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Influence of superheated steam roasting at different temperatures and times on the color changes and fats quality of the sesame seeds and its oils

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Abstract

This study was carried out to determine the effect of superheated steam and convectional roasting at 150-250°C for 5-20 mins on color changes and fat quality of the sesame seeds and its oils. Color measurements and chemical analyses were conducted to analyze the quality attribute of the roasted sesame seeds and its oils. The use of superheated steam roasting showed a great impact on overall color changes in the sesame seeds and its oils. The different roasting time at 250°C significantly ($p < 0.05$) affected the color values of sesame oils during superheated steam roasting. Linoleic acid, oleic acid, stearic acid, palmitic acid, lauric acid and butyric acid found in roasted seeds in both roasting methods. Significant ($p < 0.05$) differences existed for the fatty acids of conventional roasted sesame oil at 250°C at 20 and 25 mins. The *p*-anisidine value of sesame oil prepared from the superheated steam roasted sesame seeds was lower than conventional roasting sample at 250°C for 20 mins. The methods of superheated steam and conventional roasting significantly ($p < 0.05$) affected the *p*-anisidine values of sesame oils at 250°C for 20 and 25 mins. The *p*-anisidine value of oils obtained from the superheated steam roasted sesame seeds increased with the extension of roasting times.

Introduction

Sesame (*Sesamum indicum* L.) provides a good source of edible oil and is a major oilseed crop in this world (Namiki, 1995). Sesame is believed to have originated in Africa and is among the first recorded plants for its seeds (Ram *et al.*, 1990). Sesame is cultivated in many countries like India, China, Sudan, and Burma which contributes 60% of its total world production (Abou-Gharbia *et al*., 1997). Sesame has high nutritional values in human diets and is used in confectionary and bakery products (Abou-Gharsia *et al*., 1997). Highly stable oil contents, a protein which is rich in tryptophan, valine, and methionine, and savory nutty roasted flavor of the sesame seeds is causing the wide usage of sesame seeds in the world. In general, the sesame seeds contain 55% lipid and 20% protein (Abou-Gharsia *et al*., 1997). Besides, health-promoting characteristics of the sesame seeds have been reported in many studies (Kita *et al.,* 1995; Ozdemir and Devres, 2000).

Roasting is the most vital procedure in the nut, coffee and bean processing. This is because roasting process causing the physical and chemical changes of the roasted sesame seeds (Ozdemir and Devres, 2000). For the production of the sesame's products, the basic unit operation is roasting process. In order to promote more flavor and desired the colour that finally increases the overall palatability, the sesame is roasted. The sesame oil extracted from the roasted sesame seeds is also has a premium flavor and a longer shelf life (Kikugawa *et al*., 1983). According to Abou-Gharbia *et al.* (1997), the oil content of sesame seeds showed outstanding stability to oxidation. Yoshida and Kajimoto (1994) showed that the outstanding stability of the sesame oil to oxidation found due to plenty antioxidants (lignans) with tocopherol.

There are many methods of roasting of sesame in food industries. Superheated steam is the steam at a temperature there is higher than its vaporization point under normal pressure. Superheated steam roasting gives a lot of benefits compared to hot air roasting or conventional roasting (Asmaa *et al*., 2015). Firstly, the energy wastage that occurs with superheated steam roasting is lower than the energy wastage that occurs with conventional roasting as the superheated steam is circulated in a closed-loop drying system and the steam from the evaporation of moisture within the food material contain heat energy that can be reused in the processes to save

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the energy (Zzaman and Yang, 2013). Besides, the roasting rate is enhanced due to the high heat transfer coefficient of superheated steam roasting and this will lead to increase of the production efficiency and finally will decrease the capital cost and equipment size. Furthermore, the oxygen free environment can be created inside the system during the superheated steam roasting process, so there is no oxidation occurs and this can enhance the product qualities and remove explosion and fire risks (Yoshida and Hyodo, 1996). The superheated steam roasting can decrease or eliminated environment pollution because the small amount of vapor generated from the moist food product is released to atmosphere from the closed-loop system. The vapor can be condensed and the dust in the vapor can be collected easily. Moreover, the rate of superheated steam roasting is higher than the rate of conventional roasting (Shan *et al*., 2016). However, superheated steam roasting has some disadvantages too. The major disadvantages of superheated steam roasting drying are the very high temperature of the superheated steam roasting is unsuitable for temperature-sensitive products and superheated steam roasting needs more complex roasting systems if compared with hot-air roasting (Yoshida and Hyodo, 1996; Zzaman and Yang, 2013). The control of the roasting process is vital because of the roasting influence the quality of the sesame products. Thus, the optimum roasting conditions should be found out to ensure the quality of final sesame products. Therefore, the aims of this study were to compare the quality of color changes and fat quality of the sesame seeds and its oils subjected to superheated steam and conventional roasting methods.

Materials and Methods

Raw material

Sesame seeds (*Sesamum indicum* L.) were purchased from Meera Sahid Sdn Bhd which located at Chulia Street, George Town, Pulau Pinang. The sesame seeds were kept at room temperature until the roasting process.

Equipment

Superheated steam oven (AX-1500V, Sharp) was used for the roasting of sesame seeds. Komet Screw Oil Expeller (D 85-1G) was used to extract the oil from the roasted sesame seeds. Balance (Dragon 3002, Mettler Toledo) was used for all weighing purposes. Minolta Spectrophotometer (CM-3500d, Osaka) was used to measure the color of the roasted sesame seeds and its oils. Gas-liquid chromatography-flame ionization detector (GC-2010 Plus, Shimadzu) was used for analysis of the fatty acid composition of the sesame oils. The centrifuge (4000, Kubota) was used during preparation of methyl ester. The UV spectrophotometer (UV-160A, Shimadzu) was used to analyze the *p*-anisidine value of the roasted sesame oils.

Roasting of sesame seeds

Sesame seeds were roasted in the superheated steam oven (Healsio, AX-1500V, SHARP) at temperature 150, 200 and 250°C at a time interval of 20, 10 and 5 mins respectively. The superheated steam oven with a pressure of approximately 1 bar, steam generation capacity of 16 cm^3/min, and steam engine heater of 900 W was used and distributed in a single layer on a plate during the roasting process. Roasted beans were stored in an airtight container for further analysis. The roasted sesame seeds were undergoing the preliminary color analysis to choose the optimum temperature from the above roasting conditions. The color analysis was done in triplicate for each sample.

From the result, it showed that the overall color changes of the sesame seeds at 150 and 200°C were too slow and considered as not optimum temperature for mass production of sesame product at food industries. Besides, the changes of L-values too slow to reach the desired light color of roasted sesame seeds, so the roasting temperature of 150 and 200°C is considered as not optimum. The optimum roasted temperature chosen is 250°C and time chosen was 10, 15, 20, 25, and 30 mins as the sesame seeds are burnt after roasted for 30 mins and the burnt sesame seeds produced off-flavour which may cause the customer to reject its products.

In order to compare with the conventional roasted sesame, the sesame seeds were also roasted in the superheated steam oven (Healsio, AV-1500V, SHARP) in the conventional mode in temperature 250°C in 20 and 25 mins. Then, the oils of 250°C superheated steam roasted sesame seeds and 250°C conventional roasted sesame seeds were then extracted by using Komet Screw Oil Expeller (D 85-1G).

Oil extraction from roasted samples

The sesame oils prepared from roasted sesame seeds were extracted with Komet Screw Oil Expeller (D 85-1G). The sesame oils gained were collected and kept in the universal bottles which were wrapped with aluminum foil to avoid light sensitive reaction to occur during storage. The sesame oils were stored in the chiller at the temperature in the range of 0 to

5°C. The sesame oils were not stored in the freezer as the analysis of sesame oils need to be done in shortest time to avoid changes of the sesame oil quality.

Colour analysis

The color of the roasted sesame seeds and oils were analyzed by using the Minolta Spectrophotometer (CM-3500d, Osaka) with zero calibration. Then, it was calibrated with white calibration plate (CM-A120). *L*-value, *a*-value, and *b*-value of all roasted samples (sesame seeds) and oil samples (sesame oils) were gained. The *L*-value indicates the lightness and is a measure of light intensity of a sample (*L*=100 is the lightest and *L*=0 is the darkest); a-value stands for the chromatic scale from green color (negative a-value) to red color (positive a-value); the b-value stands for the chromatic scale from blue color (negative b-value) to yellow color (positive b-value). The color measurement analyses were carried out in triplicate for each sample. These data were used to calculate the browning index value. The graphs of the browning index of roasted sesame seeds and sesame oils versus time were plotted (Maskan, 2001).

$$\text{Browning Index} = [100(x-0.31)]/0.17$$

$$\text{Where, } x = (a+1.75L)/(5.645L+a-3.012b)$$

Analysis of fatty acid composition

The fatty acid composition of the sesame oils was analyzed by using gas-liquid chromatography-flame ionization detector (GC-2010 Plus, Shimadzu). To analyze the fatty acid composition, the fatty acids of the sesame seed oils were undergone methyl esterification to become methyl ester. The patterns of methyl esters from the test were compared with authentic oils for identification. The standard of fatty acid methyl ester mixture used for this analysis is SupelcoTM 37 Component FAME Mix.

According to the method described by Mondello (2006), methyl esters of sesame oils were prepared. Approximately 0.05 g of oil was added to 1 ml of boron trifluoride and heated to 100°C. After heating, the mixture was then left cooled for 30 mins. Then, 1 ml of hexane and followed by 4 ml of distilled water were added into the mixture after it was cooled. The solution was then agitated for 1 mins. After that, the solution was centrifuged for 1 minute by using centrifuge (4000, Kubota). Then, the upper layer of the solution was taken to analyze the fatty acid composition by using gas-liquid chromatography-flame ionization detector (GC-2010 Plus, Shimadzu).

Analysis of p-anisidine value

After the sesame oils kept in the chiller for two weeks, the *p*-anisidine value of the sesame oil was done by using AOCS Cd 18-90 (2003). The analysis was done in triplicate for each sample. Approximately 0.5 g sesame oil was weighted by using balance (Dragon 3002, Mettler Toledo) and then dissolved with isooctane and made up to 25 ml with the same solvent. Approximately 5 ml of the oil solution was transferred into one test tube. The absorbance of oil solution was measured at 350 nm with UV spectrophotometer (UV-160A, Shimadzu), using isooctane as blank in the reference cuvette.

The 0.25% *p*-anisidine solution was prepared by mixing the 0.125 g of *p*-anisidine with 50 ml of distilled water and kept it in the dark. The 5 ml oil solution was then mixed with 1 ml of 0.25% *p*-anisidine solution and kept in the dark for exactly 10 mins. The reference solution was prepared by mixing 5 ml of isooctane with 1ml of *p*-anisidine solution and left for 10 mins exactly. The absorbance of oil solution after reaction with the *p*-anisidine solution was measured at 350 nm with UV spectrophotometer (UV-160A, Shimadzu), using reference solution as blank in the reference cuvette.

The absorbance of the oil solution was used to count the *p*-anisidine value of the sesame oil by using this formula:

$$p\text{-anisidine value} = ([25X\ (1.2A_s-A_b)])/m$$

Where,
A_s= absorbance of oil solution after reaction with *p*-anisidine solution at 350 nm
A_b= absorbance of oil solution at 350 nm
m= mass (g) of the sample

Statistical analysis

The analyses were carried out in triplicate for each sample. The result of the analysis was calculated by using a computer program Statistical Package for the Social Science (SPSS) 16.0. The significance of difference was defined at $p < 0.05$.

Results and Discussion

Color analysis of sesame seeds and its oils

Three scales of measured color which represent the particular color value of the material indicated as *L-, a-,* and *b-* values. From these color values, browning index can be calculated. All analysis was done in triplicate for each sample. The result of the color measurements of the roasted sesame seeds and sesame oils are summarized in Table 1. The One-way

Table 1. Color measurement of roasted sesame seeds using superheated steam mode with different roasting times and temperatures

Temperature (°C)	Time (minutes)	Color			Browning Index
		Lightness, L*	Redness, a*	Yellowness, b*	
150	0	71.61±0.01^{c}	0.69±0.02^{j}	21.16±0.01^{j}	34.88
	20	71.84±0.03^{b}	2.60±0.02^{i}	23.83±0.01^{i}	42.06
	40	72.36±0.02^{a}	3.84±0.01^{h}	26.02±0.01^{h}	47.47
	60	71.26±0.01^{d}	4.95±0.02^{g}	27.27±0.01^{g}	52.24
	80	69.79±0.02^{e}	5.39±0.01^{f}	27.44±0.01^{f}	54.53
	100	69.63±0.01^{f}	6.22±0.01^{e}	28.62±0.01^{e}	58.29
	120	68.39±0.01^{g}	6.60±0.01^{d}	29.21±0.02^{d}	61.47
	140	66.99±0.01^{h}	7.74±0.01^{c}	30.53±0.01^{c}	67.76
	160	65.14±0.01^{i}	8.47±0.01^{b}	31.06±0.01^{b}	72.53
	180	63.37±0.03^{j}	9.74±0.01^{a}	32.14±0.01^{a}	79.82
200	0	71.02±0.03^{a}	0.71±0.02^{j}	21.03±0.02^{k}	34.88
	10	67.87±0.02^{b}	6.91±0.01^{i}	29.13±0.01^{b}	62.24
	20	50.99±0.01^{c}	12.12±0.02^{e}	30.51±0.02^{a}	104.18
	30	44.71±0.01^{d}	12.94±0.02^{b}	28.87±0.02^{c}	118.35
	40	41.05±0.01^{e}	12.95±0.01^{b}	27.00±0.01^{d}	122.94
	50	37.41±0.01^{f}	12.95±0.01^{b}	24.64±0.02^{e}	125.35
	60	36.77±0.01^{g}	13.28±0.01^{a}	24.62±0.01^{e}	128.94
	70	30.93±0.01^{h}	12.25±0.02^{d}	19.47±0.01^{f}	122.12
	80	30.32±0.01^{i}	12.31±0.02^{c}	18.66±0.04^{g}	119.82
	90	28.89±0.01^{j}	12.07±0.01^{f}	16.98±0.02^{h}	114.71
	100	28.22±0.01^{k}	11.85±0.02^{g}	16.45±0.04^{i}	113.88
	110	27.14±0.01^{l}	11.37±0.02^{h}	15.10±0.02^{j}	108.47
250	0	71.10±0.02^{a}	0.73±0.01^{k}	21.10±0.02^{k}	35.06^{g}
	5	73.69±0.01^{b}	2.29±0.02^{f}	23.21±0.01^{b}	39.29^{f}
	10	64.80±0.01^{c}	8.03±0.02^{d}	30.30±0.01^{a}	70.41^{d}
	15	32.07±0.02^{d}	13.01±0.01^{a}	21.11±0.03^{c}	129.35^{a}
	20	25.63±0.02^{e}	12.09±0.01^{b}	15.49±0.01^{d}	121.76^{b}
	25	19.21±0.01^{f}	8.47±0.02^{c}	7.26±0.03^{e}	78.12^{c}
	30	17.36±0.01^{i}	6.09±0.02^{e}	4.22±0.01^{f}	52.41^{e}
	35	14.90±0.01^{k}	1.78±0.02^{g}	0.67±0.05^{g}	13.00^{h}
	40	15.12±0.01^{j}	1.77±0.01^{g}	0.82±0.03^{h}	13.82^{h}
	45	15.39±0.01^{i}	1.24±0.02^{h}	0.57±0.01^{i}	9.47^{i}
	50	16.13±0.01^{h}	1.10±0.02^{i}	0.37±0.01^{j}	7.12^{j}
	55	16.56±0.01^{g}	0.94±0.03^{j}	0.38±0.03^{j}	6.35^{j}

-Mean ± Standard deviation. Means within a column with different letters are significantly different ($p<0.05$) at three different (150, 200 and 250^{0}C) roasting temperature.

ANOVA was used to show that roasting temperature significantly ($p<0.05$) affected the color values of sesame seeds during superheated steam roasting.

The changes in *L-, a-, b-* and browning index values of the sesame oils which prepared from superheated steam roasted sesame seeds at different times at 250°C is expressed in Figure 1. The One-way ANOVA was used to show that different roasting time at 250°C significantly ($p < 0.05$) affected the color values of sesame oils during superheated steam roasting. The color measurement of superheated steam roasted sesame oils was compared with the color measurement of conventional roasted sesame oils at 250°C for 20 and 25 mins. The One-way ANOVA was used to display that the methods of roasting which are superheated steam and conventional roasting significantly ($p < 0.05$) affected the color values of sesame oils at 250°C for 20 and 25 mins.

For food products, one of the most significant appearance characteristics is color due to customer acceptability is affected by it (Maskan, 2001). In controlling a process, the colour of the food product is a vital indicator. In general, the roasting process depends on the extent of the color formation. This is because, during the roasting process, browning and caramelization occur and enhance the formation of brown pigments of the product (Saklar *et al*., 2001).

The whiteness of the sesame seed is represented by the *L-* value. When sesame seeds were roasting with superheated steam for temperature 150°C, 200°C and 250°C, the *L-* values gradually decreased. These results showed that the sesame seeds were darker during the superheated steam roasting process. The darkening of the sesame seeds was caused by the increase of the browning pigments due to Maillard browning and caramelization process (Saklar *et al*., 2001).

The redness of the sesame seed is represented by *a-* value. When sesame seeds were roasted with superheated steam at 150°C, the *a-* values gradually increased. However, this trend was not similar as with temperature 200°C and 250°C. For the 200°C of superheated steam roasting temperature, the *a-* values for the sesame seeds increased sharply to a value of 12.12±0.02 after 10 mins of the roasting process, and a-values maintained until after 60 mins, then the a-values slowly decreased. For the 250°C superheated steam roasting temperature, the *a-* values for the sesame seeds improved sharply to a value of 8.03±0.02 after 5 mins of the roasting process, and then the *a-*values slowly decreased after 15 mins of the roasting process. The raising of the a-values was caused by the brown pigments which were formed

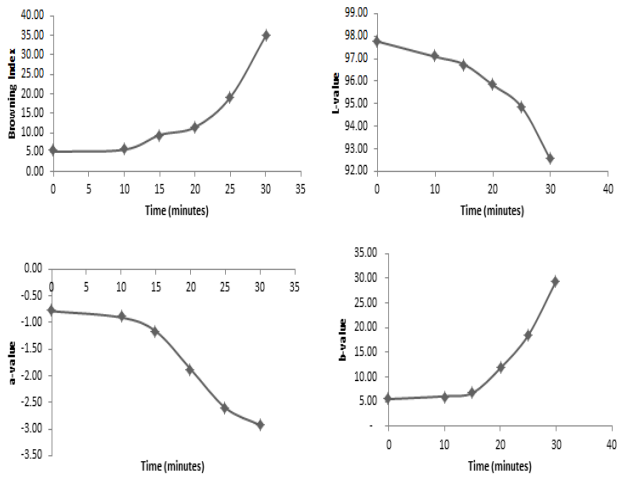

Figure 1. Changes in the colour parameters of superheated steam roasted sesame oils for 30 minutes at 250°C

through non-enzymatic browning and phospholipid degradation (Kahyaoglu and Kaya, 2006).

The spectrum of the yellowness is represented by the *b*-value. When sesame seeds were roasting with superheated steam for temperature 150°C, the *b*-values gradually increased. However, this trend was not same as with temperature 200°C and 250°C. For the 200°C superheated steam roasting temperature, the *b*- values for the sesame seeds improved to *a* value of 30.51±0.02 and then after 20 mins of the roasting process, the *b*-values decreased. For the 250°C superheated steam roasting temperature, the *b*- values for the sesame seeds increased to a value of 30.30±0.01 and then after 10 mins of the roasting process, and then the *b*-values decreased. Almost similar trends were observed as in the changes of *a*-values and *b*-values during the superheated steam roasting process (Idrus and Yang, 2012).

The purity of the brown color of the roasted sesame seeds indicated as the browning index (BI). The overall browning index value changes are shown in Figure 1. The browning index plot enabled us a better possibility to decide the roasting time when the darkening start. When sesame seeds were roasting with superheated steam for temperature 150°C, the BI was gradually increased. However, this trend was not similar as with temperature 200 and 250°C. For the 200°C superheated steam roasting temperature, the BI for the sesame seeds increased sharply until 30 mins of the roasting process, and BI was constantly up to 60 min, then BI was slowly decreased. For the 250°C superheated steam roasting temperature, the BI for the sesame seeds increased sharply up to 20 mins of the roasting process, and then sharply decreased until 35 mins before it slowly declined after that (Maskan, 2001; Idrus and Yang, 2012).

The color measurement of the sesame oils which prepared from the 250°C superheated steam roasted sesame seeds was also conducted. The *L*-value observed was reduction slowly from 0 to 30 min, while the *a*-value observed declined slowly and the *b*- value observed increased. The browning index increased slowly up to 20 mins then improved sharply to a value of 34.88 at 30 mins. The color analysis of 250°C superheated steam roasting of sesame oil was compared with the color analysis of 250°C conventional roasting of sesame oil at 20 and 25 mins. At 20 mins, the *L*-value for the superheated steam roasting sesame oil was lower than *L*-value of conventional roasting sesame oil. The *a*-value for the superheated steam roasting sesame oil was lower than *a*-value of conventional roasting sesame oil. The *b*-value for the superheated steam roasting sesame oil was higher than b-value of conventional roasting sesame oil. The BI for the superheated steam roasting sesame oil was higher than BI of conventional roasting sesame oil. At 25 mins, the *L*-value for the superheated steam roasting sesame oil was lower than *L*-value of conventional roasting sesame oil. The *a*-value for the superheated steam roasting sesame oil was lower than *a*-value of conventional roasting sesame oil. The *b*-value for the superheated steam roasting sesame oil was higher than b-value of conventional roasting sesame oil. The BI for the superheated steam roasting sesame oil was higher than BI of conventional roasting sesame oil.

The results of color measurements showed that the higher temperature of superheated steam roasting, the shorter the time taken to roast the sesame to get the desired brown color. Besides, the effect of superheated steam roasting is much greater than the effect of conventional roasting on the changes of color of the sesame oils. This is showed at the comparison of the changes of browning index of superheated steam roasted sesame oils with the changes of browning index of conventional roasted sesame oils in 25 mins at a 250°C roasting temperature (Kiralan, 2012). Overall, the color measurements which comprised of *L-, a-, b-* values and browning index varied significantly ($p<0.05$) for sesame seeds and oils subjected to superheated steam roasting with different roasting temperatures and times. This indicated that superheated steam roasting with various cooking and times showed an impact on overall color changes in the sesame seeds and oils. The effect of superheated steam roasting on the changes of color of sesame oils was desirable than produced that brown color of the oils if the roasting time was controlled.

Table 2. Fatty acid composition of the sesame oil prepared from superheated steam and conventional roasted sesame seeds at 20 min and 25 min at 250°C.

Fatty Acid (%)	Superheated steam Roasting		Conventional Roasting	
	20 min	25 min	20 min	25 min
Butyric Acid (C4:0)	4.35±0.09b	4.52±0.06ab	4.47±0.05ab	4.62±0.10a
Lauric Acid (C12:0)	13.12±0.13a	12.34±0.05c	11.65±0.06d	12.88±0.04b
Palmitic Acid (C16:0)	17.41±0.11a	15.06±0.10c	16.58±0.11b	17.49±0.07a
Stearic Acid (C18:0)	6.22±0.08a	6.32±0.04a	6.38±0.09a	6.34±0.04a
Oleic Acid (C18:1n9c)	32.57±0.11a	32.01±0.05b	31.03±0.11c	31.06±0.09c
Linoleic acid (C18:2n6c)	32.05±0.09b	32.79±0.13a	32.20±0.14b	33.12±0.16a

-Mean ± Standard deviation. Means within a column with different letters are significantly different ($p<0.05$)

Determination of fatty acid composition of sesame oils

The results for the fatty acid composition of the superheated steam roasted and conventional roasted sesame oils are summarized in Table 2. The patterns of methyl esters from the test were compared with standard of fatty acid methyl ester mixture for identification. From the results, the main fatty acid compositions of the sesame oil were linoleic acid (C18:2n6c), oleic acid (C18:1n9c), stearic acid (C18:0), palmitic acid (C16:0), lauric acid (C18:1n9c) and butyric acid (C4:0). The One way ANOVA is used to show the significant differences for the fatty acid composition of the 250°C superheated steam roasting sesame oils with various roasting temperatures. Although significant ($p < 0.05$) differences existed for those fatty acids of superheated steam roasted sesame oil at 250°C, there are no specific trends found for the minor compositional changes. For the superheated steam roasted sesame oils, the fatty acid compositions mainly consisted of 32% linoleic acid, 32% oleic acid, 6% stearic acid, 15% palmitic acid, 12% lauric acid and 5% butyric acid. For the conventional roasted sesame oils, the fatty acid compositions were 32% linoleic acid, 31% oleic acid, 6% stearic acid, 16% palmitic acid, 11% lauric acid and 4% butyric acid. Significant ($p < 0.05$) differences existed for the fatty acids of conventional roasted sesame oil at 250°C at 20 and 25 mins. Table 2 showed the fatty acids composition of superheated steam and conventional roasted sesame oil at 250°C at 20 and 25 mins. No significant ($p < 0.05$) differences existed for the fatty acids of superheated steam and conventional roasted sesame oil at 250°C at 20 and 25 mins. The results showed that these two different roasting methods significant differences in the fatty acid compositions of chicken sausages (Asmaa *et al*., 2015).

According to Yen (1990), the content of oleic and linoleic acids was sharply reduced when the sesame seeds were roasted at a temperature higher than 240°C. However, in this study, the content of oleic and linoleic acids of the superheated steam roasted sesame oil was not drastically reduced. The oxygen-free environment can be created inside the superheated steam system during the superheated steam roasting process easily, so there was no oxidation occurred and this can be explained the contents of oleic and linoleic acids of the superheated steam roasted sesame oil was not drastically reduced.

Linoleic acid (LA) is an unsaturated omega-6 fatty acid. Linoleic acid is an essential fatty acid that must be consumed for proper health. It is found in the lipids of cell membranes. It is abundant in many vegetable oils, comprising over half of poppy seed, safflower, sunflower, a corn oil (Goldberg and Williams, 1991). Oleic acid is a fatty acid that occurs naturally in various animal and vegetable fats and oils. Oleic acid is a common monounsaturated fat in the human diet. Monounsaturated fat consumption has been associated with decreased low-density lipoprotein (LDL) cholesterol and possibly increased high-density lipoprotein (HDL) cholesterol (Goldberg and Williams, 1991; Idrus *et al*., 2013).

Stearic acid is the saturated fatty acid with an 18 carbon chain and has the IUPAC name octadecanoic acid. Stearic acid is mainly used in the production of detergents, soaps, and cosmetics such as shampoos and shaving cream products (Goldberg and Williams, 1991). Palmitic acid, or hexadecanoic acid in IUPAC nomenclature, is the most common fatty acid found in animals, plants, and microorganisms. Its molecular formula is $CH_3(CH_2)_{14}CO_2H$. Palmitic acid is mainly

Table 3. p-anisidine value of superheated steam and conventional roasted sesame oils for 20 minutes and 25 minutes at 250°C.

Roasting Mode	Time (minutes)	p-anisidine value
Superheated steam roasting	20	3.63±0.04[a]
	25	7.81±0.04[b]
Conventional roasting	20	5.30±0.07[c]
	25	5.86±0.07[d]

-Mean ± Standard deviation. Means within a column with different letters are significantly different ($p<0.05$)

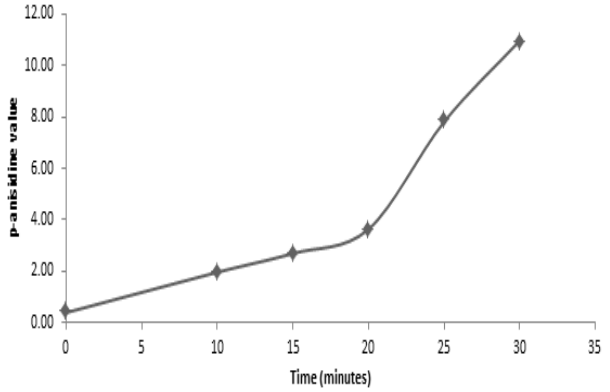

Figure 2. Changes in the p-anisidine values of oil prepared from superheated steam roasted sesame seeds at different roasting times at 250°C.

used to produce soaps, cosmetics, and release agents (Richard, 2007). Lauric acid is the saturated fatty acid with a 12-carbon atom chain, thus falling into the medium chain fatty acids. It is mainly used for the production of soaps and cosmetics (Goldberg and Williams, 1991). Butyric acid also is known under the systematic name butanoic acid is a carboxylic acid with the structural formula CH3CH2CH2-COOH. Butyric acid is a fatty acid occurring in the form of esters in animal fats. Butyric acid is used in the preparation of various butyrate esters (Richard, 2007; Issara *et al*., 2014).

Determination of p-anisidine value of sesame oils

The *p*-anisidine analysis was done after the sesame oils kept for two weeks to determine the effect of superheated steam roasting with various roasting times on the secondary oxidation products which are produced from the reaction of *p*-anisidine with unsaturated aldehydes in acidic condition. The changes of *p*-anisidine value of superheated steam and conventional roasted sesame oils for 20 and 25 mins at 250°C are shown in Table 3.

The changes in *p*-anisidine values of the sesame oils which were superheated steam roasted at a different time at 250°C were expressed in Figure 2. The One-way ANOVA was used to show that different roasting time at 250°C significantly ($p < 0.05$) affected the *p*-anisidine values of oils prepared from the superheated steam roasted sesame seeds. One-way ANOVA was also used to show that 20 and 25 mins of roasting time at 250°C significantly ($p < 0.05$) affected the *p*-anisidine values of oils prepared from the conventional roasted sesame seeds. The *p*-anisidine values of oils prepared from the superheated steam roasted sesame seeds at 250°C are gradually increased to a value of 3.63±0.04 at 20 mins and then increased sharply to a value of 10.96±0.07 at 30 mins. This showed that the secondary oxidation occurred rapidly at the 250°C superheated steam roasted sesame oil for 20 to 30 mins. This showed that the secondary oxidation occurred rapidly at the 250°C superheated steam roasted sesame oil for 20 to 30 mins. The oxidation stability of the superheated steam sesame oils affected badly during 20 to 30 mins because the *p*-anisidine value increased sharply.

The changes in the *p*-anisidine values of superheated steam and conventional roasted sesame oils were different at roasting times of 20 and 25 mins at 250°C. At roasting time of 20 mins, the *p*-anisidine values of oils prepared from the superheated steam roasted sesame seeds (3.63±0.04) was lower than the *p*-anisidine values of oils prepared from the conventional roasted sesame seeds (5.30±0.07). However, at roasting time of 25 mins, the *p*-anisidine values of oils prepared from the superheated steam roasted sesame seeds (7.81±0.04) was higher than the *p*-anisidine values of oils prepared from the conventional roasted sesame seeds (5.86±0.07). This showed that the secondary oxidation occurred much rapidly at the 250°C superheated steam roasted sesame oil during 20 to 25 mins compared with the conventional roasted one.

Yoshida and Kajimoto (1994) had been studied the *p*-anisidine value of the oil from sesame seed during microwave heating at the frequency of 2450 MHz and they reported that the *p*-anisidine value of sesame oil was 3.61 after 25 mins of microwave heating and this value was comparative low with the value reported for soybean. This reported *p*-anisidine value also was much lower than the *p*-anisidine value of

oils prepared from the superheated steam roasted and conventional roasted sesame seeds after 25 mins of roasting at 250°C which are 7.81±0.04 and 5.86±0.07 respectively. Aldehydes were the most common compounds that causing the off-flavor development in oils (Kathleen *et al*., 1995). Thus, *p*-anisidine reagent used for the reaction of α- unsaturated aldehydes and β- unsaturated aldehydes which are known as 2-alkenals and 2, 4-dienals (Nielsen, 2010). The reaction takes place in acetic acid solution and will produce Schiff base compounds (chromogen). The Schiff base compounds are in yellowish color and are measurable at 350nm wavelength of light. The *p*-anisidine value test mainly measures of 2-alkenals and 2, 4-dienals because the molar absorbance's increased if the aldehyde contains a double bond conjugated to the carbonyl double bond (Kathleen *et al.*, 1995). This analysis is particularly good at detecting unsaturated aldehydes such as alkenes, which are the ones that are most likely to generate unacceptable flavors, making it particularly useful in food quality testing (Abou-Gharsia *et al*., 1997). This analysis can also be used to monitor changes during oil processing in industries (Kathleen *et al*., 1995). However, the *p*-anisidine values are less sensitive and are not specifically suitable for estimating off-flavor compounds in oils. This test is usually estimated 2-alkenals and 2, 4-dienals which are not the only compounds that causing off-flavor of the oils and fats. The results are only comparable to each oil type as the initial anisidine values varied among oil (Kathleen *et al*., 1995; Nielsen, 2010). The effect of superheated steam roasting on the changes of *p*-anisidine value of sesame oils was high especially after 20 mins at the 250°C roasting temperature and this was not desirable. Thus, the optimum superheated steam roasting condition should be found out so that the *p*-anisidine value of the sesame oil was not high to ensure the oxidative stability of sesame oil.

Conclusion

In this study, the superheated steam roasting of sesame seeds at various times and temperatures showed an effect on the color measurements and chemical properties of the sesame oils prepared from the superheated roasted sesame seeds. Colour for superheated roasted sesame seeds at various temperatures and times found to be varied significantly ($p<0.05$) in terms of *L-, a-,* and *b*-values. The effect of superheated steam roasting on the changes of color of sesame oils was desirable to produce an attractive brown color of the oils if the roasting time controlled. The fatty acid composition of oils prepared from superheated steam roasting sesame seeds with various roasting times found to be varied significantly ($p<0.05$) but there were no specific trends for the minor compositional. The conventional roasted significantly ($p < 0.05$) affected the *p*-anisidine values of oils prepared from sesame seeds at 250°C for 20 and 25 mins. Therefore, superheated steam roasting can be used as an alternative to the conventional roasting method in the production of sesame products because the method preserves desired brown color and lower *p*-anisidine value without changing its fatty acid compositions. The suitable superheated steam roasting conditions can be fixed depend on the desired parameters but not higher than 250°C for 20 mins. Further analysis of antioxidant, flavor and mineral content can be done to know an insight of sesame oils using the superheated steam roasting method and comparison with the conventional roasting method.

References

Abou-Gharbia, H. A., Shahidi, F., Shehata, A. A. Y. and Youssef, M. M. 1997. Effects of processing on oxidative stability of sesame oil extracted from intact and dehulled seeds. Journal of the American Oil Chemists Society 74: 215–221.

AOCS. 2003. Official methods and recommended practices of the American Oil Chemists Society. 5th ed. Champaign, USA: American Oil Chemists' Society.

Asmaa A. A., Zzaman, W. and Tajul, A. Y. 2015. Effect of superheated steam cooking on fat and fatty acid composition of chicken sausage. International Food Research Journal 22(2): 598-605.

Goldberg, I. and Williams, R. 1991. Biotechnology and Food Ingredients. U.K: Van Nostrand-Reinhold.

Idrus, N. F. M. and Yang, T. A. 2012. Comparison between Roasting by Superheated Steam and by Convection on Changes in Colour, Texture and Microstructure of Peanut *(Arachis hypogaea)*. Food Science and Technology Research 18: 515-524.

Idrus, N.F.M., Febrianto, N.A., Zzaman, W., Cuang, T. E. and Yang, T.A. 2013. Optimization of the Aqueous Extraction of Virgin Coconut Oil by Response Surface Methodology. Food Science and Technology Research 19 (5): 729-737.

Issara, U., Zzaman, W. and Yang, T.A. 2014. Review on Rambutan Seed Fat as a potential source of cocoa butter substitute in Confectionary Product. International Food Research Journal 21(1): 25-31.

Kahyaoglu, T. and Kaya, S. 2006. Modeling of moisture, color, and texture changes in sesame seeds during conventional roasting. Journal of Food Engineering 75: 166-177.

Kikugawa, K., Arai, M. and Kurechi, T. 1983. Participation of sesamol stability of sesame oil. Journal of American Oil Chemist Society 60: 1528-1533.

Kiralan, M. 2012. Volatile Compounds of Black Cumin Seeds (*Nigella sativa* L.) from Microwave-Heating and Conventional Roasting. Journal of Food Science 77(4): 481–484.

Kita, S., Matsumura, Y., Morimoto, S., Akimoto, K. and Furuya, K. 1995. Antihypertensive effect of sesamin. II. Protection against two kidneys, one-clip renal hypertension and cardiovascular hypertrophy. Biological and Pharmaceutical Bulletin 18: 1283-1285.

Maskan, M. 2001. Kinetics of colour change of kiwifruit during hot air and microwave drying. Journal of Food Engineering 48: 169–175.

Mondello, L., Tranchida, P. Q., Dugo, P. and Dugo, G. 2006. Rapid, micro-scale preparation and very fast gas chromatographic separation of cod liver oil fatty acid methyl esters. Journal of Pharmaceutical and Biomedical Analysis 41(5):1566-1570.

Namiki, M. 1995.The chemistry and physiological functions of sesame. Food Review International 11: 281-329.

Ozdemir, M. and Devres, O. 2000. Analysis of color development during roasting of hazelnuts using response surface methodology. Journal of Food Engineering 45: 17-24.

Richard L. M. 2007. The 100 Most Important Chemical Compounds: A Reference Guide. Westport: Green wood press.

Saklar, S., Katnas, S. and Ungan, S. 2001. Determination of optimum hazelnut roasting conditions. International Journal of Food Science and Technology 36: 271-281.

Shan, O. E., Zzaman, W. and Yang, T. A. 2016. Impact of different temperature-time profiles during superheated steam roasting on some physical changes of Robusta coffee. Pertanika Journal of Tropical Agricultural Science 39 (3): 311-320.

Yen, G. C. 1990. Influence of Seed Roasting Process on the Changes in Composition and Quality of Sesame *(Sesame indicum)* Oil. Journal of the Science of Food and Agriculture 50: 563–570.

Yoshida, H., and Kajimoto, G. 1994. Microwave Heating Affects Composition and Oxidative Stability of Sesame *(Sesamum indicum)* Oil. Journal of Food Science 59: 613–616.

Yoshida, T. and Hyodo, T. 1996. Superheated vapor speeds drying of food. Journal of Food Engineering 38: 86-87.

Zzaman, W. and Yang, T.A. 2013. Effect of Superheated Steam and Convection Roasting on Changes in Physical Properties of Cocoa Bean *(Theobroma cacao)*. Food Science and Technology Research 19(2):181-186.