

## Quality changes of *Moringa oleifera*, variety Mbololo of Kenya, seed oil during frying

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### RESUMEN

#### Cambios en la calidad de aceite de semilla *Moringa oleifera* variedad Mbololo de Kenya, durante la fritura.

Se ha estudiado el comportamiento frente a la fritura, especialmente en el caso de frituras repetidas de aceite de semilla *Moringa oleifera* variedad Mbololo de Kenya (producido por presión en frío, extracción con n-hexano y una mezcla de cloroformo-metanol). Los aceites se usaron para la fritura intermitente de rodajas de patatas y filetes de bacalao a temperatura de  $175 \pm 5^\circ\text{C}$  durante 5 días consecutivos. Bajo estas condiciones tuvo lugar la descomposición térmica y oxidativa de los aceites. Se evaluaron los cambios químicos ocurridos en los aceites. El contenido en ácidos grasos libres, índice de peróxido, extinción específica a 232 nm, compuestos polares, color y viscosidad de los aceites aumentaron, en tanto que el índice de yodo, punto de humo, contenido en ácidos grasos poliinsaturados, período de inducción y concentración en tocoferol disminuyeron. También se determinó el efecto de los aceites sobre la calidad organoléptica de estos alimentos fritos. Los datos analíticos y sensoriales mostraron que la deterioración más baja ocurrió en el aceite producido por presión en frío y la mayor en el aceite extraído con n-hexano.

**PALABRAS-CLAVE:** Aceite de semilla *Moringa oleifera* — Bacalao — Cambios químicos — Características organolépticas — Fritura — Patata.

### SUMMARY

#### Quality changes of *Moringa oleifera*, variety Mbololo of Kenya, seed oil during frying.

The frying performance of *Moringa oleifera* variety Mbololo of Kenya seed oil (produced by cold pressure, extraction with n-hexane and a mixture of chloroform-methanol) was studied especially as regards repeated frying operations. The oils were used for intermittent frying of potato slices and cod filets at a temperature of  $175 \pm 5^\circ\text{C}$  for 5 consecutive days. Under such conditions thermal and oxidative decomposition of the oils takes place. The chemical changes occurring in the oils were evaluated. Free fatty acid content, peroxide value, specific extinction at 232 nm, polar compounds, colour and viscosity of the oils all increased, whereas the iodine values, smoke points, polyunsaturated fatty acid content, induction period and tocopherol concentration decreased. The effect of the oils on the organoleptic quality of these fried foods was also determined. The analytical and sensory data showed that the lowest deterioration occurred in cold pressure produced oil and the highest in n-hexane extracted oil.

**KEY-WORDS:** Chemical changes — Cod — Frying — *Moringa oleifera* seed oil — Organoleptic characteristics — Potato.

### 1. INTRODUCTION

Deep-fried foods and especially fried potatoes and cod are becoming more and more popular in Greece.

Deep-frying is a very important method of cooking in the food services industry. It is estimated that nearly one-half of all lunch and diner food orders in commercial restaurants include one or more deep-frying items (1).

During deep-frying the oil is exposed to elevated temperatures in the presence of air and moisture. A number of chemical reactions including oxidation and hydrolysis, occur during this time as do changes due to thermal decomposition (2).

Chang *et al.*, (1978) and Landers *et al.*, (1981) have reported that the chemical reactions taking place during deep oil frying differ from those which occur when the oil is heated continuously, thus reactions occurring in studies conducted with oils heated in the presence of air, with or without agitation, may not be representative of those of the same oils used under normal intermittent frying conditions. The decomposition products formed during frying can be divided into two broad classes: volatile and non-volatile products: Volatile decomposition products have been shown to be retained in the fried food and also inhaled by the deep-frying operator and could thus have an effect on the health of these individuals (3).

The formation of non-volatile decomposition products is due largely to thermal oxidation and polymerisation of the unsaturated fatty acids present in the frying medium and is of concern since these products not only remain in the frying oil to prevent further degradation but are also absorbed by the fried food and hence consumed (2).

Investigations of commercial frying have generally indicated that these oils have no deleterious effects upon human health (5, 6).

### 2. MATERIAL AND METHODS

#### 2.1. Vegetable oils

The oil from whole seeds (shell plus kernel) of *Moringa oleifera* VARIETY Mbololo of Kenya was

produced by cold pressure (CP) and extracted by the use of n-hexane (H) and a mixture of chloroform:methanol (50:50)(CM), as solvents.

**Cold pressure.** The extraction procedure for the cold pressure was performed as follows: the seeds were milled to a fine powder with a Vorwerk Thermomix 3300 (Vorwerk France s.a., Paris) at a speed of 12 with the addition of water (in a ratio of 1 seed/2 water) Prior to extraction which was done with a O.M.F.B. pm 25-S/1 simple hydraulic hand press (Costruz. Mecc. Oleiodinamiche Provaglio D' Ised, Brescia, Italy) with a max. pressure of 300 kg/cm<sup>2</sup> the paste was wrapped in a thick heavy-duty cloth.

**n-Hexane.** The solvent extraction was executed using a two litre soxhlet apparatus. The seeds were milled to a fine powder with a Vorwerk Thermomix 3300 (Vorwerk France s.a., Paris) at a speed of 12. The paste was positioned in a paper ampoule and the ampoule in a two litre soxhlet apparatus. Then the heater was turned on. After 12 hours the extraction was stopped. The n-hexane was evaporated under reduced pressure with a Heildolph WB 200 Rotary evaporator, and the oil was kept in sealed bottles under refrigeration (0 - 4°C) for further processing and analysis.

**Chloroform: Methanol (50:50).** The solvent extraction was executed using a two litre soxhlet apparatus. The seeds were milled to a fine powder with a Vorwerk Thermomix 3300 (Vorwerk France s.a., Paris) at a speed of 12. The paste was positioned in a paper ampoule and the ampoule in a two litre soxhlet apparatus. Then the heater was turned on. After 10 hours the extraction was stopped. The chloroform: methanol (50:50) was evaporated under reduced pressure with a Heildolph WB 200 Rotary evaporator, and the oil was kept in sealed bottles under refrigeration (0 - 4°C) for further processing and analysis.

**Degumming.** There was a need for degumming because the oils were cloudy and they were going to be used for frying. The oil was heated at 75°C and 20% boiling water was added. The mixture was mixed for 10 minutes with the aid of a glass rod. After cooling, the oil was centrifuged for 10 minutes in 3,500 rpm in tubes of 200 cm<sup>3</sup> using a Sorvall General-Purpose RC-3 Automatic Refrigerated Centrifuge (Ivan Sorvall INC., Newtown Connecticut, USA).

## 2.2. Methods

The frying method used was adapted from that developed by Tsaknis (1991). Potatoes and skinless cod fillets were deep-fried independently, each in 2 litres of oil (surface/volume ratio = 0.07). The potatoes were peeled and washed about 1 h before use, and sliced into discs 0.5 cm thick and 2.5 cm in diameter, using a mechanical slicer.

The skinless cod fillets were into square pieces (3 cm x 3 cm x 1.5 cm) and coated with wheat flour.

When the temperature of the oil reached 175°C a batch of 100 g of each were fried in separate oil samples.

Repeat frying were carried out at half hour intervals for 2 h. The frying time was 8 min for cod fillets and 6 min for potatoes. A total of five frying were done per day for five consecutive days.

At the end of each day 50 g sample of oil was removed from each fryer and stored at 0°C. The lid of the fryer was replaced and the fryings were continued the following day. Fresh oil was not added to the frying pans.

Colour was measured with a Lovibond tintometer (The tintometer Ltd., Salisbury, England), (7).

Free fatty acid content was measured according to the method described by IUPAC (1987).

The viscosity was measured using a Brookfield viscometer with spindle No 2 at temperature of 24°C (7).

Ultra-violet absorption (at 232 nm) of the oils was determined using the method of IUPAC (1987).

Smoke point was measured according to the method described by British Standards Methods of Analysis (BS 684: Section 1.8).

Iodine value was measured according to the Wijs method as described by Pearsons (1981).

The polar compounds were determined using the IUPAC (1987) method. The determination of the fatty acids composition was done by gas-liquid chromatography according to the method described by Tsaknis (1991). The FAMES preparation was done using the following procedure: About 25 mg of oil were accurately weighed into a screw cap tube, and 1.5 cm<sup>3</sup> of 1 N methanolic sodium hydroxide was added, mixed and heated at 100°C for 7 minutes. After cooling, 2 cm<sup>3</sup> of boron trifluoride were added and heated at 100°C for 5 minutes. The tube was cooled to 30 - 40°C and 1 cm<sup>3</sup> of iso-octane was added, capped and shaken using whirli mix for 30 seconds. 5 cm<sup>3</sup> of saturated sodium chloride solution was immediately added and the tube was shaken again. The tube contents were allowed to separate and the top (iso-octane containing fatty acid methyl esters) layer was removed and the lower layer was extracted again with an addition of 1 cm<sup>3</sup> iso-octane. The two iso-octane extracts were combined (dried over anhydrous sodium sulfate) and concentrated to approximately 1 cm<sup>3</sup> with a stream of nitrogen.

Analysis of fatty acid methylesters was performed on a Varian 3600 Gas chromatograph (Varian, Palo Alto, California, USA) equipped with a Carbowax 20M (Supelco, INC. Supelco Park, Bellefonte, PA 16823-0048) 10' x 1/8" (5% on Chromosorb W 80/100 mesh) column. The temperature program was 60°C for 10 min and then 2°C min<sup>-1</sup> up to 220°C. Injector and FID temperatures were set at 160°C and 280°C respectively, sample volume was 0.2 µl, the

carrier gas was N<sub>2</sub> at a flow of 30 ml min<sup>-1</sup>, chart speed was set at 0.5 cm min<sup>-1</sup> and the attenuation at 10<sup>-10</sup> x 32. In total three samples were prepared and measured separately.

The method used for the determination of tocopherols was a modification of that reported by Carpenter's (1979):

(a) 1 g of oil was accurately weighed into a 3 dram sample vial wrapped in foil paper to prevent oxidation. The oil was dissolved in a 5 cm<sup>3</sup> n-hexane before injection.

(b) A 20 µl, sample was injected into the Waters 600E HPLC pump (Millipore Corporation, Waters Chromatography Division, Massachusetts, MA 01757, USA) fitted with a Waters µ-Polarsil, 125Å, 10 µm, 3.9 x 300 mm column.

Detection was performed with a Waters 486 Tunable Absorbance Detector set at 295 nm. Iso-propanol: n-hexane: absolute ethanol (2: 97.5: 0.5) at 1 cm<sup>3</sup> / min was used as the mobile phase. A total of 5 min was necessary to assay the tocopherols. In total three samples were prepared and measured separately.

The determination of peroxide value was done using the method adapted from Lea (1952).

The determination of the induction period was done as follows:

Two and a half grams (2.5g) of oil were accurately weighed into each of the six reaction vessels and the following procedure was carried out. The «Metrohm Rancimat 679» (Metrohm Ltd., CH-9101, Herisau, Switzerland) was switched on until the temperature of the oil batch reached the temperature of 120°C. Then 50 cm<sup>3</sup> of distilled water was placed into each of the six conductivity cells and the air flow rate was set at 20 L h<sup>-1</sup>. The temperature was checked to ensure it had a constant value. The air supply was connected to the tubes containing the oil samples and the chart recorder was started. The determination continued automatically until the conductivity reached the maximum value and the induction period was read.

### 3. RESULTS AND DISCUSSION

Fish and potatoes are the most commonly fried foods in homes and restaurants. In view of this an investigation was carried out to study the physical and chemical changes which occur in oils used for frying.

**Free fatty acid (FFA) content.** Tables I, VII and XIII illustrate the changes in free fatty acids of oil used for frying potatoes and Tables IV, X and XVI illustrate the changes in free fatty acids of oil used for frying cod. No significant increases were observed after 5 days of frying in all the oils at the 95% level of significance (student's t-test). The cold pressure oil showed the

lowest increase and the n-hexane oil the highest. The steady rise in the formation of FFA can be attributed partly to the hydrolysis and partly to the component carboxylic groups present in polymeric products of frying (13). The acidity was mainly formed by hydrolysis of triglycerides, which was promoted by the presence of food moisture, and by oxidation or by the reaction of oil with moisture formed during other deterioration reactions (14). The oils used for frying cod seemed to follow the same trend. Although cod was found to cause a more rapid increase in the free fatty acid content.

**Peroxide value.** Tables I, VII and XIII illustrate the changes in peroxide value of oil used for frying potatoes and Tables IV, X and XVI illustrate the changes in peroxide value of oil used for frying cod. All the oils showed an increase at the initial stages of frying until 6 h or 8 h of frying followed by a decrease in PV. Further frying resulted in a new increase in PV. Peroxides under the heating conditions used are unstable, 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 hydroperoxides tend to decompose at 180°C, to form secondary oxidation products (15). The overall increase in peroxide value is connected with the cooling period of the oil. The length of time required to cool the oils at room temperature (28°C) was more than 4 h. During the cooling period the oils were exposed to air at high temperature and hydroperoxides were formed again (16). In view of these factors, peroxide value is not to be recommended for measuring frying oil deterioration. The method suggested by Tsaknis *et al.*, (1997) would be more suitable for measuring frying oil deterioration, because it determines malondialdehyde, which is a stable secondary oxidation product. The oils used for frying cod seemed to follow the same trend with the only exception of cold pressure oil used for frying cod that showed a continuous increase of PV.

**Iodine value.** Tables I, VII and XIII illustrate the changes in iodine value of oil used for frying potatoes. Tables IV, X and XVI illustrate the changes in iodine value of oil used for frying cod. The results showed that there were not significant changes between the fresh and used oils after 5 days frying. The decrease of iodine value correlated well with the decrease of unsaturated fatty acids ( $r = 0.992$ ), and more over this analysis confirmed that less oxidation of unsaturated fatty acids has taken place in cold pressure oil. The oils used for frying cod seemed to follow the same trend. Although cod was found to cause a more rapid decrease in the iodine value.

**Viscosity.** Tables I, VII and XIII illustrate the changes in viscosity of oil used for frying potatoes and Tables IV, X and XVI illustrate the changes in viscosity of oil used for frying cod. As the oxidation is accelerated by heat proceeded, the values of

viscosity progressively increased (13). Cold press oil showed the lowest change in viscosity after 10 h of frying, while chloroform-methanol and n-hexane oil showed much higher changes. These results clearly indicated the higher deteriorative effect of oxidation and polymerisation of chloroform-methanol and n-hexane oil compared to cold pressure oil. The increase in viscosity of frying oils was due to polymerisation which resulted in formation of higher molecular weight compounds (carbon to carbon and/or carbon to oxygen-to carbon bridges) between fatty acids (14). The oils used for frying cod seemed to follow the same trend. Although cod was found to cause a more rapid increase in viscosity.

**Smoke point.** Tables I, VII and XIII illustrate the changes in smoke point of oil used for frying potatoes and Tables IV, X and XVI illustrate the changes in smoke point of oil used for frying cod. As expected a decrease of smoke point of the oils was observed. The chloroform-methanol and n-hexane oil showed a significant decrease in smoke point after 4 days of frying, while the cold pressure oil showed no significant increase after 5 days of frying. Morton and Chidley (1988) reported that the amount of smoke emanating from a cup is directly proportional to the concentration of low molecular weight decomposition products in the oil. The free fatty acids and other volatile substances leaving the fat as gases, will not appear as smoke until their concentration is great enough to permit aggregation to colloidal sized particles. The oils used for frying cod seemed to follow the same trend. Although cod was found to cause a higher decrease in the smoke point.

**Polar compounds.** Tables I, VII and XIII illustrate the changes in polar compounds of oils used for frying potatoes and Tables IV, X and XVI illustrate the changes in polar compounds of oil used for frying cod. The results demonstrated that cold pressure oil exhibited the lowest increase in polar compounds, while the n-hexane oil the highest. Fritch (1981), reported that the analysis of percentage polar compounds is considered to be one of the more reliable indicators of the state of the oil deterioration. This latter statement is supported by those of other research workers (20).

**Colour.** Tables II, VIII and XVI illustrate the changes in colour of oil used for frying potatoes and Tables V, XI and XVII illustrate the changes in colour of oil used for frying cod. Darkening is attributed to the presence of unsaturated carbonyl compounds or to non-polar compounds of foodstuff solubilised in the oil (21). The results indicated that there was an increase in red units of the colour measurement of frying oils, while yellow units showed only minor changes. The colour change was a result of the diffusion of pigments into the oil during frying. n-Hexane oil showed the highest increase in colour while cold pressure oil showed the lowest. Although

cod was found to cause less increase in red units of colour. The higher increase of oil colour during frying of potatoes than that during oil frying cod is due to the fact that reactions between the aldehyde group of sugar and amino acids give brown products. Burton (1989) reported that the alpha, beta unsaturated carbonyl compounds, derived from the sugars are the first formed intermediates that react with substances containing alpha-amino groups to give carbonyl-nitrogen compounds which conjugate to form brown products.

**Fame analysis by gas-liquid chromatography.** Tables III, IX and XV illustrate the changes in fatty acid composition of oil used for frying potatoes and Tables VI, XII and XVIII illustrate the changes in fatty acid composition of oil used for frying cod. It was observed that there was a decrease in polyunsaturated fatty acids and a resulting increase in the saturated acids content. However, the changes in polyunsaturated fatty acids were not statistically significant. Changes in fatty acid profile of all oils during frying are basically among the unsaturated fatty acids, whereas the saturated fatty acids (myristic, palmitic and stearic) were slightly increased (13).

**HPLC of tocopherols.** Tables II, VIII and XIV illustrate the changes in tocopherols of oil used for frying potatoes and Tables V, XI and XVII illustrate the changes in tocopherols of oil used for frying cod. The relative decomposition rates after 5 days of frying were  $\delta > \gamma > \alpha$ . The results are in agreement with those of Sonntag (1979), who reported that the decomposition rates of tocopherols, after 10 hours frying, were  $\gamma > \alpha$ . Lea (1960) showed that the order of antioxidant activity changed with the oil used for the experiment. In contrast Miyagawa *et al.*, (1991), in their experiments, using a mixture of soybean and rapeseed oils to fry potatoes, found that the decomposition rates of tocopherols were  $\gamma > \delta > \alpha$  after 32 batches of frying. Also Carlson and Tabach (1986), reported that the decomposition rates of tocopherols in fried soybean oil with french fries were  $\gamma > \delta > \alpha$ .

**Specific extinction ( $E_{1cm}^{1\%}$ ) at 232 nm.** Tables II, VIII and XIV illustrate the changes in specific extinction at 232 nm of oil used for frying potatoes and Tables V, XI and XVII illustrate the changes in specific extinction at 232 nm of oil used for frying cod. The specific extinction at 232 nm which measures the degree of the primary oxidation products increased during frying time and was significant after the first day of frying in all the used oils.

**Induction Period.** Tables II, VIII and XIV illustrate the changes in induction of oil used for frying potatoes and Tables V, XI and XVII illustrate the changes in induction of oil used for frying cod. The results showed that cold pressure oil had the longest

induction period followed by chloroform-methanol and n-hexane oil. Induction period measurements were carried out on frying oils in order to provide a quick indication of the trends in resistance to oxidative rancidity of the heated oils. The induction period determined via accelerated oxidation methods on the original oil can not guarantee or predict the actual frying performance of the oil as other factors will be introduced once frying commences (e.g. badly operated fryer or heat exchanger will ruin even the best quality oil). Nevertheless, it is considered that the «Rancimat» induction period can be useful to act as a «screening» test and eliminate the possibility of introducing lower stability oils into the production area with all the attendant consequences (18). The oils used for frying cod seemed to follow the same trend. Although cod was found to cause a higher decrease in induction period.

The oils used for frying cod, showed higher deterioration in all the quality parameters, with the exception of colour, compared with the same oils used for frying potatoes. This greater deterioration could be due to the leaching of fish oil from the cod

which is rich in polyunsaturated fatty acids which are rapidly oxidised.

**Sensory evaluation.** A number of panellists were chosen to taste potatoes and cod for the overall characterisation of the organoleptic properties (appearance, colour, flavour and texture) after each batch had been fried. A taste panel score sheet with a numerical scale of rating was developed, using descriptive terms against each numerical score for each quality parameter. Throughout the frying time the overall acceptance scores showed a significant difference in overall acceptance of fried potatoes with cold pressure and chloroform-methanol oil after 5 days of frying, while this difference was significant after 4 days of frying with n-hexane oil. The overall acceptance scores showed that fried cod was unacceptable after having been fried in oil for 5 days in cold pressure oil, after 4 days of frying in chloroform-methanol oil and after 3 days in n-hexane oil. The panel scores confirmed that cold pressure oil is the most suitable oil for repeating frying compared to the other oils involved in this study.

Table I

**Changes of the quality characteristics of Kenya *Moringa oleifera* (cold pressure) oil during frying potatoes at 175°C**

DETERMINATION						
Time (h)	Acidity (% as oleic acid)	Peroxide value (meq O <sub>2</sub> /kg of oil)	Iodine value (g of I/100g of oil)	Viscosity (mPa s)	Smoke point (°C)	Polar compounds (g/100 g oil)
0	2.06 (0.24)	0.36 (0.19)	66.81 (0.51)	103.00 (0.43)	201 (2.1)	3.58 (0.73)
2	2.10 (0.13)	0.61 (0.22)	66.73 (0.39)	103.08 (1.12)	201 (1.8)	3.79 (1.01)
4	2.19 (0.31)	1.15 (0.56)	66.62 (0.55)	103.19 (0.98)	199 (2.4)	4.15 (0.77)
6	2.32 (0.11)	1.63 (0.77)	66.47 (0.84)	103.42 (1.25)	198 (1.6)	4.76 (0.64)
8	2.59 (0.18)	1.08 (0.44)	66.28 (0.96)	103.69 (1.36)	197 (2.2)	5.51 (0.80)
10	2.90 (0.21)	3.44 (1.16)	65.93 (0.43)	104.08 (0.16)	195 (1.8)	6.62 (1.12)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table II  
Changes of the quality characteristics of Kenya *Moringa oleifera* (cold pressure) oil during frying potatoes at 175°C

DETERMINATION						
Time (h)	$E_{1\%}^{1\text{cm}}$ at 232 nm	Induction period (h)	$\alpha$ -tocopherol (mg/kg oil)	$\gamma$ -tocopherol (mg/kg oil)	$\delta$ -tocopherol (mg/kg oil)	Colour red, yellow
0	1.66 (0.25)	18.90 (0.91)	42.61 (7.56)	15.82 (1.91)	24.21 (1.68)	1.90, 30 (0.10), (6.0)
2	1.74 (0.31)	18.61 (0.43)	42.15 (3.41)	14.01 (2.74)	23.09 (3.16)	2.08, 30 (0.14), (4.3)
4	1.88 (0.43)	18.24 (0.55)	41.09 (2.85)	11.88 (4.13)	20.01 (2.88)	2.21, 30 (0.23), (5.7)
6	2.13 (0.61)	17.82 (1.28)	39.72 (5.14)	9.73 (2.91)	15.92 (1.86)	2.45, 30 (0.31), (2.3)
8	2.54 (0.84)	17.54 (0.76)	36.86 (2.81)	7.04 (1.95)	10.88 (3.16)	3.21, 30 (0.94), (1.4)
10	3.16 (0.58)	16.50 (1.15)	33.31 (2.56)	3.81 (1.17)	4.75 (1.21)	4.30, 30 (0.18), (3.5)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table III  
Fatty acid composition of Kenya *Moringa oleifera* (cold pressure) oil during frying potatoes at 175°C

FATTY ACID																
Time (h)	8:0	14:0	16:0	16:1 $\omega$ 9	16:1 $\omega$ 7	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1cis	26:0
0	0.03 (0.01)	0.11 (0.07)	5.73 (0.31)	0.10 (0.05)	1.32 (0.89)	0.09 (0.03)	0.04 (0.01)	3.83 (0.16)	75.39 (0.75)	0.72 (0.36)	0.20 (0.07)	2.52 (0.65)	2.54 (0.44)	5.83 (0.56)	0.15 (0.06)	0.96 (0.11)
2	0.05 (0.02)	0.11 (0.10)	5.73 (0.16)	0.09 (0.03)	1.30 (0.41)	0.10 (0.03)	0.04 (0.02)	3.86 (0.41)	75.41 (0.84)	0.70 (0.41)	0.17 (0.06)	2.54 (0.12)	2.53 (0.20)	5.84 (0.81)	0.14 (0.03)	0.96 (0.14)
4	0.07 (0.04)	0.12 (0.04)	5.74 (0.24)	0.08 (0.02)	1.27 (0.24)	0.11 (0.07)	0.05 (0.03)	3.89 (0.23)	75.40 (0.18)	0.68 (0.34)	0.16 (0.09)	2.55 (0.04)	2.51 (0.30)	5.87 (0.47)	0.12 (0.07)	0.93 (0.09)
6	0.08 (0.03)	0.13 (0.05)	5.72 (0.80)	0.09 (0.01)	1.25 (0.18)	0.12 (0.03)	0.07 (0.04)	3.92 (0.09)	75.38 (0.21)	0.64 (0.16)	0.13 (0.10)	2.57 (0.28)	2.51 (0.16)	5.88 (0.09)	0.12 (0.02)	0.91 (0.26)
8	0.11 (0.07)	0.14 (0.07)	5.76 (0.94)	0.06 (0.03)	1.23 (0.31)	0.14 (0.06)	0.03 (0.02)	3.99 (0.14)	75.35 (0.86)	0.60 (0.38)	0.09 (0.02)	2.58 (0.14)	2.49 (0.33)	5.90 (0.51)	0.11 (0.04)	0.88 (0.22)
10	0.07 (0.03)	0.16 (0.11)	5.70 (0.66)	0.05 (0.02)	1.24 (0.18)	0.11 (0.04)	0.02 (0.01)	4.18 (0.39)	75.28 (0.28)	0.55 (0.16)	0.07 (0.03)	2.57 (0.41)	2.47 (0.18)	5.92 (0.21)	0.10 (0.05)	0.86 (0.08)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table IV  
Changes in the quality characteristics of Kenya *Moringa oleifera* (cold pressure) oil during frying cod at 175°C

DETERMINATION						
Time (h)	Acidity (% as oleic acid)	Peroxide value (meq O <sub>2</sub> /kg of oil)	Iodine value (g of I/100g of oil)	Viscosity (mPa s)	Smoke point (°C)	Polar compounds (g/100 g oil)
0	2.06 (0.24)	0.36 (0.19)	66.81 (0.51)	103.00 (0.43)	201 (2.1)	3.58 (0.73)
2	2.12 (0.18)	0.56 (0.27)	66.70 (1.13)	103.14 (0.63)	200 (1.8)	3.78 (0.24)
4	2.24 (0.32)	1.01 (0.30)	66.57 (0.61)	103.29 (1.01)	198 (1.1)	4.41 (0.27)
6	2.43 (0.21)	1.65 (0.44)	66.39 (0.41)	103.52 (0.93)	197 (2.4)	5.14 (0.70)
8	2.68 (0.17)	2.50 (0.63)	66.10 (1.03)	103.91 (1.18)	195 (1.6)	6.11 (0.83)
10	3.03 (0.80)	3.95 (0.80)	65.77 (0.49)	104.45 (1.21)	193 (2.2)	7.28 (1.04)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table V  
Changes in the quality characteristics of Kenya *Moringa oleifera* (cold pressure) oil during frying cod at 175°C

DETERMINATION						
Time (h)	$E_{1cm}^{1\%}$ at 232 nm	Induction period (h)	$\alpha$ -tocopherol (mg/kg oil)	$\gamma$ -tocopherol (mg/kg oil)	$\delta$ -tocopherol (mg/kg oil)	Colour red, yellow
0	1.66 (0.25)	18.90 (0.91)	42.61 (7.56)	15.82 (1.91)	24.21 (1.68)	1.90, 30 (0.10), (6.0)
2	1.77 (0.43)	18.54 (0.73)	42.03 (0.99)	13.91 (3.16)	22.87 (1.63)	2.06, 30 (0.08), (3.7)
4	1.94 (0.16)	18.11 (0.56)	40.82 (2.63)	11.66 (2.16)	19.64 (0.86)	2.13, 30 (0.41), (4.2)
6	2.22 (0.83)	17.59 (0.21)	38.74 (1.56)	9.13 (1.46)	14.99 (1.28)	2.29, 30 (0.80), (1.6)
8	2.81 (0.36)	16.62 (1.85)	35.73 (2.81)	6.05 (0.86)	9.76 (2.63)	2.65, 30 (0.31), (0.8)
10	3.60 (0.74)	15.29 (2.13)	31.51 (3.85)	1.57 (1.03)	3.17 (1.65)	3.6, 31 (0.20), (0.7)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table VI  
Fatty acid composition of Kenya *Moringa oleifera* (cold pressure) oil during frying cod at 175°C

FATTY ACID																
Time (h)	8:0	14:0	16:0	16:1 $\omega$ 9	16:1 $\omega$ 7	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1cis	26:0
0	0.03 (0.01)	0.11 (0.07)	5.73 (0.31)	0.10 (0.05)	1.32 (0.89)	0.09 (0.03)	0.04 (0.01)	3.83 (0.16)	75.39 (0.75)	0.72 (0.36)	0.20 (0.07)	2.52 (0.65)	2.54 (0.44)	5.83 (0.56)	0.15 (0.06)	0.96 (0.11)
2	0.03 (0.02)	0.13 (0.07)	5.73 (0.11)	0.07 (0.03)	1.28 (0.40)	0.11 (0.03)	0.04 (0.01)	3.84 (0.11)	75.41 (0.63)	0.69 (0.18)	0.18 (0.09)	2.55 (0.41)	2.52 (0.12)	5.87 (0.81)	0.13 (0.06)	0.93 (0.31)
4	0.04 (0.02)	0.15 (0.09)	5.78 (0.98)	0.05 (0.02)	1.25 (0.33)	0.13 (0.07)	0.02 (0.01)	3.89 (0.48)	75.35 (0.44)	0.66 (0.23)	0.15 (0.07)	2.58 (0.21)	2.49 (0.80)	5.90 (0.39)	0.11 (0.04)	0.89 (0.22)
6	0.07 (0.03)	0.18 (0.06)	5.81 (0.38)	0.08 (0.03)	1.24 (0.30)	0.09 (0.03)	0	3.91 (0.25)	75.32 (0.21)	0.58 (0.31)	0.11 (0.03)	2.56 (0.11)	2.47 (0.74)	5.94 (0.71)	0.10 (0.05)	0.83 (0.31)
8	0.10 (0.04)	0.18 (0.09)	5.86 (0.18)	0.06 (0.01)	1.26 (0.17)	0.11 (0.04)	0	3.94 (0.19)	75.27 (0.19)	0.53 (0.08)	0.07 (0.03)	2.60 (0.61)	2.45 (0.38)	5.96 (0.52)	0.09 (0.02)	0.77 (0.44)
10	0.12 (0.07)	0.24 (0.11)	5.88 (0.14)	0.07 (0.02)	1.26 (0.32)	0.14 (0.06)	0	3.99 (0.87)	75.23 (0.44)	0.41 (0.16)	0.02 (0.01)	2.62 (0.92)	2.42 (0.26)	5.97 (0.94)	0.07 (0.04)	0.72 (0.38)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table VII  
Changes in the quality characteristics of Malawi *Moringa oleifera* (n-hexane) oil during frying potatoes at 175°C

DETERMINATION						
Time (h)	Acidity (% as oleic acid)	Peroxide value (meq O <sub>2</sub> /kg of oil)	Iodine value (g of I/100g of oil)	Viscosity (mPa s)	Smoke point (°C)	Polar compounds (g/100 g oil)
0	1.32 (0.20)	1.80 (0.21)	66.83 (0.63)	57.00 (0.16)	198 (1.6)	3.29 (1.06)
2	1.40 (0.71)	2.38 (0.98)	66.78 (0.48)	57.36 (0.28)	196 (2.3)	3.68 (0.64)
4	1.53 (0.36)	2.66 (0.84)	66.71 (0.34)	57.92 (0.66)	194 (1.7)	4.23 (0.47)
6	1.72 (0.54)	3.44 (1.15)	66.56 (0.71)	58.64 (0.41)	191 (1.1)	5.46 (0.38)
8	2.11 (0.48)	3.24 (1.35)	66.22 (0.61)	59.67 (0.73)	188 (3.2)	7.08 (0.43)
10	2.77 (0.43)	3.62 (0.76)	65.39 (1.04)	60.80 (0.84)	184 (1.4)	9.19 (0.56)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table VIII  
Changes in the quality characteristics of Kenya *Moringa oleifera* (n-hexane) oil during frying potatoes at 175°C

DETERMINATION						
Time (h)	$E_{1\text{cm}}^{1\%}$ at 232 nm	Induction period (h)	$\alpha$ -tocopherol (mg/kg oil)	$\gamma$ -tocopherol (mg/kg oil)	$\delta$ -tocopherol (mg/kg oil)	Colour red, yellow
0	1.66 (0.25)	10.80 (0.20)	34.59 (4.01)	10.88 (1.44)	27.04 (1.99)	0,40 , (7.12)
2	1.75 (0.36)	10.01 (0.74)	32.15 (3.36)	7.35 (2.45)	18.06 (1.36)	0.41, 40 (0.28), (5.16)
4	1.91 (0.18)	8.76 (0.45)	28.63 (2.15)	2.86 (1.35)	5.16 (0.98)	0.89, 40 (0.66), (4, 13)
6	2.45 (0.28)	7.35 (0.61)	23.36 (1.35)	0	0	1.83, 40 (0.99), (2.12)
8	3.46 (0.48)	5.77 (0.60)	17.17 (0.88)	0	0	3.09, 41 (1.20), (0.95)
10	4.84 (0.73)	3.90 (0.71)	9.58 (0.33)	0	0	5.60, 41 (0.18), (1.70)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table IX  
Fatty acid composition of Malawi *Moringa oleifera* (n-hexane) oil during frying potatoes at 175°C

FATTY ACID															
Time (h)	8:0	14:0	16:0	16:1 $\omega$ 9	16:1 $\omega$ 7	17:0	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1cis	26:0
0	0.03 (0.01)	0.11 (0.07)	6.04 (0.41)	0.11 (0.06)	1.46 (0.88)	0.09 (0.03)	4.14 (0.19)	73.60 (0.77)	0.73 (0.41)	0.22 (0.08)	2.76 (0.55)	2.40 (0.38)	6.73 (0.29)	0.14 (0.07)	1.08 (0.12)
2	0.05 (0.02)	0.13 (0.11)	6.05 (0.18)	0.11 (0.08)	1.44 (0.71)	0.11 (0.08)	4.16 (0.39)	73.56 (0.41)	0.70 (0.31)	0.20 (0.12)	2.77 (0.20)	2.38 (0.17)	6.74 (0.13)	0.13 (0.09)	1.06 (0.23)
4	0.07 (0.04)	0.13 (0.04)	6.07 (0.29)	0.09 (0.04)	1.41 (0.31)	0.13 (0.09)	4.23 (0.53)	73.51 (0.28)	0.66 (0.43)	0.15 (0.14)	2.79 (0.14)	2.35 (0.25)	6.77 (0.44)	0.11 (0.06)	1.04 (0.11)
6	0.09 (0.03)	0.15 (0.11)	6.08 (0.33)	0.08 (0.08)	1.36 (0.18)	0.15 (0.11)	4.27 (0.36)	73.46 (0.17)	0.59 (0.19)	0.11 (0.08)	2.81 (0.36)	2.31 (0.41)	6.81 (0.27)	0.08 (0.04)	1.01 (0.21)
8	0.11 (0.07)	0.16 (0.09)	6.11 (0.18)	0.05 (0.03)	0.34 (0.11)	0.18 (0.09)	4.31 (0.20)	73.40 (0.43)	0.37 (0.14)	0.07 (0.04)	2.84 (0.49)	2.29 (0.19)	6.82 (0.33)	0.06 (0.03)	0.97 (0.28)
10	0.16 (0.10)	0.17 (0.12)	6.14 (0.45)	0.03 (0.02)	1.29 (0.24)	0.23 (0.13)	4.39 (0.29)	73.33 (0.41)	0.07 (0.07)	0.02 (0.01)	2.89 (0.21)	2.24 (0.39)	6.89 (0.31)	0.05 (0.02)	0.90 (0.36)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table X  
Changes of the quality characteristics of Kenya *Moringa oleifera* (n-hexane) oil during frying cod at 175°C

DETERMINATION						
Time (h)	Acidity (% as oleic acid)	Peroxide value (meq O <sub>2</sub> /kg of oil)	Iodine value (g of I/100g of oil)	Viscosity (mPa s)	Smoke point (°C)	Polar compounds (g/100 g oil)
0	1.32 (0.20)	1.80 (0.21)	66.83 (0.63)	57.00 (0.16)	198 (1.6)	3.29 (1.06)
2	1.46 (0.61)	2.55 (0.76)	66.76 (0.44)	57.43 (0.28)	197 (2.4)	3.76 (0.76)
4	1.68 (0.53)	3.12 (1.23)	66.62 (0.81)	57.98 (0.34)	194 (3.4)	4.41 (0.48)
6	1.97 (0.46)	2.86 (0.98)	66.38 (0.41)	58.71 (0.93)	192 (2.9)	5.50 (0.22)
8	2.42 (0.27)	3.95 (0.88)	65.86 (0.65)	59.99 (0.83)	187 (1.9)	7.16 (0.66)
10	2.92 (0.38)	5.04 (1.70)	65.25 (0.92)	61.55 (0.76)	183 (2.4)	9.87 (0.76)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XI  
Changes in the quality characteristics of Kenya *Moringa oleifera* (n-hexane) oil during frying cod at 175°C

DETERMINATION						
Time (h)	E <sub>1cm</sub> <sup>1%</sup> at 232 nm	Induction period (h)	α-tocopherol (mg/kg oil)	γ-tocopherol (mg/kg oil)	δ-tocopherol (mg/kg oil)	Colour red, yellow
0	1.66 (0.25)	10.80 (0.20)	34.59 (4.01)	10.88 (1.44)	27.04 (1.99)	0, 40 -, (7.12)
2	1.78 (0.34)	10.13 (0.76)	32.75 (1.85)	6.75 (0.91)	19.34 (1.63)	0.30, 40 (0.16), (5.12)
4	1.89 (0.11)	8.92 (0.44)	28.59 (0.96)	0	6.15 (1.70)	0.81, 40 (0.78), (1.71)
6	2.57 (0.22)	7.36 (0.22)	23.01 (1.82)	0	0	1.70, 40 (1.10), (3.41)
8	3.66 (0.29)	5.62 (0.44)	15.36 (0.46)	0	0	2.78, 40 (1.63), (0.80)
10	5.31 (0.48)	3.37 (0.61)	3.58 (1.74)	0	0	4.20, 41 (0.96), (1.15)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XII  
Fatty acid composition of heated Kenya *Moringa oleifera* (n-hexane) oil during frying cod at 175°C

FATTY ACID															
Time (h)	8:0	14:0	16:0	16:1 ω <sub>9</sub>	16:1 ω <sub>7</sub>	17:0	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1cis	26:0
0	0.03 (0.01)	0.11 (0.07)	6.04 (0.41)	0.11 (0.06)	1.46 (0.88)	0.09 (0.03)	4.14 (0.19)	73.60 (0.77)	0.73 (0.41)	0.22 (0.08)	2.76 (0.55)	2.40 (0.38)	6.73 (0.29)	0.14 (0.07)	1.08 (0.21)
2	0.03 (0.02)	0.12 (0.09)	6.04 (0.18)	0.11 (0.07)	1.43 (0.34)	0.11 (0.04)	4.17 (0.29)	73.56 (0.56)	0.70 (0.39)	0.20 (0.11)	2.78 (0.41)	2.39 (0.16)	6.76 (0.42)	0.13 (0.11)	1.08 (0.17)
4	0.07 (0.04)	0.14 (0.11)	6.07 (0.23)	0.09 (0.05)	1.39 (0.18)	0.14 (0.04)	4.21 (0.48)	73.51 (0.40)	0.65 (0.44)	0.18 (0.13)	2.80 (0.36)	2.36 (0.45)	6.79 (0.24)	0.10 (0.08)	1.06 (0.27)
6	0.09 (0.05)	0.15 (0.06)	6.09 (0.36)	0.08 (0.04)	1.34 (0.18)	0.14 (0.07)	4.26 (0.33)	73.49 (0.23)	0.49 (0.28)	0.13 (0.09)	2.83 (0.36)	2.32 (0.36)	6.82 (0.14)	0.08 (0.04)	1.04 (0.18)
8	0.13 (0.11)	0.17 (0.13)	6.11 (0.43)	0.07 (0.03)	0.31 (0.16)	0.18 (0.12)	4.32 (0.21)	73.41 (0.16)	0.16 (0.11)	0.06 (0.03)	2.87 (0.15)	2.28 (0.12)	6.86 (0.22)	0.06 (0.03)	1.03 (0.23)
10	0.15 (0.08)	0.21 (0.15)	6.11 (0.17)	0.04 (0.02)	1.25 (0.18)	0.24 (0.13)	4.44 (0.19)	73.29 (0.38)	0	0	2.91 (0.26)	2.22 (0.14)	6.91 (0.47)	0.02 (0.01)	0.92 (0.34)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XIII  
Changes in the quality characteristics of Kenya *Moringa oleifera* (chloroform:methanol) oil during frying potatoes at 175°C

DETERMINATION						
Time (h)	Acidity (% as oleic acid)	Peroxide value (meq O <sub>2</sub> /kg of oil)	Iodine value (g of I/100g of oil)	Viscosity (mPa s)	Smoke point (°C)	Polar compounds (g/100 g oil)
0	1.56 (0.21)	0.94 (0.25)	66.66 (0.54)	66.00 (0.16)	202 (1.9)	3.32 (0.63)
2	1.59 (0.45)	1.15 (0.78)	66.61 (0.87)	66.16 (0.43)	202 (2.3)	3.62 (0.39)
4	1.66 (0.78)	2.63 (0.94)	66.49 (0.55)	66.42 (0.48)	200 (1.4)	4.15 (0.66)
6	1.88 (0.44)	1.44 (0.78)	66.27 (0.95)	66.89 (0.66)	197 (2.6)	5.06 (0.53)
8	2.18 (0.19)	2.03 (1.02)	65.94 (0.38)	67.45 (0.41)	195 (1.2)	6.21 (0.72)
10	2.61 (0.38)	4.90 (1.15)	65.54 (0.32)	68.40 (0.71)	191 (2.7)	7.67 (0.67)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XIV  
Changes in the quality characteristics of Kenya *Moringa oleifera* (chloroform:methanol) oil during frying potatoes at 175°C

DETERMINATION						
Time (h)	E <sub>1%</sub> <sub>1cm</sub> at 232 nm	Induction period (h)	α-tocopherol (mg/kg oil)	γ-tocopherol (mg/kg oil)	δ-tocopherol (mg/kg oil)	Colour red, yellow
0	1.17 (0.21)	16.50 (0.40)	40.96 (3.51)	13.38 (2.12)	25.61 (1.97)	3.30, 72.00 (0.40), (9.90)
2	1.24 (0.56)	16.30 (0.71)	39.99 (2.23)	10.02 (1.85)	22.16 (0.34)	3.49, 72.00 (0.78), (3.12)
4	1.43 (0.18)	15.85 (0.38)	37.06 (3.17)	6.07 (2.43)	17.73 (0.42)	3.76, 73.00 (0.44), (1.80)
6	1.79 (0.43)	15.19 (0.56)	34.23 (1.69)	1.18 (0.01)	10.35 (0.04)	4.18, 73.00 (1.25), (1.36)
8	2.41 (0.24)	14.15 (0.18)	31.05 (2.70)	0	1.16 (0.01)	5.41, 74.00 (2.30), (1.36)
10	3.30 (0.18)	12.40 (0.33)	26.78 (0.54)	0	0	7.00, 75.00 (2.14), (4.70)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XV  
Fatty acid composition of Kenya *Moringa oleifera* (chloroform:methanol) oil during frying potatoes at 175°C

FATTY ACID																
Time (h)	8:0	14:0	16:0	16:1 ω <sub>9</sub>	16:1 ω <sub>7</sub>	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1cis	26:0
0	0.02 (0.01)	0.11 (0.05)	5.81 (0.36)	0.10 (0.06)	1.44 (0.91)	0.09 (0.03)	0.04 (0.01)	4.00 (0.20)	73.91 (0.79)	0.71 (0.39)	0.20 (0.04)	2.70 (0.49)	-2.46 (0.39)	6.38 (0.36)	0.14 (0.08)	1.06 (0.13)
2	0.04 (0.02)	0.12 (0.04)	5.82 (0.17)	0.10 (0.03)	1.43 (0.39)	0.10 (0.06)	0.04 (0.02)	4.02 (0.36)	73.90 (0.44)	0.67 (0.22)	0.19 (0.08)	2.73 (0.36)	2.44 (0.55)	6.39 (0.25)	0.13 (0.04)	1.02 (0.43)
4	0.04 (0.02)	0.12 (0.08)	5.84 (0.12)	0.09 (0.02)	1.41 (0.16)	0.11 (0.04)	0.03 (0.02)	4.07 (0.44)	73.87 (0.28)	0.59 (0.34)	0.16 (0.08)	2.75 (0.66)	2.39 (0.28)	6.42 (0.44)	0.11 (0.07)	0.98 (0.17)
6	0.05 (0.03)	0.14 (0.09)	5.83 (0.28)	0.09 (0.03)	1.39 (0.41)	0.11 (0.06)	0.02 (0.01)	4.13 (0.68)	73.83 (0.35)	0.48 (0.72)	0.12 (0.09)	2.77 (0.74)	2.37 (0.36)	6.45 (0.33)	0.10 (0.04)	0.97 (0.61)
8	0.07 (0.04)	0.17 (0.10)	5.86 (0.17)	0.08 (0.04)	1.38 (0.16)	0.13 (0.09)	0.02 (0.01)	4.17 (0.48)	73.78 (1.13)	0.36 (0.28)	0.07 (0.04)	2.79 (0.34)	2.33 (0.16)	6.51 (0.16)	0.07 (0.03)	0.91 (0.63)
10	0.10 (0.06)	0.16 (0.08)	5.88 (0.83)	0.05 (0.02)	1.35 (0.35)	0.16 (0.07)	0	4.24 (0.28)	73.73 (0.84)	0.28 (0.14)	0	2.83 (1.24)	2.30 (0.61)	6.55 (1.16)	0.02 (0.01)	0.84 (0.41)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XVI

Changes in the quality characteristics of Kenya *Moringa oleifera* (chloroform:methanol) oil during frying cod at 175°C

DETERMINATION						
Time (h)	Acidity (% as oleic acid)	Peroxide value (meq O <sub>2</sub> /kg of oil)	Iodine value (g of I/100g of oil)	Viscosity (mPa s)	Smoke point (°C)	Polar compounds (g/100 g oil)
0	1.56 (0.21)	0.94 (0.25)	66.66 (0.54)	66.00 (0.16)	202 (1.9)	3.32 (0.63)
2	1.63 (0.18)	1.13 (0.80)	66.59 (0.31)	66.78 (0.25)	200 (2.4)	3.66 (0.91)
4	1.72 (0.44)	2.10 (3.95)	66.41 (0.48)	67.02 (0.44)	198 (1.8)	4.24 (0.70)
6	1.92 (0.12)	3.95 (0.94)	66.13 (0.81)	67.31 (0.36)	195 (2.8)	5.21 (0.77)
8	2.25 (0.84)	3.65 (0.66)	65.80 (1.73)	67.85 (0.94)	192 (1.6)	6.55 (0.64)
10	2.78 (0.61)	5.76 (1.80)	65.41 (0.45)	68.95 (0.36)	189 (1.8)	8.42 (0.77)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XVII

Changes in the quality characteristics of Kenya *Moringa oleifera* (chloroform:methanol) oil during frying cod at 175°C

DETERMINATION						
Time (h)	E <sub>1%</sub> <sub>1cm</sub> at 232 nm	Induction period (h)	α-tocopherol (mg/kg oil)	γ-tocopherol (mg/kg oil)	δ-tocopherol (mg/kg oil)	Colour red, yellow
0	1.17 (0.21)	16.50 (0.40)	40.96 (3.51)	13.38 (2.12)	25.61 (1.97)	3.30, 72 (0.40), (9.90)
2	1.26 (0.43)	16.02 (0.53)	39.76 (2.80)	9.85 (3.15)	21.33 (2.25)	3.44, 72 (0.63), (6.30)
4	1.48 (0.55)	15.41 (0.48)	36.81 (1.36)	2.83 (1.10)	14.17 (1.63)	3.66, 73 (0.66), (4.17)
6	1.97 (0.83)	14.42 (0.22)	33.75 (1.72)	0	4.08 (2.55)	4.03, 73 (0.26), (2.15)
8	2.74 (0.11)	12.89 (0.66)	28.46 (2.95)	0	0	5.01, 73 (0.91), (1.80)
10	4.02 (0.31)	10.70 (0.73)	19.96 (0.36)	0	0	6.20, 74 (1.17), (3.40)

# Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

Table XVIII

Fatty acid composition of Kenya *Moringa oleifera* (chloroform:methanol) oil during frying cod at 175°C

FATTY ACID																
Time (h)	8:0	14:0	16:0	16:1 ω <sub>9</sub>	16:1 ω <sub>7</sub>	17:0	17:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1cis	26:0
0	0.02 (0.01)	0.11 (0.05)	5.81 (0.36)	0.10 (0.06)	1.44 (0.91)	0.09 (0.03)	0.04 (0.01)	4.00 (0.20)	73.91 (0.79)	0.71 (0.39)	0.20 (0.04)	2.70 (0.49)	2.46 (0.39)	6.38 (0.36)	0.14 (0.08)	1.06 (0.13)
2	0.03 (0.02)	0.12 (0.06)	5.81 (0.22)	0.10 (0.04)	1.42 (0.66)	0.11 (0.09)	0.03 (0.02)	4.03 (0.71)	73.87 (0.85)	0.68 (0.25)	0.16 (0.11)	2.72 (0.36)	2.46 (0.18)	6.41 (0.52)	0.12 (0.07)	1.04 (0.22)
4	0.06 (0.03)	0.14 (0.04)	5.83 (0.16)	0.09 (0.04)	1.39 (0.24)	0.12 (0.08)	0.02 (0.01)	4.07 (0.64)	73.84 (0.92)	0.62 (0.34)	0.13 (0.09)	2.74 (0.16)	2.43 (0.24)	6.43 (0.64)	0.10 (0.04)	1.01 (0.44)
6	0.08 (0.05)	0.15 (0.07)	5.83 (0.34)	0.07 (0.05)	1.37 (0.16)	0.14 (0.07)	0.02 (0.01)	4.10 (0.25)	73.82 (0.16)	0.49 (0.27)	0.08 (0.04)	2.75 (0.34)	2.41 (0.33)	6.46 (0.78)	0.07 (0.03)	0.98 (0.24)
8	0.11 (0.06)	0.17 (0.11)	5.88 (0.44)	0.06 (0.03)	1.34 (0.18)	0.16 (0.10)	0	4.14 (0.36)	73.78 (1.15)	0.31 (0.12)	0	2.77 (0.58)	2.38 (0.71)	6.48 (0.19)	0.04 (0.02)	0.95 (0.12)
10	0.13 (0.09)	0.24 (0.13)	5.95 (0.68)	0.03 (0.01)	1.31 (0.21)	0.18 (0.11)	0	4.22 (0.36)	73.71 (0.56)	0.13 (0.09)	0	2.81 (0.42)	2.32 (0.28)	6.52 (1.15)	0	0.93 (0.19)

# \* Values are means of triplicate determinations and percentage coefficient of variation are given in parenthesis.

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## REFERENCES

1. Lawson, H. (1985).—«Standards for fats and oils».—The Avi Publishing Company Inc., Westport (Connecticut), USA.
2. Stevenson, S.G., Vaisey-Genser, M., Eskin, N.A.M. (1984).—«Quality control in the use of deep frying oils».—*J. Am. Oil Chem. Soc.* **61**, 1102-1108.
3. Chang, S.S., Peterson, R. J., Ho, C.T. (1978).—«Chemistry of deep fat frying» in «Lipids as a source of flavour».—M. K. Supran (Ed), American Chemical Society, USA.
4. Landers, R. E. and Rathman, D.N. (1981).—«Vegetable oils: Effects of processing, storage and use on nutritional values».—*J. Am. Oil Chem. Soc.* **58**, 255-259.
5. Guillamin, R., Rondot, G., Coquet, B. (1980).—«Physiopathology of heated rapeseed oil and edible oil suet. Rat feeding studies».—*Rev. Fr. Corps. Gras.* **27**, 189.
6. Van Gastel, A., Mathur, R., Roy, V.V., Rukmini, C. (1984).—«Ames mutagenicity tests of repeatedly heated edible oils».—*Food Chem. Toxicol.* **22**, 403.
7. Tsaknis, J. (1991).—«Quality changes of olive oil and other selected vegetable oils during frying».—Mphil Thesis, University of Humberside.
8. IUPAC. (1987).—«Standard Methods for the Analysis of Oils Fats and Derivatives».—7th Ed.-C. Paquot (ed), Blackwell Scientific Publications.
9. British Standards Methods of Analysis. (1976).—«Fats and Oils».—part. 1, Physical Methods, Section 1.8.
10. Pearsons, D.—H. Egan, R.S. Kird and R. Sawyer (Ed.), (1981).—«Chemical Analysis of Foods».—8th Ed, Churchill Livingstone, Edinburgh, Britain, 520-547.
11. A.P. Carpenter, J.R. (1979).—«Determination of the tocopherols in vegetable oils».—*J. Am. Oil Chem. Soc.* **56**, 668-671.
12. Lea, C.H. (1952).—«Methods for determination of peroxide in lipids».—*J. Sci. Food Agric.* **11** 586-594.
13. Tyagi, V.K., Vasishtha, A.K. (1996).—«Changes in characteristics and composition of oils during deep-fat frying».—*J. Am. Oil Chem. Soc.* **73**, 499-506.
14. Al-Harbi, M.M., Al-Kabtani, H.A. (1993).—«Chemical and biological evaluation of discarded frying palm oil commercial restaurants».—*Food Chemistry.* **48**, 395-401.
15. Perkins, E.G. (1967).—«Non-volatile decomposition products in heated fats and oils».—*Food Technology.* **21**, 611-616.
16. Augustin, M.A. and Berry, S.K. (1983).—«Efficacy of the antioxidants BHA and BHT in palm olein during heating and frying».—*J. Am. Oil Chem. Soc.* **60**, 1520-1522.
17. Tsaknis, J., Lalas, S., Hole, M., Smith, G. and Tychopoulos, B. (1998).—«An HPLC rapid method of determining malonaldehyde (MDA) for evaluation of rancidity in edible oils».—*Analyst*, **123**, 325-327.
18. Morton, I.D. and Chidley, J.E. (1988).—«Methods and equipment in Frying» in: «Frying Food: Principles, changes, new approaches».—Varela, G., Bender, A.E. and Morton, I.D. (Ed), Ellis Horwood Series in Food Science and Technology, Chichester, England.
19. Fritch, C.W. (1981).—«Measurements of frying fat deterioration: A brief review».—*J. Am. Oil Chem. Soc.* **58**, 272-274.
20. Gere, A. (1982).—«Studies of the changes in edible fats during heating and frying».—*Die Nahrung* **26**, 923-932.
21. Gutiérrez González Quijano, R. and Dobarganes, M.C.—«Analytical Procedures for the evaluation of Used Frying Fats» in: «Frying of Food: Principles, changes, new approaches» p. 141-154.—Varela, G., Bender, A.E. and Morton, I.D. (Ed), VCH Publishers Ltd., London.
22. Burton, W.G. (1989).—«The cooking and processing of potatoes as food» in: «The potato» 3rd (Ed), 336-364.—John Wiley and Sons, New York, .
23. Sonntag, N.O.V. (1979).—«Composition and characteristics of individual fats and oils» in «Bailey's Industrial Oil and Fat Products. 4th Ed.» Vol. 11, 389-398.—Swern, D.(Ed), John Wiley and Sons, New York, USA.
24. Lea, C.H. (1960).—«On the antioxidant activities of the tocopherols. II-Influence of substrate, temperature and level of oxidation».—*J. Sci. Food Agric.* **11**, 212-215.
25. Miyagawa, K., Hirai, K. and Takezoe, R. (1991).—«Tocopherol and fluorescence levels in deep-frying oil and their measurement for oil assessment».—*J. Am. Oil Chem. Soc.* **68**, 163-166.
26. Carl B.L., Tabacch, N.H. (1986).—«Frying oil deterioration and vitamin loss during foodservice operation».—*J. Food Sci.* **51**, 218-221.

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