International Scientific Organization
http://iscientific.org/
Chemistry International
www.bosaljournals.com/chemint/

Comparison of physicochemical properties of edible vegetable oils commercially available in Bahir Dar, Ethiopia

Tilahun Mengistie, Agegnehu Alemu and Alemayehu Mekonnen*

Department of Chemistry, Science College, Bahir Dar University, P.O. Box 79, Ethiopia
*Corresponding author's E. mail: negaalex@yahoo.com

ARTICLE INFO

Article type:
Research article
Article history:
Received June 2017
Accepted April 2018
April 2018 Issue
Keywords:
Edible oil
Physico-chemical properties
Acid values
Peroxide value
Omega 3

ABSTRACT

The physicochemical properties of six imported and one locally produced edible vegetable oils (soybean oil, sunflower oil, sunlit oil, hayat oil, avena oil, USA vegetable oil and Niger oil) purchased from Bahir Dar city, Ethiopia, were examined for their compositional quality. All the oil samples were characterized for specific gravity, moisture content, color, relative viscosity, refractive indices, ash content, peroxide value, saponification value, smoke point, acid value, free fatty acid value and trace metals contents using established methods. The result clearly indicates that some of the oil samples exhibited unacceptable value when compared with physicochemical parameters recommended by the Codex Alimentations Commission of FAO/WHO and the specification of Ethiopian standards. The contents of nickel (Ni), copper (Cu) and iron (Fe) in seven samples were determined using ICP-OES and their concentrations were found in the range of 1.8-20.4, 45.8-82.2 and 136.04-445.0 mg/kg, respectively.

Capsule Summary: The source and nature of the edible oils is relevant, as harmful oil impurities can have a significant impact on health and wellbeing. This paper describes the analysis of purity and nutritional value of several edible oils by the measurement of key quality parameters. Such information is vital to assess vegetable oil purity.

Cite This Article As: T. Mengistie, A. Alemu and A. Mekonnen. Comparison of physicochemical properties of edible vegetable oils commercially available in Bahir Dar, Ethiopia. Chemistry International 4(2) (2018) 130-135.

INTRODUCTION

The importance of edible oils is one of the most central areas of concern and investigation in the in the area of human nutrition. They give vital functional and sensory roles for food products. They provide distinctive textures and flavors to foods. They are also major sources of essential fatty acids such as linoleic and linolenic acid. Vegetable oils act as carriers of fat soluble vitamins like as A, D, E, and K (Kostik et al., 2013).

The crude oils are mixture of different free fatty acids, mono-, di-and triglycerides, phosphatides, glycolipids, pigments, sterols and tocopherols. Flavonoids, tannins, and trace amounts of metals may also be present. The predominant fatty acids present in vegetable oils are saturated and mono-unsaturated fatty acids mainly with straight aliphatic chains (Rui et al., 2007).

In human nutrition, polyunsaturated fatty acids, PUFA, found in vegetable oil are physiologically important food constituents but they are the most susceptible ones to oxidative degradation and as such may contribute to an overall enhancement of peroxidative stress in the body. Lipid oxidation is a major cause of the deterioration of oils, leading to the loss of nutritional value, and to alteration of sensory properties like flavor, aroma, and color. The degree of oxidation and the potential for deterioration are important quality parameters of edible oils. Therefore, it is essential to determine the composition of fatty acids of oils to identify their characteristics and determining more precisely the stability and quality of the products (Rajko et al., 2010). The purity and stability of edible oils are the main factors that influence their acceptability, desirable use and market value. A number of factors have been reported to affect oil quality (Justyna and Waldermar, 2011).

Vegetable oil quality is largely dependent on its resistance to oxidation. Chemical stability, which might ultimately be regarded as resistance to oxidation, depends on the chemical composition of the oil, especially antioxidants and oxidizable compounds, and on physical interfaces and microenvironments in which the reactants interact. In this context, edible vegetable oils are available as refined or cold-pressed oils. Typically, refined oils present higher losses of phenolic compounds, tocopherols, phytosterols, and carotenoids, becoming more prone to oxidation. In contrast, cold-pressing does not involve heat or chemical processes, resulting in oils that maintain high contents of these antioxidant compounds. However, cold pressed oils tend to contain more oxidizable compounds than refined oils. Therefore, the quality of the oil should be considered holistically by simultaneously considering the industrial process, chemical composition, and oxidative stability (Rui et al., 2007; Elham, 2008).

The dynamics of oil deterioration mostly due to oxidation depends upon the fatty acid content and presence or absence of antioxidants and pro-oxidants. Oxidative and hydrolytic degradation are main reactions occurring during and after oil processing that reduce shelf life and result in low quality products (Rajko et al., 2010).

The quality of vegetable oil has been reported to be evaluated by several physical and chemical parameters that are dependent on the source of oil processing and storage conditions. Some physical parameters (moisture content, refractive index, viscosity, specific gravity, color, etc) and chemical parameters (smoke point, saponification value, acid value, iodine value, ash content and peroxide value) can be used to evaluate the purity and quality of oils (Mohammed, and Ali, 2015).

Quality can also depend on the type and amount of trace metals present in edible oils. It is known that trace metals like Pb, Ni, Fe, etc affect the rate of oxidation, nutritional value, preservation properties and storability of oils. These metals may be added to the edible oils during the growing season or during oil processing activities such as refining, bleaching, deodorization and hardening or by contamination from the metal processing equipment (corrode equipment). Therefore, the concentration of trace metal should be minimized using chelating agents at various processing steps (Elham, 2008). The application of a direct spectrometric technique, particularly ICP-OES, is the best way to analyze the concentration of trace metals in edible oils and other food substances.

Nowadays, food safety is an issue that regards credence and trust on food products, which is becoming more and more important for consumer. Currently, the demand of consumers for receiving diet-health information on food quality and safety determines in great extent the characteristics of the food chains and the strategies developed by the industry. The search of products with a better quality has become one of the main strategic priorities of the food industries. In addition, cconsumers like to known the quality of products that they purchase. For this reason, most products are packaged in a container that allows visual inspection. Due to poor light stability, however, this in turn allows visible light to reach the product that can cause off-flavors to develop from oils.

Like other societies, our community from their experience forward different opinion about health problems related with the use of currently available edible oils. The majority of the society believes that currently available oils are source of several health problems such as back pain, muscle pain, heart diseases, etc. We believed that this dilemma needs to be addressed and we are motivated to run this study for the purpose of creating awareness.

MATERIAL AND METHODS

Sample collection

Seven edible oils; soybean oil, sunflower oil (hatun and sunlit oil), palm oil (hayat and avena oils), USA vegetable oil (brand name) and Niger oil (locally produced) were collected from Bahir Dar supermarkets, Ethiopia. Six were imported and one sample was locally produced. These were the only branded oils available in the market.

Determination of the physical and chemical parameters

Physical and chemical parameters were performed for all oil samples following standard procedures described for the determination of specific gravity (Horwitz, 1984), refractive index and peroxide value (Nawal-A-Al, 2014), color (Tintometer group, 2016), moisture content (Asean Manual of Food Analysis, 2011), viscosity (Othman and Ngaasapa, 2010), acid and saponification value (Kirk and Sawyer, 1991), smoke point (Nancyet al., 2016) and ash content (Ngaasapa and Othman, 2001). All these tests were performed in triplicates

RESULTS AND DISCUSSION

Refractive index (RI)

The refractive index (RI) is the ratio of the speed of light in a vacuum to the speed of light through a given material (Mohammed and Ali, 2015; Jack et al., 2013). The summary of the refractive indices of the investigated oils at 20 ^{0}C are depicted in Table 2. Out of the seven samples evaluated, the RI value of USA vegetable oil (1.475), soybean oil (1.474), sunflower oil (1.475) and sunlit oil (1.473) were slightly above the level recommended by FAO/WHO (1.466-1.470) (Suzanne, 2010). This signifies that the above mentioned samples probably contain highly unsaturated or long chain fatty acids in their triglycerides. The remaining avena oil (1.466), hayat oil (1.466) and Niger oil (1.471) exhibited RI values in the range set by FAO/WHO.

Table 2 shows that at 20 °C, hayat and avena oils demonstrated low RI value as compared to other oils. Therefore, hayat and avena oils will have low boiling point relative to other oils. It explains that the viscosity and density increases with saturation and polymerization. From the nutritional point of view, edible oils rich in unsaturated fatty acids, especially with monounsaturated fatty acid, are more useful than oils with saturated fatty acids (Nawal-A-Al et al., 2014; Amos et al., 2013). Therefore, in terms of RI parameter, USA vegetable oil, soybean oil, sunflower oil (hatun) and sunlit oil are nutritionally better.

Specific gravity

Density or specific gravity of a vegetable oil depends on the type of oil and temperature. Different values of density may attribute to the different in fatty-acid composition, total solid content and degree of unsaturation. The results tabulated in Table 2 shows that at 20 °C, the values of the specific gravity obtained were in between 0.9296 and 0.9166. The highest and lowest values were recorded for soybean and hayat oils, respectively. However, all the values are nearly in line with the level advised by FAO/WHO (0.919-0.925). The highest specific gravity obtained for soybean oil probably attributed to the presence of high content of linoleic acid. In addition, the presence of other unsaturated fatty-acids such as eicosenoic (C20:1) and C18 polyunsaturated acids could also be a major factor for the increase in relative density of these oils (Mohammed and Ali, 2015).

Moisture content

The conversion of the triglycerides in oils to free fatty acids is just one of the side-reactions that lead to oil decomposition. Therefore, the determination of water content in oils is quite valuable. The moisture contents measured for Niger and avena oils were relatively high. Sunlit and USA vegetable oils demonstrated very close to the acceptable values (0.2%). High moisture content observed for Niger and avena oils might be due to improper treatment during oil processing. Samples with low moisture contents are good for the reason that they withstand growth of micro-organisms and other transportation related problems. They could be also stored for long period (Nangbes et al., 2013; Abitogun and Olasehinde, 2012).

Viscosity

Triglycerides (TGs) are major components of edible oils. The nature and arrangement of the fatty acids on the glycerol backbone of the triglyceride determine viscosity. Therefore, the oil viscosity has a direct relationship with degree of unsaturation and chain length of the fatty acids in lipids. Its value increases with increasing degree of saturation (Fazal et al., 2015]. Results tabulated in Table 2 revealed that avena and hayat (palm) oils were the most (1.633 and 1.400, respectively) while sunflower oil was the least viscous (0.133.06) at 25 °C. This showed that avena and hayat oils contain relatively more percentage of saturated components while sunflower oil is rich in unsaturated fatty acids (Musa et al., 2012). Hayat and avena oils are prepared from palm tree. Oils obtained from palm plant normally exhibits low unsaturated to saturated fatty acid ratio (1.0) while oils from sunflower seeds have highest ratio in the triacylglyceride chain (10.1) (Nangbes et al., 2013).

Color

Refined oils have usually soft tastes, clear and transparent appearance (Suzanne, 2010). The color values for the seven edible oils are given in Table 2. The results were in the range between R =1.0/Y =11.0 to R = 3.5/Y =22.5 TU. From the Table, four samples, namely, Niger oil (R=3.5), USA vegetable oil (R=3.5), avena oil (R=3.3) and Hayat oil (R=3.2) demonstrated maximum red color compared to the international standard. This is probably due to insufficient color reduction during the bleaching process. For instance, the acceptable value and a good grade level for any palm oil must be R=1.4/Y=15 [22]. But, in our study, oils produced from palm tree (avena and hayat oils) gave higher red values than expected. This might be due to the presence of carotenoids and other red pigments. Moreover, overheating, dilution ratios, presence of dissolved impurities and other unfinished product could give color to oils (Nangbes et al., 2013).

Acid value (AV) and free fatty acid (FFA) content

The acid and free fatty acid (FFA) values are used to indicate the level of rancidity and edibility of oils (Amos et al., 2012). Acid value represents the mg KOH required to neutralize the free fatty acid in 1 g of oil while free fatty acid is the percentage by weight of a specified fatty acid such as percent oleic acid in oil. Therefore, acid value is a good indicator of oil degradation caused by hydrolysis or enzymes (Othman and Ngaasapa, 2010).

As it is seen in Table 4, except Niger oils, the FFA values for oil samples were within the range recommended by both FAO/WHO and Ethiopian Standards (ES) (1.0-3.0%). The percentage of acid values of oil samples ranged from 0.75% for soybean oil to 7.98% for Niger oil. The variation of acid value in our samples could be due to difference in moisture contents as well as difference in the refining and deodorization technologies. High level of free fatty acids, especially linoleic acid, is undesirable in finished oils because they can cause off-flavors and shorten the shelf life of the oils (Mohammed et al., 2015; Amos et al., 2013).

Niger oil exhibited unacceptably the highest (15.89) while soybean oil gave the lowest (1.49) FFA value compared to other oil samples. High FFA value, mainly for Niger oil could be attributed to decomposition, poor extraction techniques, use of damaged seeds and incorrect or lengthy storage that can be accelerated by light and temperature. Nevertheless, the most common factor is being not refined which lead to remain higher in acidity (Rajko et al., 2010;

Fazal et al., 2015). According to the result, edibility of Niger oil is very low and not recommended for consumption. Therefore, Niger oil needs further treatment to lower its acid content (Ngaasapa. and Othman, 2001; Musa et al., 2012).

Saponification measures the average chain length of the fatty acid that makes up the oil. In other words, saponification values are useful in providing information as to the quantity, type of glycerides and mean weight of the acids in a given oil sample (Mohammed and Ali, 2015; Fazal et al., 2015]. The lower the saponification value, the larger the molecular weight of fatty acids in the glycerides or the number of ester bonds is less and vice versa (Musa et al., 2012).

Table 1: Physical parameters set by FOA/WHO as standards for seven edible oils (Asean Manual of Food Analysis, 2011; Codex Alimentarius Commission, 1999)

Oil type	Moisture %	specific gravity	Refractive index at 20^{0}C	Colour (TU) 5 1/4 inch cell
Soybean oil	0.20%	0.919-0.925	1.466-1.470	R=2/Y=20
Sunflower oil	0.20%	0.918-0.923	1.467-1.469	R=1.1/Y=11
Sunlit oil	0.20%	0.918-0.923	1.467-1.469	R=1.1/Y=11
Hayat oil	0.20%	0.889 - 0.899	1.454 - 1.456	R=1.4/Y=15
Avena oil	0.20%	0.891-0.999	1.454 - 1.456	R=1.4/Y=15
USA oil	0.20%	-	-	-
Niger oil	0.20%	0.917-0.920	1.4665-1.4691	-

Table 2: Summary of physical parameters of edible oil samples investigated

No.	Physical Parameters	Refractive index at 20 ^{0}C	Specific gravity	Moisture %	Viscosity (cps)	Color (TU)
1	Soybean oil	1.474±0.00	0.9296±0.01	0.4000±0.20	0.300±0.00	R=1.1/Y= 12.20
2	Sunflower oil	1.475±0.00	0.9253±0.00	0.4667±0.11	0.133±0.06	R=1.0/Y= 11.10
3	Sunlit oil	1.473±0.00	0.9243±0.00	0.2667±0.11	0.200±0.00	R=1.0/Y= 11.00
4	Hayat oil (palm oil)	1.466±0.00	0.9166±0.01	0.4000±0.20	1.400±0.20	R=3.2/Y= 11.10
5	Avena oil (palm oil)	1.466±0.00	0.9170±0.00	0.9000±0.70	1.633±0.06	R=3.3/Y= 11.20
6	USA oil	1.475±0.00	0.9246±0.02	0.2660±0.11	0.233±0.06	R=3.5/Y=12.30
7	Niger oil	1.471±0.00	0.9183±0.00	1.1333±0.11	0.333±0.05	R=3.5/Y=22.00

Peroxide value

Peroxide value is used as a measure of the extent to which rancidity reactions have occurred during storage and it is used as a good criterion for the prediction of the quality and stability of oils (Nangbes et al., 2013). High peroxide value could be resulted from high degree of unsaturation and found to increase with the storage time, temperature, light and contact with atmospheric oxygen (Mohammed and Ali, 2015).

The peroxide values tabulated in Table 4 for all oils range from 4.33–9.26 meq/kg. Soybean oil (9.26), sunflower oil (8.80), sunlit oil (8.52) and Niger oil (8.00) exhibited higher values than the rest. Therefore, these oils are relatively more susceptible to oxidative rancidity than the other oil samples. However, the values for all the samples were within the range of FAO/WHO and ES (Ngaasapa and Othman, 2001; Musa et al., 2012). In general, the analysis showed that oil samples exhibited 28% (4.33-4.93), 14% (6.73), 57% (8-10) peroxide values have excellent, good and acceptable qualities, respectively.

Saponification value

Among seven oil samples studied, golden soya oil (195.56 mg KOH/g) and sunlit oil (194.75 mg KOH/g) are relatively in line with the recommended value (188-195 mg KOH/g). Hayat oil (213.18 mg KOH/g) and avena oil (210.84 mg KOH/g) gave the highest saponification value which can be used as valuable raw materials for soaps and cosmetics (Nangbes et al., 2013). Sunflower, USA vegetable and Niger oils demonstrated slightly higher values. Therefore, hayat and avena oils are characterized by the presence of relatively high concentration of low molecular weight free fatty acid in their triglycerides (Ngaasapa and Othman, 2001; Nangbes et al., 2013).

Smoke point

Smoke point is an indicator of thermal stability and it is the beginning of both flavor and nutritional degradation. It is the temperature at which the sample begins to smoke under specified conditions. Heating produces free fatty acid from oils and as the time of heating increases, more free fatty acids will be released, thereby decreases the smoke point of the oil.

Table 3: Chemical parameters set by FOA/WHO as standards for seven edible oils (Asean Manual of Food Analysis, 2011; Codex Alimentarius Commission, 1995)

Oil type	Free fatty acid (as % oleic)	Acid value (mg OH per gm)	Saponification value (mg KOH/g oil)	Peroxide value (Meq/Kg)	Ash content %	Smoke point, ⁰c
Soybean oil	-	0.6	189-195	10	1.5-2.5	232
Sunflower oil	-	0.6	188-194	10	1.5-2.5	232
Sunlit oil	-	0.6	188-194	10	1.5-2.5	232
Hayat oil	0.15%	0.6	190-209	10	1.5-2.5	230
Avena oil	0.15%	0.6	190-209	10	1.5-2.5	230
USA oil	-	0.6	-	10	1.5-2.5	high
Niger oil	-	0.6	189-193	10	1.5-2.5	-

Table 4: Summary of chemical parameters of edible oil samples investigated

No.	Chemical Parameters	Smoke point (⁰C)	Free fatty acid (as % oleic acid)	Acid value, %	Saponification value (mg KOH/g oil)	Peroxide value (Meq/Kg)	Ash content %
1	Soybean oil	224.33±0 .58	0.75±0.16	1.49±0.32	195.56±1.35	9.26±0.11	0.015±0.00
2	Sunflower oil	221.66± 1.52	1.21±0.16	2.43±0.32	197.14±0.56	8.80±0.20	0.925±0.00
3	Sunlit oil	219.00±1.00	1.31±0.16	0.61±0.32	194.75±1.39	8.52±0.15	0.020±0.00
4	Hayat oil (palm oil)	215.00±5.00	2.07±0.58	3.17±0.32	213.18±1.40	4.33±0.11	0.053±0.00
5	Avena oil (palm oil)	209.00± 1.00	2.05±0.25	4.48±0.57	210.84± 0.80	4.93±0.11	0.012±0.00
6	USA oil	239.00±1.00	1.40±0.28	2.80±0.56	199.48±0.58	6.73±0.11	0.016±0.00
7	Niger oil	161.66±1.53	7.98±0.81	5.89±1.62	197.00±1.93	8.00±0.20	0.022±0.00

Therefore, it is one of the decisive factors when selecting oil for frying (Nangbes et al., 2013; Oladiji et al., 2010).

As indicated in Table 4, the results of the smoke points were 224.33, 221.66, 219.00, 215.00, 209.00, 239.00, 161.66⁰C for soybean oil, sunflower oil, sunlit oil, hayat oil, avena oil, USA vegetable oil, Niger oil, respectively. Except Niger oil, the smoke points of other samples were slightly closer to the values accepted by WHO (230-232 ⁰C) [Codex Alimentarius Commission, 1995]. However, all samples exhibited lower values than recommended values. This demonstrates that oil samples were not properly refined because the smoke point and free fatty acid content parameters are good to measure the extent of refinement. The more refined an oil, the higher the smoke point. That is because refining process removes impurities that can cause the oil to smoke.

Ash content

Ash is the residue remaining after water and organic matter have been removed by heating in the presence of oxidizing agents. It is a measure of the total amount of minerals within a sample (Fazal et al., 2015). As summarized in Table 4, the amount of total inorganic residues in our samples was lower than the acceptable limits (1.5-2.5%) (Othman and Ngaasapa, 2010).

CONCLUSIONS

In the present study, various physicochemical parameters have been examined for seven edible oil samples. Regarding physicochemical characteristics, seven samples do not exactly demonstrate all parameters in line with the recommended values however; some of them have acceptable values. The measurement of the physicochemical data indicated that Niger oil is characterized by high moisture content, high acid and FFA values, low smoke point, high color value and high peroxide value (more susceptible to oxidative rancidity. Niger oil doesn't fulfill most parameters accepted by ES and FAO/WHO to be used for consumption. Like Niger oil, USA vegetable oil, avena oil and hayat oil demonstrated high red values which confirm insufficient color reduction during the bleaching process. Therefore, the companies should take the appropriate measures during the production process to treat products before selling them to markets.

ACKNOWLEDGEMENTS

The authors wish to thank Bahir Dar University for financial support.

REFERENCES

Abitogun, A.S., Olasehinde, E.F., 2012. Nutritional evaluation of seed and characterization of crude jack bean (*Canavalia ensiformis)* oil. Journal of Applied Chemistry (IOSRJAC) 1(6), 36-40

Amos, T., Bamidele, M.W., Onigbinde, A.O., 2013. Physicochemical properties and fatty acid profiles of crude oil extracts from three vegetable seeds. Pakistan Journal of Nutrition 12(7), 647-650.

Asean Manual of Food Analysis. 2011. Regional Center of Asean Network of Food Data System, Institute of Nutrition, Mahidol University, Thailand, 2011, 1-3.

Codex Alimentarius Commission. Codex general standard for contaminants and toxins in food and feed (Codex stan 193-1995).

Codex Alimentarius Commission. 1999. Standard for named vegetable oils (Codex stan 210).

Elham, T., 2008. Lipid and phytosterol oxidation in vegetable oils and fried potato products. Faculty of Natural Resources and Agricultural Sciences, Department of Food Science, Doctoral thesis, Uppsala, Sweden.

Fazal, W., Musa, K.B., Mohsan, N., Khakemin, K., 2015. Comparison of some physico-chemical properties of different oils available in the local market in Pakistan. International Journal of Recent Research Aspects 2(2), 93-98.

Helrich, K., 1990. Official methods of analysis. Association of Official Analytical Chemists, 5th Edition, USA.

Jack, P. D., Daniel, S. S. Kristin, M., Price, L. L., Dean, T. H. S.2013. Refractive index and density measurements of peanut oil for determining oleic and linoleic acid contents. Journal of the American Oil Chemists' Society 90, 199–206.

Justyna, G., Waldermar, W., 2011. Trends in edible vegetable oils analysis. Part A. Determination of different components of edible oils- a review. Polish Journal Of Food And Nutrition Sciences 61(1), 33-43.

Kirk, S., Sawyer, R., 1991. Pearson's composition and analysis of foods. Longman Group Ltd.

Kostik, V., Memeti, S., Bauer, B., 2013. Fatty acid composition of edible oils and fats. Journal of Hygienic Engineering and Design 4, 112-116.

Manuel, A., Karolina, C., 2015. Determining trace elements in edible oils using inductively coupled plasma-optical emission spectrometry. Solution for materials analysis. Spectroscopy 11(30), 26-31.

Mohammed, I.H.A., Ali, T.B., 2015. Physicochemical characteristics of some imported edible vegetable oils in Iraq. Research Journal of Pharmaceutical, Biological and Chemical Sciences 6(5), 488-494.

Musa, M., Sulaiman, A.U., Bello, I., Itumoh, J.E., Bello, K., Bello, A.M., Arzika, A.T., 2012. Physicochemical properties of some commercial groundnut oil products sold in Sokoto Metropolis, Northwest Nigeria. Journal of Biological Science and Bioconservation 4, 17-24.

Nancy, I., George, Y., Obeng, E.M., 2016. Repetitive use of vegetable cooking oil and effects on physico-chemical properties– Case of frying with redfish (*Lutjanus fulgens*). Science and Technology 6(1), 8-14 9

Nangbes, J.G., Nvau, J.B., Buba, W.M., Zukdimma, A.N., 2013. Extraction and characterization of castor (*Ricinus Communis*) seed oil. The International Journal of Engineering and Science 2(9), 105-109.

Nawal-A-Al, B., Shaistra, A.A., Zubaida, N.B., 2014. Characteristics and fatty acid composition of commonly consumed cooking oil marketed locally in Riyadh city. International Journal of Biosciences 4(9), 227-238.

Ngaasapa, F.N., Othman, O.C., 2001. Physicochemical characteristics of some locally manufactured edible vegetable oils marketed in Dar Salaam. Tanzania Journal of Science 27, 49-58.

Oladiji, A.T., Yakubu, M.T., Idoko, A.S., Adeyemi, O., Salawu, M.O., 2010. Studies on the physicochemical properties and fatty acid composition of the oil from ripe plantain peel (*Musa paradisiaca*). African Scientist 11(1), 1-6.

Othman, O.C., Ngaasapa, F.N,, 2010. Physicochemical characteristics of some imported edible vegetable oils and fat marketed in Dare Salaam. Tanzania Journal of Natural and Applied Sciences 1(2), 138-147.

Rajko, V., Sergeja, V., Helena, A., 2010. Biochemical parameters and oxidative resistance of thermal treatment of refined and unrefined vegetable edible oils. Czech Journal of Food Sciences 28(5), 376-384.

Rui, C.Z., Roman, P., Moema, W.Z., Carla, B. M., 2007. Fatty acid composition of vegetable oils and fats. B.CEPPA, Curitiba 25(1), 112-120.

Suzanne, N., 2010. Food analysis, chemical properties and characteristics of foods. Springer New York Dordrecht Heidelberg London, 4th edition, 245.

Tintometer group. 2016. A Guide to understanding color communication. Retrieved April 2, 2016 from: www.lovibondcolour.com.

Vesna, K., Shaban, K.M., Biljana, B., 2013. Fatty acid composition of edible oils and fats. Journal of Hygienic Engineering and Design 112-116.