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Changes in the quality characteristics of Moringa oleifera oil compared with olive oil during potato frying

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ABSTRAC

Deep-fat frying is the oldest and most popularly known food preparation method. The fried foods have a desirable flavor, color, and crispy texture, making them deep-fat fried foods and are very popular among consumers. Oleic acid is the most abundant monounsaturated fatty acid in all the common edible oils.The effect of potato frying on the quality characteristics of moringa seed oil and olive oil was investigated. The moringa oil and olive oil were used in frying potatoes at 175 ^{0}C and the change in the quality characteristics after four times showed a significant difference ($P \leq 0.05$) between the moringa and olive oil in peroxide value and yellow color but no significant difference ($P \leq 0.05$) in free fatty acids, iodine value, viscosity, refractive index, and red color between the two samples. Fatty acids compositions of samples after frying were detected using GLC which were palmitoleic (0.1543), palmitic (1.8698), linoleic (0.0616), oleic (70.8325), linolenic (0.1200), stearic (5.0682), arachidic (0.3054), gadoleic (1.4825), behenic (2.1098), and arachidonic (0.1078). Moringa oleifera oil is a high-oleic vegetable oil typical of the Mediterranean region, recognized for its nutritional, technological, and sensorial properties. Its use for frying, alone or in blends, includes the physical and chemical alterations of the oil bath under deep-frying conditions, and the sensory characteristics of fried potatoes

Keywords: Olive oil, Peroxide value, Iodine value, Refractive index, Frying

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INTRODUCTION

Deep-fat frying is one of the oldest and most popular food preparation methods. Fried foods have a desirable flavor, color, and crispy texture, which make deep-fat fried foods very popular with

consumers, Deep-fat frying is the a process of immersing food in hot oil with contact among oil, air, and food at a high temperature of 150 ^{0}C to 190 ^{0}C. Oleic acid is the most abundant monounsaturated fatty acid in all the common edible oils. Compared with polyunsaturated fatty acids, oleic acid is more stable against oxidation both at ambient storage temperatures and at the high temperatures that prevail during the cooking and frying of food. Therefore, oils with high amounts of oleic acid are slower to develop oxidative rancidity during shelf life or undergo oxidative decomposition during frying than those oils that contain high amounts of polyunsaturated fatty acids. Modified oils containing high-oleic acid, low-linoleic, and low-linolenic acid are produced by various methods, including genetic modification, and are more stable to deterioration during deep-frying than regular oils.

The fried potatoes are eaten all over the world. The nutritional relevance of potatoes is supported by their richness in carbohydrates, minerals, proteins, dietary fibers, vitamins (like vitamin C and pro-vitamin A), and phytochemicals, mainly phenolic compounds (Camire et al., 2009). However, when it is deep fried, the oil from the frying medium becomes a component of the fried food. Therefore, the nutritional qualities of fried potatoes are the combined results of the initial potato constituents, the incorporated frying Moringa oleifera oil and olive oil, and the products of their physical and chemical interactions (Chiou et al., 2012). The frying oils supply additional nutritional value to deep-fried potatoes, because of the addition of important lipid components, such as essential fatty acids and vitamin E, which also increase their energetic density (Chiou et al., 2012). During the frying process of potatoes, diverse chemical reactions take place, such as oxidation, hydrolysis, and polymerization (Choe and Min., 2007; Li et al., 2020), that affect the performance and qualities of the oil. However, under the high temperatures of the frying process, some of the compounds are degraded, and undesirable toxic molecules may be generated, either in the frying oil, such as trans fatty acids or volatile aldehydes (Chiou et al., 2012; Bouchon., 2009). High-oleic vegetable oils are increasingly being recognized as appropriate for frying due to their fatty-acid profile and oxidative stability (Iranloye et al., 2021; Ziaiifar et al., 2008). Moringa oleifera oil (MOO) is a high-oleic vegetable oil typical of the Mediterranean region, recognized for its nutritional, technological, and sensorial properties. Its use for frying, alone or in blends, includes the physical and chemical alterations of the oil bath under deep-frying conditions, and the sensory characteristics of fried potatoes (Iranloye et al., 2021; Boukandoul et al., 2019; Tsaknis et al., 1999). However, the compositional and nutritional quality of fried potatoes in MOO, alone or blended with olive oils through frying time, has been given limited attention.

MATERIALS AND METHODS

Materials:

-Many kilograms of Moringa seeds were collected from the Aldamzine and Khartoum north areas. These seeds were cleaned by removing foreign particles and kept at room temperature in polyethylene bags for further analysis and experimental work.

=Many liters of olive oil were brought from the local market.

-The chemicals and reagents used are analytical grades and were purchased from the laboratory. Line. Company, Khartoum.

Frying process:

Fresh potatoes were peeled and sliced to a thickness of 1 cm2 using a mechanical slicer, and they were kept in distilled water at room temperature ($37 \mp 1°37 \mp 1°$). They were then slightly blotted dry with tissue paper before being weighed into batches, each of which contained 100 grams. For frying such a product, exactly 1.5 liters of moringa oil were put into a jacket batch fryer. The temperature was raised to $(180 \mp 5°)$ $(180 \mp 5°)$, and after 20 minutes, 100 grams of raw sliced potato was fried for 2.5 minutes. After the frying process, 100g of oil samples were collected in amber bottles at 60^0C for further analysis. All samples were stored under nitrogen at 20^0C. The physicochemical analysis of oil was carried out immediately after the frying experiment. Fresh oil was not added to the frying vessel during the frying process.

Physical analysis of moringa oil:

Refractive index:

The refractive index (RI) was determined by the Abbe 60 Refractometer as described by the AOAC method (1990). The double prism was opened using a screw head, a few drops of oil were placed in the prism, the prism was closed firmly by tightening the screw head and the instrument was then left to stand for a few minutes before reading to equilibrate the sample temperature with that of the instrument (32 ± 2^oC 32 ± 2^oC). The prisms were cleaned between readings by wiping off the oil with a soft cloth, then with petroleum ether, and left to dry, The test was repeated three times.

Oil density:

The oil density was determined according to AOAC (1990) methods, using a psychometer. An empty the stoppered psychometer was weighed, and the psychometer was filled with water and kept at a constant temperature of 25°C in a water bath for 30 minutes. The weight of water at 25^0C was determined by subtracting the weight of an empty psychometer from its weight filled with water. At the end of time, the Stoppered psychometer was adjusted to the proper level, dried with a cloth, and weighed. In the same manner, the weight of the oil at 25°C was determined. The density was calculated as follows:

The density at °C= W/W1

Where:

W = weight of oil at 25°C.

W1 = weight of water at 25°C.

Oil viscosity:

The viscosity of oil samples was detected using an Ostwald-U-tube viscometer according to Cocks and Van Rede (1966). The viscometer was suspended in a constant temperature bath ($32 \pm 32 \pm$ 2°C), Using the pressure on the respective arm of the tube, the oil was moved into the other arm so that the meniscus was 1cm above the mark at the top of the upper reservoir. The liquid was then allowed to flow freely through the tube and the time required for the meniscus to pass from the mark above the upper reservoir to that at the bottom of the upper reservoir was recorded.

Calculation:

The viscosity of the oil = $\frac{T - T_o}{T_o}\frac{T - T_o}{T_o}$

Where:

T: flow- time of the oil.

T_0: flow- time of the distilled water.

Oil color:

The color intensity of oil was recorded using a Lovibond Tintometer as units of red, yellow, and blue, in the manner described by Balla (2001). The oil sample was filtered through a filter paper immediately before testing. An appropriate 5.25 inches was filled with oil and placed in the tintometer in a specific place. The instrument was switched on, and looked through the eyepiece. Then the slides were adjusted until a color match was obtained. The values obtained by matching were recorded as red, yellow, and blue.

Chemical Analysis of Moringa Oil:

Peroxide value:

The peroxide value (PV) of the oil samples was determined according to the AOAC method (2000). 5gm ($\pm 5gm$ $\pm 5gm$) of the sample were weighed into a 250ml stoppered conical flask. 30ml of acetic acid and chloroform solvent mixtures were added and swirled to dissolve. 0.5ml of saturated potassium iodide solution was added with a Mohr pipette and stood for 1min in the dark with occasional shaking, and then about 30ml of water was added. Slowly the liberated iodine was titrated with 0.1 N sodium thiosulphate solutions, with vigorous shaking until the yellow color almost disappeared. About 0.5ml starch solution as an indicator was added and titration continued with vigorous shaking to release all iodine gas from the CHCL layer until the blue color disappeared. If less than 0.5ml of 0.1 N Na_2 S_2O_3 was used 0.01 N $Na_2S_2O_3$ was repeated. Blank determination (must be less than 0.1ml 0.1 N $Na_2S_2O_3$) was conducted.

Peroxide value expressed as mille equivalent of peroxide oxygen per kg sample (Meq per Kg oil).

Calculation:

$$peroxide\ Value = \frac{Titre \times N \times 1000}{Weight\ of\ the\ sample\ used}$$

Where:

Titer = ml of sodium Thiosulphate used (blank corrected).

N = Normality of sodium thiosulphate solution.

Free fatty acid:

Free fatty acids were determined according to the AOAC method (2000). About 5 to 10 g of the cooled oil sample was weighed in a 250 ml conical flask 50 to 100 ml of freshly neutralized hot ethyl alcohol was added, along with about 1 ml of phenolphthalein indicator solution, The mixture was warmed for about 5 minutes, and titrated while hot against a standard alkali solution shaking vigorously during the titration. The weight of the oil was taken for the estimation and the strength of the alkali used for titration will be such that the volume of alkali required for the titration must not exceed 10 ml.

$$free\ fatty\ acids\ as\ oleic\ acid\ percent\ by\ weight = \frac{28.2 \times VXN}{W}$$

Calculation:

Where:

V =Volume in ml of standard sodium hydroxide used.

N = Normality of the sodium hydroxide solution.

W = weight in g of the sample.

Iodine value

The iodine value of the oils, which quantifies their unsaturation level, was determined according to the AOAC method (2000). Approximately, 0.2 g of oil was accurately weighed and placed in a dry and clean flask specially offered for the test. 25 ml of pyridine sulfated dibromide solution was added to the contents of the flask. The flask was then stopped and the mixture was allowed to stand for 10 minutes in a dark place. The stopper and the side of the flask were rinsed with enough distilled water, the contents of the flask were then shaken and titrated against a 0.1N sodium thiosulphate solution using starch liquid as an indicator. A blank determination was carried out simultaneously.

Calculation:

$$Iodine\ value = \frac{12.69(B - S)N}{W}$$

Where **B** = volume in ml of standard sodium thiosulphate solution is required for the blank.

S = volume in ml of standard sodium thiosulphate solution required for the sample.

N = normality of the standard sodium thiosulphate solution.

W = weight in g of the sample.

Saponification value

The determination of saponification value (SV) was carried out according to the AOAC method (2000). Two grams of oil were weighed accurately into 200ml conical flask. 25 ml of 0.5 N alcoholic KOH solutions were added, and the contents of the flask were boiled under reflux for 1hr with frequent rotation. 1ml of phenolphthalein indicator was added, while the solution was still hot, and the excess alkali was titrated with 0.5 N HCL. The ml of HCL required (a) were noted. The same process was repeated without oil and the numbers of l m of the acid required (blank) were also recorded.

Calculation:

$$SV = \frac{(B - A) \times 28.05}{S}$$

Where:

A: ml of HCL for sample.

B: ml of HCL for blank.

S: weight of oil (gm).

Saponification and etherification of moringa oil method before injecting in the GLC:

Eight drops of moringa oil were transferred to a 25 ml volumetric flask, 5 ml 0.5M methanolic NaOH was added, and the flask was to stand in a water bath at 65 C^{o} with the stopper open. The content was cooled under cold water and then 7-8 ml of methanolic BF_3 reagent was added. The flask was left to stand in a water bath at 65^{o}C for three minutes and then cooled under cold water. One ml of heptanes was added and well shaken. After that saturated NaCl solution was added until the heptane layer came to the top. A small amount of anhydrous Na_2SO_4 was sprinkled through the heptanes layer to remove water . The heptane layer was transferred for injection into the GLC device

Determination of fatty acids composition in moringa oil:

The fatty acid composition of the oil was determined by gas chromatography apparatus (Py E-UNICAM model GCD) according to the acid-catalyzed method lipid technology 2.42-49 1900) as follows:

1 ml of oil was taken in a 100 ml round-bottomed flask 100ml, 6ml f 0.5ml methanolic and was well shaken, 6ml 1% methanolic Hs50 was well shaken, and the mixture was left overnight at 50 ^{0}C, then 2ml Hexane was added and shaken, enough saturated sodium chloride was added to bring the level to the neck of the flask, 1ml of the upper layer was taken into Stoppered tube and some anhydrous sodium sulfate was added to remove the moisture, then sample now was ready for injection in GLC. Exact 0.5 oil was injected in GLC with a conductivity detector.

The area of each peak was calculated by the triangulation method, and the ratio of the constituents was determined by measuring the area of all peaks and the percentage represented by each.

Determination of vitamin (E) content:

One ml of oil was depressed with 1 ml of ethanol, and then the solution was extracted with 1 ml of chloroform. The extract was shaken for 5min before centrifugation. The extracted layer was evaporated and dried under nitrogen. The dried extract was dissolved in 100ml of methanol. All reconstituted anti-oxidants are mixed before being injected into the HPLC system (Carpenter., 1979).

Frying process:

Fresh potatoes were peeled and sliced to a thickness of 1 cm2 using a mechanical slicer, and they were kept in distilled water at room temperature ($37 \mp 1°37 \mp 1°$). They were then slightly blotted dry with tissue paper before weighing into batches, each one contained 100 grams. For frying such a product, exactly 1.5 liters of moringa oil were put into a jacket batch fryer. The temperature was raised to $(180 \mp 5°)(180 \mp 5°)$, after 20 minutes 100 grams of raw sliced potato was fried for 2.5 min. After the frying process, 100 g of oil samples were collected in amber bottles at $60°C60°C$ for further analysis. All samples were stored under nitrogen at $20°C20°C$. Physicochemical analysis of oil was carried out immediately after the frying experiment. Fresh oil was not added to the frying vessel during the frying process.

Statistical analysis:

The data were statistically analyzed by the student's t-test and analysis of variance (ANOVA). The mean separation was assessed by Duncan's Multiple Range Test (DMRT) (Peterson., 1985).

RESULTS AND DISCUSSION

Change in the quality characteristics of Moringa oleifera and olive oil during potatoes fraying:

Free fatty acids:

The results in Table (1) showed that the change in the free fatty acids of the moringa oil was 019%, 0.84%, 0.88%, 0.99%, and 1.19% for the first, second, third, and fourth fryings, respectively, and 0.95%, 1.2%, 1.5%, 1.9% and 2.2% for olive oil. A significant difference ($p>$ 0.01) was observed in free fatty acid values during the frying of the moringa and olive oils. The free fatty acids were mainly formed by the hydrolysis of

triglycerides, which is the oxidation or reaction of oil with moisture during other deterioration reactions. The moringa oil showed a lower increase in free fatty acids.

Peroxide value:

As shown in Table (1). The peroxide value of moringa oil was changed during frying from 0.49 to 0.97, 1.5, 1.79, and 2.4 mg O_2/ Kg of oil, and for olive oil from 0.7 to 5.9, 1.13, 1.7, and 2.5 mg O_2/ Kg of oil. A significant increase ($p< 0.01$) in Peroxide value was observed during the frying of moringa oil and olive oil. peroxide under heating conditions used are stable and react to form secondary oxidation products.

An increase in the initial stage of frying would be expected to be followed by a decrease with further frying because the hydroperoxide content decomposes at 180^{o}C to form secondary oxidation products (Perkins, 1967) The overall increase in peroxide value is related to the cooling period of the oil. The length of time required to cool the oils at room temperature (28^{o}C) was more than 4 hours. during the cooling period, the oil was exposed to air at high temperatures and hydroperoxide was formed again (Augustin and Berry., 1983) because of these factors, peroxide value is not recommended for measuring heating oil deterioration.

Iodine value:

Table (1) shows changes in the iodine value for the moringa oil from 63.5 to 63.39, 63.24, 63.03, and 62.81 mg I/ Kg of oil and from 81.5 to 79.8, 79.5, 79.1and 78.5 mg I/ Kg of oil for olive. The results showed that there was a significant ($P<0.05$) difference in iodine value during frying for moringa oil and olive oil. A decrease in IV can be attributed to the destruction of double bonds by oxidation and polymerization. Oxidation, which consists of a complex series of chemical reactions is characterized by a decrease in the total unsaturated content of the oil.

Viscosity:

The change in viscosity is shown in Table (1). The viscosity of moringa oil was changed during frying from 23.8 to 23.97, 24.12, 24.25, and 24.53 cent poise and from 73.52 to 73.8, 74.2, 74.5, and 76.0 cent poise for olive oil. The results show a significant ($P<0.01$) difference between moringa oil and olive oil in the viscosity during frying. The viscosity of all oils increased during frying times. Increase in viscosity due to the formation of high molecular weight polymers. The more viscous the frying oil, the higher the degree of deterioration. (Abdulkarim., 2007).

Color

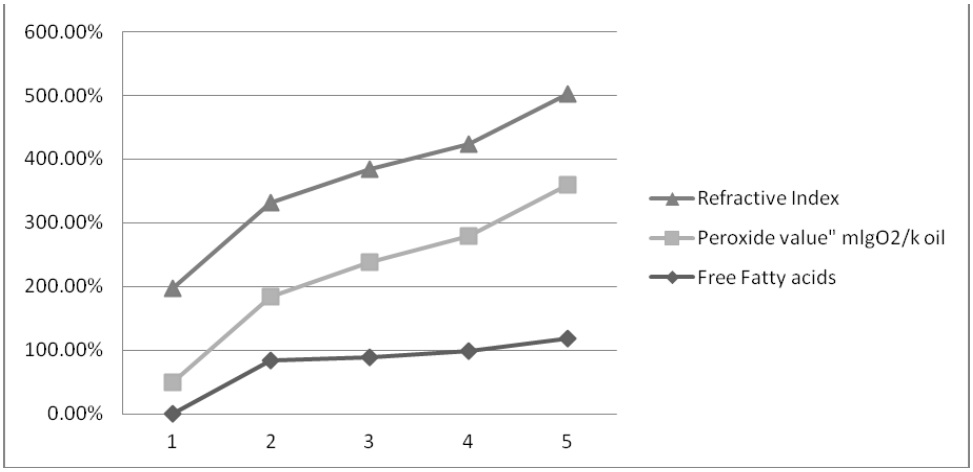
Table (1) shows changes in degrees of red color during frying from 1.5 to 6.1, 6.5, 6.9, and 7.2 and from 2.30 to 2.70, 2.90, 3.20 and 3.30 for moringa and olive oil, respectively, while the yellow color degrees were changed during the frying from 18.00 to 30.00, 29.00, 28.10 and 26.00 for moringa and from 31.90, 32.30, 32.60,33.10 and 34.00 for olive oil. A significant ($P<0.01$) variation was observed for both colors during the frying of moringa and olive oil. The color change in frying oil even visual indication of the extent of oil deterioration caused by oxidation. An increase in the color intensity is due to the accumulation of nonvolatile decomposition produces such as oxidized triacylglycerol and F.F.A. All the oils darkened during the frying and the rate of darkening was proportion to the frying time. (Abdulkarim etal., 2007).

Refractive index:

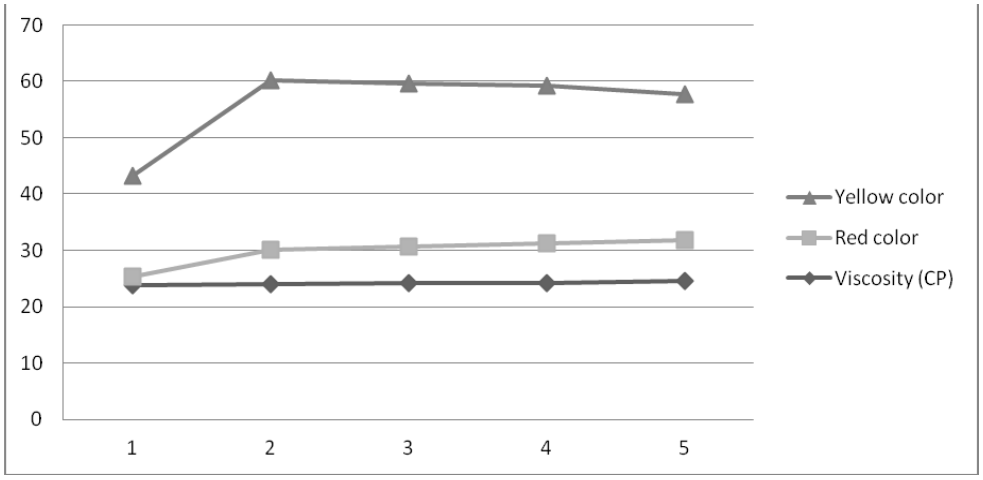
As shown in Table (1). The refractive index of moringa oil was changed during frying from 1.48 to 1.47, 1.46, 1.45, and 1.45 for moringa oil and from 1.55 to 1.53, 1.51, 1.49,

and 1.45 for olive oil. The results showed no significant (P>0.05) differences in the refractive index of moringa and olive oil.

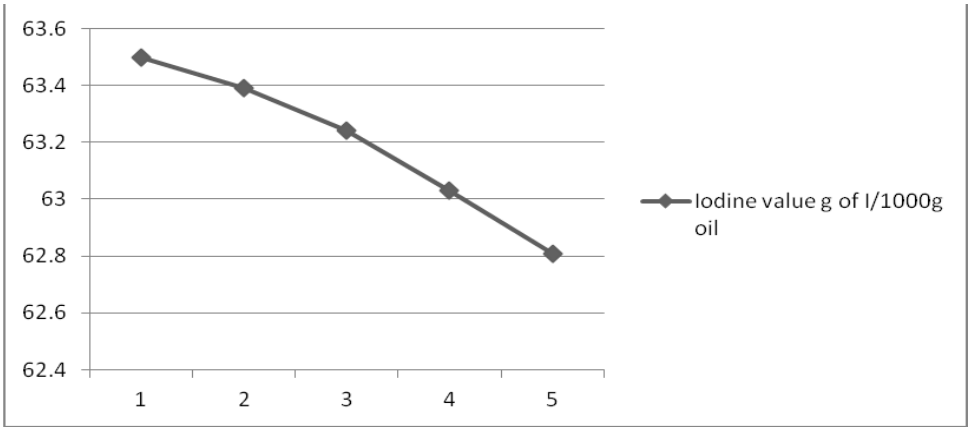
Changes in RI, PV, and FFA of Moringa oil during frying



Changes in colors of Moringa oil during frying

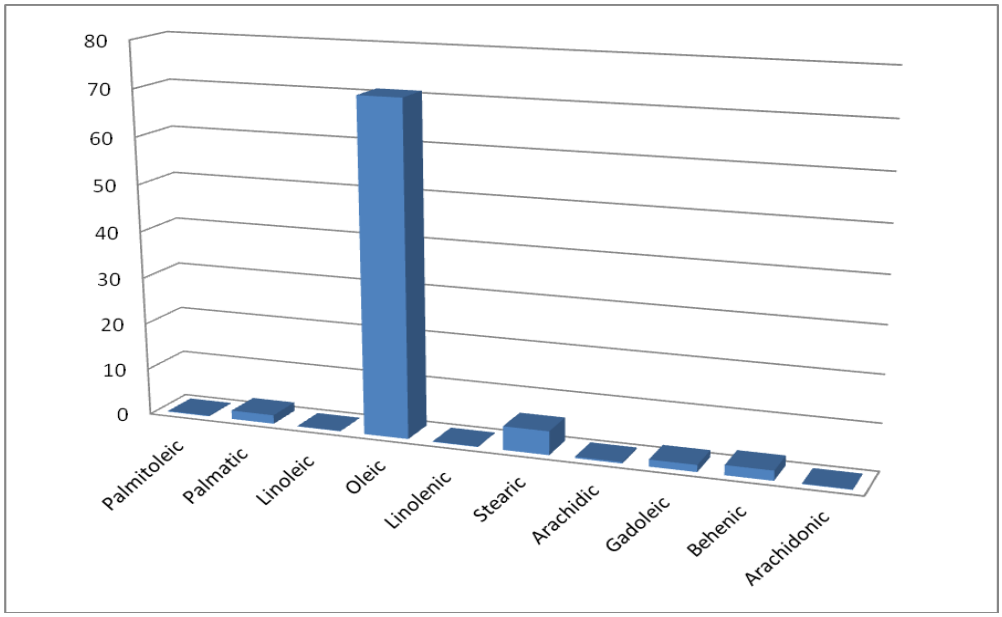


Change in Iodine value of the moringa oil during frying



The fatty acid composition of moringa oil before and after frying is presented in Table (2), The most prominent fatty acids in the oil are palmitic, oleic, and linoleic (3.248%), (71.57%) and (0.06%), respectively for moringa oil which decreased after frying to (1.86%), (70.83%) and (0.06 %) for palmitic, oleic and linoleic, respectively. The total monounsaturated acids in the moringa oil are very high (75.1%). A high amount of monounsaturated fatty acids is needed for health benefits, oil with a high amount of monounsaturated fatty acids "oleic type" is associated with a decreased risk of coronary heart disease "mensink & katan., 1990".

Fatty Acid Composition of Moringa Oil Before Frying



Fatty Acid composition of moringa oil after frying

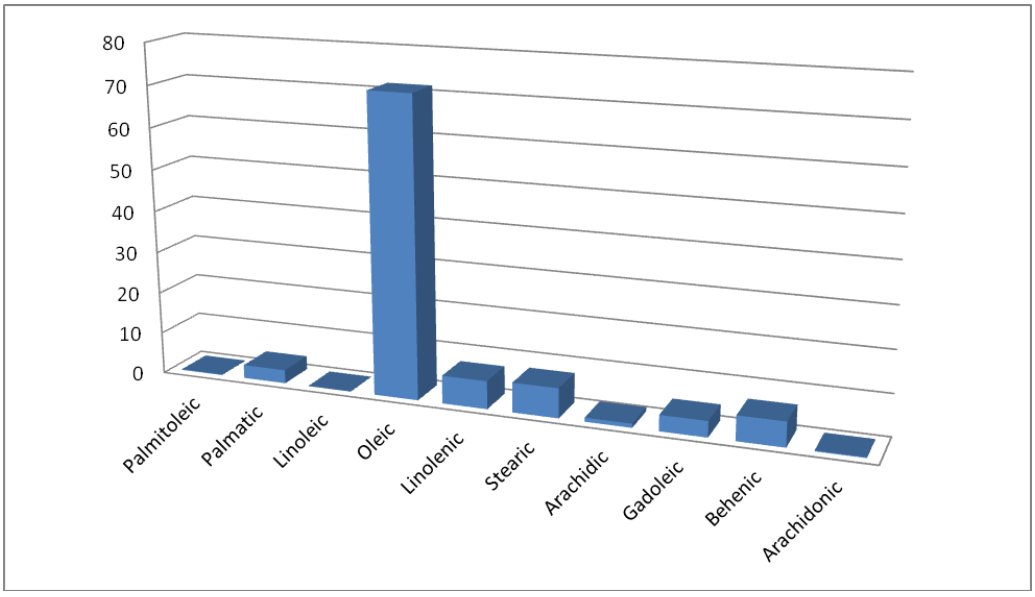


Table (1): Change in the quality characteristics of Moringa and olive oil during Potatoes fraying at 175 ºC

Oil types	Free fatty acids (%)				
	0	1	2	3	4
Moringa	0.19^{d}	0.84^{c}	0.88^{c}	0.99^{b}	1.20^{a}
Olive	0.95^{e}	1.20^{d}	1.50^{c}	1.87^{b}	2.30^{a}
Oil types	Peroxide value mlgO2/k oil				
	0	1	2	3	4
Moringa	0.49^{e}	0.97^{d}	1.50^{c}	1.79^{b}	2.40^{e}
Olive	0.70d	5.67a	1.37c^{d}	1.75b^{c}	2.47^{b}
Oil types	Iodine value g of /1000g oil				
	0	1	2	3	4
Moringa	63.50^{a}	63.40^{a}	63.21^{ab}	63.03^{ab}	62.81^{b}
Olive	81.47^{a}	79.73^{b}	79.50^{c}	79.04^{d}	78.47^{e}
Oil types	Viscosity (Cp)				
	0	1	2	3	4
Moringa	23.81^{c}	23.97^{c}	24.12^{b}	24.25^{b}	24.53^{a}
Olive	73.52^{e}	73.80^{d}	74.20^{c}	74.50^{b}	76.00^{a}
Oil types	Red color				
	0	1	2	3	4
Moringa	1.50^{e}	6.10^{d}	6.50^{c}	6.90^{b}	7.20^{a}
Olive	2.30^{e}	2.70^{d}	2.90^{c}	3.20^{b}	3.30^{a}
Oil types	Yellow color				
	0	1	2	3	4
Moringa	18.00^{e}	30.00^{a}	29.00^{b}	28.10^{c}	26.00^{d}
Olive	31.90^{e}	32.30^{d}	32.60^{c}	33.10^{b}	34.00^{a}
Oil types	Refractive index				
	0	1	2	3	4
Moringa	1.48^{a}	1.48^{a}	1.46^{a}	1.45^{a}	1.45^{a}
Olive	1.5500^{a}	1.5310^{b}	1.5100^{c}	1.4900^{d}	1.4500^{e}

Means followed by the same letters are not significantly different at 0.05 level of probability according to DMRT

Table 2: Changes in Fatty Acid Composition (%) of Moringa oil during frying.

No.	Fatty acid	Before frying	After frying
1.	Palmitoleic	0.1860	0.1543
2.	Palmitic	3.248	1.8698
3.	Linoleic	0.0690	0.0616
4.	Oleic	71.57	70.8325
5.	Linolenic	6.725	0.1200
6.	Stearic	7.127	5.0682
7.	Arachidic	0.9820	0.3054
8.	Gadoleic	3.842	1.4825
9.	Behenic	5.973	2.1098
10.	Arachidonic	0.2320	0.1078

Conclusion

The free fatty acids and peroxide values were increased during frying times for both samples, while the iodine value was decreased. The viscosity increased gradually in both samples when frying times were increased. The intensity of colors (red and yellow) increased during frying times for both samples. Total monounsaturated fatty acids were very high (75%) in moringa oil (health benefits). The oil with a high amount of mono-unsaturated fatty acids "oleic type" is associated with a decreased risk of coronary heart disease

Conflict of Interest:

All the authors read and approved the manuscript and declare that there is no conflict of interest.

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The research work was conducted at the Department of Basic Medical Sciences, Faculty of Applied Medical Sciences, Al-Baha University, Al-Baha, Saudi Arabia, and the Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum, Khartoum, and Omdurman Islamic University, Omdurman, Sudan.

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