values compared to RSF. This is an indication that the colour of the roasted flour is darker and less saturated than that of the unroasted flour. Colour development depends on the creation of brownish-colored polymeric compound known as melanoidins. Melanoidins are water-insoluble, high molecular weight compounds formed through Maillard browning products that correspond directly to colour development in foods.

Effect of roasting on oil constants

The peroxide and iodine values of raw and roasted sesame seed oil are presented in Table 6. The chemical properties of oil are amongst the most important properties that measures of oil quality. The lowest peroxide value was the characteristics of oil extracted from RSF (1.43 $mEqO_2$/kg oil) while 10.05 and 11.40 $mEqO_2$/kg oil were recorded for the MRSF and ORSF respectively. The peroxide value is a measure of the content of hydroperoxides, which are primary oxidation products. They are extremely unstable and decompose *via* fission, dehydration, and formation of free radicals to yield a variety of chemical products, such as alcohols, aldehydes, ketones, acids, dimmers, trimers, polymers, and cyclic compound (Tan *et al.*, 2001) including the volatile compounds responsible for off-flavours in seed oils and olive oils. The oxidation of oil seeds accelerates during microwave heating, which leads to the formation of reactive radicals which account for the higher peroxide value compared to RSF. This is an indication of decreased stability and increased rancidity of the oil during microwave heating. Yoshida *et al.* (1990) have also reported an increased peroxide value during microwave treatment of linseed, soybean, corn, olive and palm oil. Meanwhile the only condition for obtaining the highest peroxide value for ORSF was as a result of roasting the seeds in air with higher humidity.

Table 5. Colour values of sesame seed flour

Attribute	Samples		
	RSF	ORSF	MRSF
L*	70.40±0.19^{c}	57.22±0.16^{a}	60.18±0.12^{b}
a*	-1.13±0.01^{a}	9.20±0.03^{c}	7.86±0.08^{b}
b*	12.91±0.07^{a}	28.38±0.15^{c}	26.20+0.05^{b}

Values are means ± standard deviation of triplicate determinations
Means within a row not followed by the same superscript are significantly different ($p \leq 0.05$).
RSF- Raw sesame flour; ORSF- Open pan roasted sesame flour; MRSF- Microwave roasted sesame flour

Table 6: Characteristics of oil extracted from sesame seed.

Parameters	Samples		
	RSF	ORSF	MRSF
Iodine value (g I/100g oil)	118.65±0.48^c	106.44±0.15^a	109.71±0.16^b
Peroxide value (mEqO^2/Kg oil)	1.43±0.03^a	11.21±0.04^c	10.02±0.03^b

Values are means ± standard deviation of triplicate determinations
Means within a row not followed by the same superscript are significantly different ($p \leq 0.05$).
RSF- Raw sesame flour; ORSF- Open pan roasted sesame flour; MRSF- Microwave roasted sesame flour

The properties of fat may depend on the moisture content contained in it. Increased water content in the material subjected then to thermal treatment contributes to the formation of smaller quantities of bronze substances, which significantly influence the nature of oxidative changes in fat (Yoshida *et al*., 1995). Fresh oils have values less than 10 mEq O_2/kg oil, however, it has been shown that oils become rancid when the peroxide value ranges from 20.0 to 40.0 mEq O_2/kg oil (Ajayi *et al.*, 2006).

Iodine value of RSF was 118.65 g I/100 g oil while 106.44 and 109.71 g I/100 g oil were recorded for the ORSF and MRSF respectively. The iodine number of oil is the number in grams of iodine which can be absorbed by 100g of the oil, and it measures the amount of unsaturated fatty acids occurring in the oil. Iodine does not react readily with the double bonds of oil/fat molecule and the quantity of iodine absorbed by oil is an index of its degree of unsaturation. The RSF oil had the highest iodine value indicating a high degree of unsaturation. This loss of the unsaturation degree in ORSF and MRSF as a result of roasting due could be due to the degradation of the natural antioxidants (tocopherol, sesamin and sesamol) of sesame oil. Moreover, it has been reported that the oxidative degradation of the oil during microwave heating depends on its natural antioxidant content (Dostalova *et al*., 2005). However, it is imperative to note that the quality of oil depended on power, time and temperature of microwave treatment as longer microwave heating times, temperatures and high-power setting resulted in a greater degree of oil deterioration (Tan *et al*., 2001).

CONCLUSIONS

This work has shown that significant improvement in the nutritional value of *Sesamum indicum* can be attained through roasting of the seeds prior to conversion into flour. However, open pan roasting offers greater reduction of inherent anti-nutrients (phytate and oxalate), over its microwave counterpart. Extracted oil from open pan and microwave roasted seeds showed similar characteristics but significantly different from that of raw sesame oil, indicating that quality of oil is affected by roasting treatment. The present study indicates that microwave roasting can be used as a desirable energy - saving alternative to open pan roasting technique of sesame seeds; however, further study is needed to evaluate the cost of this process, as well as the technical feasibility of setting up an industrial process.

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