Fatty Acids Profile of Repeatedly Used Vegetable Oils by the Roadside Food Vendors in Owo Metropolis, Ondo State, Nigeria

***Folahan, O.O, **Bolajoko, O.O, and ***Olanrewaju, O.I**

*Nutrition and Dietetics Department, Ogun State College of Health Technology, Ilese,
*Nutrition and Dietetics Department, Federal University of Agriculture, Abeokuta
***Nutrition and Dietetics Department, Rufus Giwa Polytechnic, Owo, Ondo State

*****Correspondence Author:** opebolajoko@gmail.com, tunakinsmentoring@gmail.com

ABSTRACT

Background: *The consumption of saturated fatty acid is a major risk factor for the rise in the mortality rate among individuals who suffer from cardiovascular and cerebrovascular diseases.*

Objective: *The study investigated the fatty acid profile of repeatedly used vegetable oils by the road side food vendors in Owo metropolis.*

Methods: *Two (2) different vegetable oils used for frying fish and bean cake by the vendors were collected in Owo. The oils were chosen on the bases that they have been reused for at least five days. Fresh palm olien oil and palm oil were used as control samples. The fatty acid composition of the oil samples was determined using gas chromatography equipped with a flame ionization detector. The data obtained were statistically analyzed using ANOVA to test for the level of significant difference in the variation of the means.*

Results: *Findings showed that repeatedly used palm olien oil and palm oil respectively had higher values of total saturated fatty acid (62.36% and 60.09%) compared to the control samples (45.50% and 51.00%) Total unsaturated fatty acid (40.21% and 45.13%), total Polyunsaturated fatty acid (9.96% and 9.98%), and total monounsaturated fatty acid (26.42% and 30.05%) of the reused oil samples were significantly lower when compared to the control samples (54.50% and 49.00%), (11.50% and 10.00%), and (43.90% and 39.00%), respectively.*

Conclusion: *Repeatedly used oils increased the concentration of TSAs and decreased TUSFAs, which can negatively impact on the cardiovascular health of the consumers.*

Keywords: Palm olien oil, palm oil, reused oil, unsaturated fatty acid, cardiovascular health

INTRODUCTION

The use of oil for frying is one of the most popular cooking methods globally for both domestic and industrial food preparation procedures. The use of fat or oil for frying remains one of the most popular methods for the preparation of foods in Nigeria, where a deep-fried food forms the staple food item in the diet and is widely available from street vendors (1). Frying is an intense process that induces the multitude of chemical reactions in the frying medium and generates a plethora of chemical compounds. In frying, whichever type the oil is, it is usually heated to about 170 °C to 220 °C. When the oil is heated to these temperatures in the presence of oxygen (air), the oil undergoes thermal, physical, and chemical degradation by reaction (2). There are potential health hazards generated by the consumption of oxidized products resulting from oils used

repeatedly in frying processes (3, 4).

Fried fish and bean cake, also known as "Akara," are the major Nigeria snack commonly consumed by southerners. The fried fish is mostly eaten with "Garri" while the bean cake as either as a breakfast meal when combined with pap or with bread. The repeated use of fried oil in the preparation of these snacks is a common practice among the street and roadside food vendors. The organoleptic and sensory properties of fried food products, such as good flavor, crispy texture, juicy taste, and brownish color, are primarily desired and relished by consumers (5).

Fried foods indeed have unique sensory properties, which make them very attractive to consumers. However, the chemical changes in the oil due to repeated frying are often deteriorative, and fatty acids undergo chemical changes that could make fried foods unsuitable products in terms of nutritional value (6). The over-use of deep-frying oil causes adverse effects on flavor, stability, color, and texture of the fried product and may be harmful to human health. Repeated use of vegetable oil lowers the smoke point, which is the temperature at which the oil breaks down, creating acrolein, an obnoxious smelling compound, and visible fumes are given off. This makes the oil smoke at a lower temperature during heating. Prolong exposure of cooking oil to high temperatures generates lipid peroxidation products that may be harmful to human health (6). The presence of excess polar compounds in the repeated use of frying oil has been associated with increased risk of developing hypertension, atherosclerosis and is also associated with increased total serum lipid and low-density lipoprotein (LDL) levels. Furthermore, thermally oxidized lipids enhance peroxidation of membrane macromolecules, contributing to their mutagenicity and genotoxicity, which could potentially lead to carcinogenesis (4).

Maintaining concentrations of PUFAs is likely to favor enhanced cognitive learning and memory functions. Some properties of PUFAs make them attractive options in the treatment of cancer (7). Polyunsaturated fatty acids (PUFAs) modify cell membrane phospholipids; modify cellular functions, which may reduce tumor motile/invasive potential. Besides, they are directly toxic to tumor cells, modify the sensitivity of tumor cells to chemotherapeutic agents and radiation, as well as exert a protective role on normal tissues (1,6).

Despite the warnings issued by nutritionists that moderate consumption of fat is a way to ensure a balanced and healthy diet, many households are not judicious in the consumption of fried foods, which dense in calories, cholesterol, and saturated fats. Still, they also indulge in overusing of oil in frying (8). Studies have shown that degradation occurs when oil is reused. This affects the physical and chemical composition and quality of the oil (4, 8). Many studies have speculated that consumption of reheated oil is risk factors for cardiovascular diseases but few studies have quantitatively determined the fatty acid composition of repeatedly used vegetable oils. Therefore, this study quantitatively determined the fatty acid composition of repeatedly used vegetable oils (palm oil and palm olein) by roadside food vendors in Ondo state, southwest Nigeria

Materials and methods

Source of Raw Materials

Different oil samples used for fried fish and bean cake were collected in Owo metropolis, Ondo statefrom roadside food vendors. The samples were collected based on frying frequency/day and type of food being fried with the oils and length of oils usage. Two (2) different types of oils were collected based on their duration/length of usage (5 days) and types of food being fried (fish or bean cake). Fresh palm oil and palm olein were purchased from the market in Abeokuta South local government area, and it served as a control for the oil used in this study.

Fatty acid composition determination

The fatty acid profile was determined as fatty acid methyl esters (FAMEs) by gas chromatography equipped with a flame ionization detector; 50 mg

of the sample was saponified (esterifies) for five (5) minutes at 95 °C with 3.4 ml of the 0.5 M KOH in dry methanol. The mixture was neutralized by using 0.7M HCl. Moreover, 3 ml of the 14% boron triflouride in methanol was added. The mixture was heated for 5 minutes at the temperature of 90 °C to achieve a complete methylation process. The fatty acid methyl esters were thrice extracted from the mixture with redistilled hexane. The content was concentrated to 1 ml for gas chromatography analysis, and l µl was injected into the injection port of gas chromatography. The sample was introduced by split injection in split mode (ratio 20:1). The initial oven temperature was at 60 °C for 20mins at 120 C/min and then second. Ramping at 150 C/min for 3-minute while the carrier gas was used (9).

Statistical Analysis

The results were expressed as mean ± standard deviation, and the test for statistical significance was carried out using one-way analysis of variance (ANOVA). The Statistical Package for Social Sciences (SPSS, Version 20) software was used to determine significant differences. Means were separated using Duncan's New Multiple Range Test (DNMRT), and differences were considered significant at ($p<0.05$).

RESULTS

Table 1 shows the saturated and unsaturated fatty acid profile of repeatedly used palm oil for the frying of fish and bean-cake. The saturated fatty acid (SFAs) of UPOFF and UPOBC were 59.76% and 54.83%, respectively, and were significantly

Table 1: Saturated and unsaturated Fatty acid profile of repeatedly used palm oils for fried fish and bean cake

Param eters	Samples		
palm oil 100ml	**UPOFF** (%)	**UPOBC** (%)	**FPO** (%)
Monounsaturated fatty Acid (MUFA)	30.05 ± 0.06^{c}	30.57 ± 0.15^{b}	39.00 ± 0.00^{a}
Poly-unsaturated fatty acid (PUFA)	9.83 ± 0.13^{c}	9.84 ± 0.08^{b}	10.00 ± 0.00^{a}
Unsaturated fatty acid(USFA)	39.91 ± 0.04^{c}	45.13 ± 0.15^{b}	49.00 ± 0.00^{a}
Saturated fatty acid (SFA)	59.76 ± 0.11^{a}	54.83 ± 0.13^{b}	51.00 ± 0.00^{c}

Values are mean ± standard deviation of triplicate analyses. Values with the same superscript in the same column are statistically not significantly at ($P>0.05$).UPOFF: Used palm oil for fried fish, UPOBC: Used palm oil for bean cake, FPO: Fresh palm oil

Table 2: Fatty acid profile of repeatedly used palm oil for fried fish and bean cake

Fatty Acids (100ml)	UPOFF (%)	UPOBC (%)	FPO (%)
Palmitic	41.04 ± 0.06^{a}	36.15 ± 0.18^{c}	40.50 ± 0.00^{b}
Oleic	29.56 ± 0.12^{c}	32.34 ± 0.11^{b}	43.50 ± 0.00^{a}
Linoleic	9.59 ± 0.13^{a}	9.37 ± 0.09^{b}	9.30 ± 0.00^{c}
Stearic	10.02 ± 0.04^{a}	6.12 ± 0.07^{b}	5.20 ± 0.00^{c}
Myristic	0.91 ± 0.05^{b}	0.86 ± 0.06^{b}	0.50 ± 0.00^{c}
Lauric	ND	ND	ND
Arachidic	0.32 ± 0.00^{b}	0.35 ± 0.12^{a}	0.35 ± 0.00^{c}
Lignoceric	1.23 ± 0.08^{b}	1.39 ± 0.13^{a}	0.10 ± 0.00^{c}
Linolenic	0.24 ± 0.31^{a}	0.01 ± 0.00^{c}	0.20 ± 0.00^{b}
Palmitoleic	0.22 ± 0.05^{a}	0.19 ± 0.01^{b}	0.10 ± 0.00^{c}

Values are mean ± standard deviation of triplicate analyses. Values with the different superscript in the same column are statistically t significantly at ($P<0.05$). **UPOFF**: Used palm oil for fried fish, **UPOBC:** Used palm oil for bean cake, **FPO**: Fresh palmoil. ND: not detected

higher than FPO (51.0%). The monounsaturated fatty acid (MUFAs) of UPOFF and UPOBC were 30.05% and 30.57%, respectively, and were significantly lower than FPO (51.0%).

Table 2 shows the fatty acid profile of repeatedly used palm oil for fried fish and bean cake. The palmitic acid (41.04%), linoleic acid (9.59%), and stearic acid (10.09%) in palm oil were significantly higher than the value obtained in the control sample (40.50%, 9.30%, and 5.20%) respectively. Oleic acid decreased in value (29.56%) across the row compared to the control (43.50%). Lauric was not detected in the palm oil, both in the one used in frying fish and bean cake.

Table 3 shows the saturated and unsaturated fatty acid profile of repeatedly used palm olien for the frying of fish and bean-cake. The saturated fatty acids (SFAs) of UPOOFF and UPOOBC were 62.36% and 60.09%, respectively, and were significantly higher than FPOO (45.50%). Similarly, unsaturated fatty acids (USFAs) of UPOOFF and UPOOBC were 37.62% and 40.21% and were significantly lower than FPOO (54.50%), respectively. Monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) values were lower than that of the control sample.

Fatty acid profile of repeatedly used palm olein oil for fried fish and bean cake

Table 4 shows the fatty acid profile of repeatedly used palm oil for fried fish and bean cake. Palmitic acid (38.52%), oleic acid (21.10%), and

Table 3 Saturated and unsaturated fatty profile of used palm olein oil for fried fish and bean cake

Parameters	Samples		
Palm olien 100ml	**UPOOFF (%)**	**UPOOBC (%)**	**FPOO (%)**
Monounsaturated fatty Acid (MUFA)	26.42 ± 0.48^{c}	30.35 ± 0.11^{b}	43.90 ± 0.00^{a}
Poly-unsaturated fatty acid (PUFA)	10.86 ± 0.01^{b}	9.96 ± 0.16^{c}	11.50 ± 0.00^{a}
Unsaturated fatty acid (USFA)	37.62 ± 0.15^{c}	40.21 ± 0.11^{b}	54.50 ± 0.00^{a}
	62.36 ± 0.11^{a}	60.09 ± 0.16^{b}	45.50 ± 0.00^{c}

Values are mean ± standard deviation of triplicate analyses. Values with the same superscript in the same column are statistically not significantly at (P>0.05). **UPOOFF:** Used palm olien oil for fried fish **UPOOBC:** Used palm olien oil for bean cake **FPOO:** Fresh palm olien oil

Table 4: Fatty acid profile of repeatedly used palm olein oil for fried fish and bean cake

Fatty Acids (100ml)	UPOOFF (%)	UPOOBC (%)	FPOO (%)
Palmitic	38.52 ± 0.11^{b}	33.05 ± 0.75^{c}	40.80 ± 0.00^{a}
Oleic	21.01 ± 0.09^{c}	24.85 ± 0.90^{b}	43.50 ± 0.00^{a}
Linoleic	10.67 ± 0.11^{b}	9.77 ± 0.12^{c}	11.00 ± 0.00^{a}
Stearic	18.74 ± 0.12^{b}	19.25 ± 0.15^{a}	5.20 ± 0.00^{c}
Myristic	0.95 ± 0.03^{b}	0.72 ± 0.10^{c}	0.50 ± 0.00^{a}
Lauric	0.27 ± 0.07^{a}	0.23 ± 0.00^{b}	0.20 ± 0.00^{c}
Arachidic	0.39 ± 0.07^{a}	0.34 ± 0.01^{b}	0.20 ± 0.00^{c}
Lignoceric	0.89 ± 0.04^{b}	0.93 ± 0.03^{a}	0.10 ± 0.00^{c}
Linolenic	0.06 ± 0.00^{c}	0.06 ± 0.00^{b}	0.30 ± 0.00^{a}
Palmitoleic	9.71 ± 0.11^{a}	9.35 ± 0.06^{b}	0.20 ± 0.00^{c}

Values are mean ± standard deviation of triplicate analyses. Values with the same superscript in the same column are statistically not significantly at (P<0.05). UPOOFF: Used palm olein oil for fried fish UPOOBC: Used palm olein oil for bean cake FPOO: Fresh palm olein oil

linoleic acid (10.67%) in palm olein and were significantly lower than the value obtained in the control sample (40.80%, 43.90%, and 11.00%, respectively). While stearic acids in UPOOFF and UPOOBC were 18.74% and 19.25%, respectively and were significantly higher than FPOO (5.20%). Palmitoleic acid in the palm oil both in the one used in frying fish (9.71%) and bean cake (9.35%) and were higher in the two samples than the control sample (0.2%).

Discussion

The present study confirmed that repeatedly heating of the cooking oil increased the degree of saturation in the edible oil. As a result, when the same cooking oil is reused excessively, the chemical reactions enhance foaming, darkening of oil color, increased viscosity, and off-flavor. Hence, this action could lead to degradation of the chemical and physical properties of the cooking oil. (10).The values of saturated fatty acid (SFA) in the repeatedly used vegetable oils were higher compared to the FPOO (control). Evidence has shown that repeated intake of oil high in saturated fatty acids could cause elevation of blood cholesterol and low-density lipoproteins (LDL), leading to cardiovascular diseases. Unsaturated fatty acid (USFA) was lower in palm olein oil and palm oil used for the frying of fish and bean cake compared to the control. The polyunsaturated fatty acid (PUFA) decreased with length of usage in both heating medium for fried fish and bean cake. Reheating of the palm olein oil at high temperatures leads to oxidation, which produces rancid odour and off flavour (3,4).

The monounsaturated fatty acid (MUFA) in both frying medium, decreased in the oil used in frying fish and bean cake compared to the control. A high amount of MUFAs in oils are associated with a decreased risk of coronary heart disease, thereby inducing a desirable effect on health benefits (11). The polyunsaturated Omega-6 fatty acid linoleic acid is present in a significantly high amount in the palm oil used to fry fish and bean cake. There was a decrease in the value of linoleic acid in the palm olein oil used in the frying compared to the control sample,which could be ascribed to the reheating of the oils.

Polyunsaturated fatty acids have been greatly appreciated for reducing the risks of chronic heart disease and cardiovascular disease (12). Linoleic acid is an essential fatty acid that must be consumed for proper health. A diet deficient in linoleic acid caused mild skin scaling, hair loss, and poor wound healing in rats (13). With an increased time of usage, there was a decrease in palmitic acid value in palm olein oil, which is contrary to Abiona *et al*. (2) of 40.16%, but this was not in the case of palm oil. Palmitic acid has been found to comprise 21–30% (molar) of human adipose tissue fat (14). Excessive intake of palmitic acid, which makes up 44% of palm oil, increases blood levels of low-density lipoprotein and total cholesterol and therefore increases the risk of cardiovascular diseases (15). World Health Organization and the US National Heart, Lung and Blood Institute have encouraged consumers to limit the consumption of palm oil, palmitic acid, and foods high in saturated fat (16). With the increased usage of oil, the value of oleic acid decreased in both frying oils (i.e., fried fish and bean cake). The value of stearic acid increased with time of usage in both frying medium for fried fish and bean cake, this agreed with the report of Abiona et al. (2), with a value of 24.12% for palm olein and 11.96% for palm oil. Epidemiologic and clinical studies reported that stearic acid was associated with lowering LDL cholesterol. (17). The increased value of stearic acid in these oils can have a negative effect on the body because the greatest danger from ingestion of large quantities of stearic acid caused intestinal obstruction and skin sensitisation, (18). Values obtained for Lauric acid in this study was similar to the finding of Abiona et al., (2). Lauric acids increase total serum cholesterol and HDL in humans (19, 20). As a result, Lauric acid has been characterized as having "a more favorable effect on total HDL cholesterol than any other fatty acid, either saturated or unsaturated" (19, 20).

Monounsaturated fatty acid was present in a very small amount in the used palm oil, and a high amount in used palm olein oil was Palmitoleic acid. Palmitoleic acid blocks fat accumulation in the liver as well as inhibits the destruction of insulin-secreting pancreatic beta cells (21,

22,23).In both frying media, the total saturated fatty acid (TSFA) increased with length of usage; this was similar to what was observed by Alireza et al. (2) and Sulieman et al.(24). In both frying mediums, increased in the value of TSFAs corresponds to the decrease in the total unsaturated fatty acids (TUSFAs). The value of total monounsaturated fatty acid (MUFA) decreased in both frying medium for fried fish and bean cake with an increase in the length of usage, and this finding was contrary to what was observed by Sulieman et al., (24), but agreed to the report of Alireza et al. (2). According to Isabella et al. (11), and Mensink, and Katan, (20), the highest composition of monounsaturated fatty acids (MUFAs) in samples of oil is associated with a decreased risk of coronary heart disease. Hence, oil with high amounts of MUFAs induces a desirable effect on health benefits. The total unsaturated fatty acid (USFA) decreased with length of usage in both frying mediums for fried fish and bean cake, which was as seen in earlier reports (2, 24). In the vegetable oil used for frying fish and bean cake, palmitic and linoleic acids decreased with the length of usage. The amount of linoleic acid in the oil sample is usually used to determine the degree of fat deterioration (2), because linoleic acid is more susceptible to oxidation, whereas palmitic acid is more stable. In the case of palm oil used for fried fish and bean cake, there was an increase in the values of linoleic acid, indicating that this acid is less prone to oxidation than palmitic acid (25, 26).

Conclusion

This study established that repeatedly used of vegetable oil and palm oil increased total saturated fatty acids (TSFAs), decreased total monounsaturated fatty acids (TMUFAs) and total polyunsaturated fatty acids (TUSFAs). Also, the study established that Palmitic acid, linoleic acid and stearic acid in palm oil were increased.Palmitic acid, linoleic acid and stearic acid increased in palm oil which is detrimental to health. Although frying with palm oil may be more preferred topalm olien because of linoleic acid value content in both.

References

1. Abiona, O.O., Awojide, S.H., Anifowoshe, A.J Babalola, O.B. (2011). Comparative study on effect of frying Process on the fatty acid profile of Vegetable oil and palm oil. International Scientific Research Journal.: 3 (3)189-196
2. Alireza, S., Tan, C. P., Hamed, M. and Che Man, Y. B. (2010). Effect of frying process on fatty acid composition and iodine value of selected vegetable oils and their blends International Food Research Journal 17: 295-302
3. Fauziah A, Razali I, Nor-Aini S (2000) Frying performance of palm olein and high oleic sunflower oil during batch frying of potato crisps. Palm Oil Developments 3: 1-7.
4. Nancy Idun-Acquah1, George Y. Obeng, Ebenezer Mensah (2016).1Repetitive Use of Vegetable Cooking Oil and Effects on Physico-Chemical Properties – Case of Frying with Redfish (*Lutjanusfulgens*). Science and Technology 6(1): 8-14
5. Mancini, A; Imperlini, E; Nigro, E; Montagnese, C; Daniele, A; Orrù, S; Buono, P (2015). "Biological and Nutritional Properties of Palm Oil and Palmitic Acid: Effects on Health". Molecules. 20 (9): 17339–61.
6. Obeng M.E (2013). Assessment of waste vegetables oils from hotels for bio-diesel feedstock and CO2 savings in Ghana. International journal of engineering research and science and technology, 2; 1-2
7. Youdim K. A., Martin A. and Joseph J. A. (2000): Essential fatty acids and the brain: possible health implications. International Journal of Developmental Neuroscience, 18, 383-399
8. Ngozi, E.O, Giwa, Olamiposi H, Adeoye, B.K, Ani, I.F, Ajuzie and Olutayo, T.I (219). Quality effect of Repetitive use of frying oil by street food vendors on quality of the oil. Nigerian journal of nutritional sciences 40(1) 73-78
9. AOAC (2011). Official methods of analysis of AOAC International (18thed.) Gaithersburg, MD, USA: AOAC International.
10. Leong X.F, Ng C.Y, Jaarin K.,Mustafa, M.R (2015).Effectsof Repeated Heating of

Cooking Oils on Antioxidant Content and EndothelialFunction.Austin Journal of Pharmacology and Therapeutics. 4 (2) 170-181

11. Isabella L.N, Luciana, O.D, Grazieli, B.P and Daurea, A.D (2016). Nutritional issues concerning streets foods. Journal of clinical Nutritional and Dietetics 1-9
12. Willett W.C, Giovannucci E(2014). Epidemiology of diet and cancer risk. In: Shils ME and others, eds. Modern nutritionin health and disease .Baltimore: Lippincott Williams & Wilkins. pp 56-60
13. Jiang W. G., Bryce R. P. and Horrobin D. F. (1998). Essential fatty acids: molecular and cellular basis of their anti-cancer action and clinical implications. Critical Reviews in Oncology/Hematology, 27, 179-209
14. Matthäus, Bertrand (2007). "Use of palm oil for frying in comparison with other high-stability oils". European Journal of Lipid Science and Technology.109 (4): 400–409.
15. Lichtenstein AH, Sacks FM, Wu JH, Appel LJ, Creager MA, Kris-Etherton PM, Miller M, Rimm EB, Rudel LL, Robinson JG, Stone NJ, Van Horn LV (2017). "Dietary Fats and Cardiovascular Disease: A Presidential Advisory from the American Heart Association". Circulation. 136 (3): e1–e23.
16. World Health Organization (2003). Limit the consumption of palm oil, palmitic acid and foods high in saturated fat. US National Heart, Lung and Blood Institute and World Health Organization.
17. Mozaffarian, D; Clarke, R (2009). "Quantitative effects on cardiovascular risk factors and coronary heart disease risk of replacing partially hydrogenated vegetable oils with other fats and oils" (PDF). European Journal of Clinical Nutrition. 63 Suppl 2: S22–33.
18. Oguntibeju, O.O; Esterhuyse, A.J.; Truter, E.J. (2009). "Red palm oil: nutritional, physiological and therapeutic roles in improving human wellbeing and quality of life". British Journal of Biomedical Science. 66 (4): 216.
19. Ashaye, O.A and Olusoji, O.C (2006). Evaluation of some quality attributes of soybean oils in Ibadan. Africa journal of Agricultural research 1(1) 17-19
20. Mensink, R. P. and Katan, M. B. (2003). Effect of Dietary trans-fatty acids on high-density and low-density lipoprotein cholesterol levels in healthy subjects. New England Journal of Medicine 323: 439–445.
21. Romero A, Cuesta C and Sanchez-Muniz FJ (1998) Effect of oil replenishment during deep-fat frying of frozen foods in sunflower oil and high-oleic acid sunflower oil. Journal American Oil Chemical Society 75: 161-167.
22. Soriguer F, Rojo-Martínez G, Dobarganes MC, García Almeida JM, Esteva I, Beltrán M, et al. Hypertension is related to the degradation of dietary frying oils. America Journal of ClinicalNutrition. 2003; 78: 1092-1097
23. Orthoefer FT, Cooper DS (1996) Evaluation of used frying oil, in: Deep frying chemistry, Nutrition and practical Applications, Ed by Perkin EG and Erickson MD. AOCS Press, Champaign, IL, pp 285-310.
24. Suleiman
25. Nagendran, B.; Unnithan, U. R.; Choo, Y. M.; Sundram, Kalyana (2000). "Characteristics of red palm oil, a carotene- and vitamin E–rich refined oil for food uses". Food and Nutrition Bulletin.21 (2): 77–82.
26. Tyagi, V. K. and Vasishtha, A. K. (1996). Changes in the characteristics and composition of oils during deep-fat frying. Journal of the American Oil Chemists' Society 73 (4): 499–506.