PHYSICOCHEMICAL CHARACTERISTICS OF SOME LOCALLY MANUFACTURED EDIBLE VEGETABLE OILS MARKETED IN DAR ES SALAAM

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ABSTRACT

The physicochemical properties (refractive index, saponification value, Free Fatty Acid (FFA) value, iodine value, acid value, peroxide value and tocopherol content) of seven edible vegetable oils manufactured in Tanzania, were assessed using standard procedures of the Association of Official Analytical Chemists (AOAC). Also determined were the levels of these properties with respect to shelf storage of the products. When compared with standard values recommended by the Codex Alimentarius Commission of FAO/WHO and with other published results, the locally produced vegetable oils were found to be of fair quality but of poor storage stability.

INTRODUCTION

Millions of people in developing countries especially children under the age of five years suffer from acute and chronic protein and energy deficiencies. At the current trend of population increase, it is projected that, by the year 2010, there will be as many as 300 million chronically undernourished people in Sub-Saharan Africa (Anon. 1996). There is need for food production to keep pace with the increase in world population. The national development strategies in many agriculture-based tropical countries are biased towards increasing the diversity of consumable food products in order to alleviate malnutrition and stress on promotion and broadening of agricultural based industries to ensure that their products are both wholesome and safe. The dietary roles of edible oils and fats are highly recognized. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended an average daily intake of 55 g-fat per capita to compliment the requirement for energy (Kabyemera *et al.* 1992) and a 20-30% conversion rate for fat to energy to ensure good health (Anon. 1977). Vegetable oils and fats constitute a large group of oils and fats produced in the world. They have wide application in foods where they are used in frying, salad dressing, shortening of pasty margarine, cooking and ice cream

manufacture. In Tanzania, vegetable oils constitute about 80 - 85% of the edible oils and fats (Fupi 1990) but very little is known about their quality with respect to public health. The present paper describes the quality of some of the locally manufactured edible oils found marketed in Dar es Salaam, Tanzania.

METHODS

Seven brands of locally produced edible vegetable oils (Table 1) were randomly collected off the shelf around Dar es Salaam.

Table 1: Edible oils, their brand and manufacturer names, collected off shelves in Dar es Salaam shops in 1996.

Type of oil	Brand name*	Manufacturer
a) Sunflower seed	i) Afya	Banco Products Ltd., Tanzania
	ii) Flora	Flora Products Ltd., Tanzania
	iii) Alizeti	Tako Ltd., Tanzania
b) Palm Oil	Mpishi	Tradeco Oil Industries Ltd., Tanzania
c) Cotton Seed	Okay	VOIL, Tanzania
d) Soya bean	Marhaba	Tradeco Oil Industries Ltd., Tanzania
e) Coconut	Mafuta ya Nazi	Coastal region of Tanzania

* All brands except for Mafuta ya Nazi indicated an expiry date of about a year at the time the oils were bought. No dates were given on the Mafuta ya Nazi brand

Analytical grade sodium sulphate, sodium hydroxide, potassium hydroxide, chloroform and glacial acetic acid were supplied by the BDH Chemicals company Ltd. of England. Analytical grade hydrochloric acid, sulphuric acid, ether, potassium iodide, sodium thiosulphate, diethylether, iodine and ethanol were obtained from the Aldrich Chemical Company Limited of England. A Sertling digital balance, model OB152-A4 ZA IBA (UK), was used for all analytical weighing. The refluxing equipment was from Electromantle MA of UK. A CIBA CORNING colorimeter 252 (EEC) was used for the colorimetric determination of Vitamin E and an Abbe (UK) refractometer was used for the determination of refractive indices.

Five samples of each oil brand were collected during the sampling exercise and analyzed. Each oil sample was filled into two 250 cm^3 glass bottles that were then sealed airtight. One of these glass bottles was stored in a dark room. The other was left in ambient light. Each oil sample was also poured into a 500 cm^3 open beaker. Initial refractive indices, tocopherol and free fatty acid contents as well as saponification, iodine, peroxide and acid values for the oils were immediately determined. Aliquots of the oil samples were periodically drawn from the open beaker and analyzed for free fatty acid content, acid and peroxide values every ten days over a storage period of 60 to 90 days. The oils in the sealed bottles were similarly analyzed for peroxide value over 60 days.

The refractive indices, η_D^{40}, of the oils were measured using the Abbe (UK brand) refractometer at a constant temperature of 40°C. A thermostatically controlled water bath, which used a water-circulating pump, was connected to the Abbe refractometer to maintain the temperature of the refractometer to within ± 0.1°C of the required temperature. The determination was done following the procedures of Cocks (1966).

Saponification value, which is the number of milligrams of KOH required to neutralize the fatty acids resulting from complete hydrolysis of one gram of oil, was determined according to the procedure of Jayaraman (1985).

Iodine value, the number of grams of iodine absorbed by 100 parts by weight of the oil or fat, was determined using the Hanus method as described by Horwitz (1975).

Free fatty acid was determined, as percent by mass oleic, palmitic or lauric acid, using the procedure adopted by Jayaraman (1985).

The peroxide values, the weight (mg) of active oxygen contained in one gram of the oil or fat, were determined following the method of the AOAC as described by Horwitz (1975).

The procedure described by Egan *et al.* (1981) was used to determine Vitamin E (Tocopherol). Vitamin E capsules containing 100-mg α-tocopheryl acetate I.P. were used as standards.

RESULTS AND DISCUSSION

The standard requirements for essential composition and quality of the oils as specified by the Codex Alimentarius Commission of the FAO/WHO (Anon. 1993) and by the Tanzania Bureau of Standards (TBS) are summarized in Table 2. The analytical results for all the determinations are presented in the Tables 3 to 9. Table 3 presents the initial physicochemical properties of the edible vegetable oils studied. The final physicochemical properties of the edible vegetable oils i.e. after sixty days of storage under various conditions are presented in Table 9. Tables 4, 5, and 6 show the observed values for acid value, free fatty acid content and peroxide value for samples exposed to ambient conditions. The peroxide values for edible oil samples exposed to light only are presented in Table 7 while the results of peroxide determinations of the oils which were stored in the dark in airtight containers are presented in Table 8.

Table 2: Recommended (standard) physicochemical characteristics of edible oils as given by FAO/WHO (1993) and by TBS.

Oil type	Refractive index at 40°C	Saponification value	Iodine value (Wijs)	FFA (as % oleic acid)	Acid value (mg KOH per gram)	Peroxide value (meq/kg)	Tocopherol (mg/100-g)
	FAO/WHO STANDARDS						
Sunflower	1.467 – 1.469	188 - 194	110 - 143	0.085	≤0.6	≤10	50
Palm	1.449 – 1.455*	190 - 209	50 - 55	1.376	≤0.6	≤10	50
Cottonseed	1.458 – 1.466	189 - 198	99 - 119	0.225	≤0.6	≤10	50
Soya bean	1.466 – 1.470	189 - 195	120 -143	0.176	≤0.6	≤10	50
Coconut	1.448 – 1.450	248 - 265	6 - 11	2.540	≤0.6	≤10	50
	TBS STANDARDS						
Sunflower	1.464 – 1.480	188 - 194	110 - 143	0.085	≤0.5	-	Not limited
Palm	1.454 – 1.456*	190 - 202	50.6 – 55.1	1.376	≤0.5	≤3	Not limited
Cottonseed	1.463 – 1.466	190 - 198	99 - 112	0.225	≤0.3	-	Not limited
Soya bean	1.466 – 1.470	189 - 195	120 -143	0.176	≤0.5	-	Not limited
Coconut	1.448 – 1.449	250 - 265	7.5 - 10	2.540	≤0.6	-	Not limited

* At 50°C.

Table 3: Initial physicochemical characteristics of the oils, collected off-shelf in Dar es Salaam in 1996

Oil brand name	Refractive index at 40°C	Saponifi-cation value	Iodine value (Hanus)	FFA (% as oleic acid)	Acid value (mg KOH/g)	Peroxide value (meq/kg)	Total Tocopherol (mg/100-g)
Afya	1.468	194	130	0.085	0.17	10.5	72
Flora	1.467	200	125	1.376	2.74	24.0	13
Alizeti	1.459	198	60	0.225	0.45	3.2	50
Mpishi	1.455*	208	55	0.176	0.69	2.6	28
Mafuta-ya-Nazi	1.448	269	9	2.540	7.13	1.6	4
Marhaba	1.468	195	126	0.148	0.29	10.8	100
Okay	1.465	197	104	0.253	0.50	4.2	87
Av. Error	± 0.004	± 1	± 0.7	± 0.009	± 0.02	± 0.1	± 0.5

* At 50°C.

All results are averages of five samples of the same brand of oil

Table 4: Acid values (mg KOH/g-oil) for oils exposed to both atmospheric oxygen and light during storage off-shelf in Dar es Salaam in 1996

	Storage time in days						
name	0	10	20	30	40	50	60
Afya	0.17	0.17	0.17	0.17	0.22	0.28	0.29
Flora	2.74	2.75	2.77	2.81	2.84	2.89	3.03
Alizeti	0.45	0.46	0.48	0.52	0.53	0.56	0.59
Mpishi	0.69	0.80	0.84	0.88	0.90	0.92	0.97
Mafuta-ya-Nazi	7.13	14.0	14.2	14.5	14.9	15.8	17.1
Marhaba	0.29	0.29	0.31	0.32	0.33	0.34	0.34
Okay	0.50	0.50	0.50	0.50	0.50	0.51	0.51
Av. Error	± 0.02	± 0.02	± 0.02	± 0.02	± 0.01	± 0.03	± 0.04

Table 5: Free Fatty Acid (as % oleic acid) for oils exposed to both atmospheric oxygen and light collected off-shelf in Dar es Salaam in 1996

Oil brand	Storage time in days						
name	0	10	20	30	40	50	60
Afya	0.085	0.085	0.086	0.086	0.11	0.13	0.14
Flora	1.38	1.38	1.39	1.41	1.43	1.45	1.52
Alizeti	0.23	0.23	0.24	0.26	0.27	0.28	0.29
Mpishi	0.35	0.40	0.42	0.44	0.47	0.48	0.53
	0.31*	0.36*	0.38*	0.40*	0.42*	0.44*	0.49*
Mafuta-ya-Nazi	2.54	5.00	5.07	5.17	5.34	5.63	6.10
	3.58*	7.05*	7.16*	7.30*	7.52*	7.93*	8.60*
Marhaba	0.14	0.15	0.15	0.16	0.17	0.17	0.17
Okay	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Av. Error	± 0.01	± 0.02	± 0.02	± 0.03	± 0.02	± 0.02	± 0.02

* - as palmitic acid * - as lauric acid

Table 6: Peroxide values (meq/kg-oil) for oils exposed to atmospheric oxygen and light collected off-shelf in Dar es Salaam in 1996

Oil brand	Storage time in days									
name	0	10	20	30	40	50	60	70	80	90
Afya	10.5	12.7	15.9	33.7	43.5	63.1	75.4	82.6	108.0	122.0
Flora	24.0	28.5	34.5	54.1	66.1	91.0	104.6	110.2	137.1	158.8
Alizeti	3.2	3.8	5.8	6.2	7.1	8.30	16.5	16.50	16.5	16.6
Mpishi	2.6	4.6	7.0	9.5	12.6	15.5	18.1	20.6	22.3	26.4
Mafuta-ya-Nazi	1.6	1.7	1.9	2.0	2.3	2.9	2.4	2.8	2.4	3.1
Marhaba	10.8	18.2	27.9	51.0	69.2	97.2	116.8	128.2	142.6	157.5
Okay	4.2	6.1	8.1	18.2	27.9	37.1	43.6	44.4	45.9	81.9
Av. Error	± 0.1	± 0.1	± 0.1	± 0.1	± 0.1	± 0.2	± 0.2	± 0.2	± 0.2	± 0.2

Table 7: Peroxide values (meq/kg-oil) for oils exposed to light only. Oils collected off-shel in Dar es Salaam in 1996

Brand name of the oil	Storage time in days				
	0	10	30	50	60
Afya	10.5	12.0	13.2	15.3	18.2
Flora	24.0	27.0	48.2	73.3	89.0
Alizeti	3.2	ND	ND	ND	ND
Mpishi	2.6	7.5	7.3	9.4	14.5
Mafuta-ya-Nazi	1.6	1.6	1.8	2.1	3.1
Marhaba	10.8	11.5	12.0	12.4	17.6
Okay	4.2	6.8	7.2	11.8	14.5
Average Error	± 0.2	± 0.2	± 0.2	± 0.2	± 0.2

ND – not determined

Table 8: Peroxide values (meq/kg-oil) for oils subjected to different treatments. Oils collected off-shelf in Dar es Salaam in 1996

Oil brand name	Initial values	Oil stored airtight in the dark (90 days)	Oil exposed to light only (60 days)	Oil in atm. oxygen and light (60 days)	Oil exposed to atm. oxygen and light (90 days)
Afya	10.5	15.4	18.2	75.4	122.0
Flora	24.0	36.0	89.0	104.6	158.8
Alizeti	3.8	7.7	ND	16.5	16,6
Mpishi	2.6	4.8	14.5	18.1	26.4
Mafuta-ya-Nazi	1.6	2.0	3.1	2.4	3.1
Marhaba	10.8	28.5	17.6	116.8	157.5
Okay	4.2	13.0	14.5	43.6	81.9
Average Error	± 0.2	± 0.2	± 0.2	± 0.2	± 0.2

ND – not determined

Table 9: Final physicochemical characteristics of the oils after 60 days of storage. Oils collected off-shelf in Dar es Salaam in 1996

Oil brand name	Refractive index at 40°C	Free Fatty Acids (% as oleic acid)	Acid value (mg KOH/g)	Peroxide value (meq/kg-oil)
Afya	1.469	0.14	0.29	75.4
Flora	1.468	1.52	3.03	104.6
Alizeti	1.459	0.29	0.59	16.5
Mpishi	1.456*	0.53	0.97	18.1
Mafuta-ya-Nazi	1.448	6.1	17.1	2.4
Marhaba	1.468	0.17	0.34	116.8
Okay	1.465	0.25	0.51	43.6
Av. Error	± 0.004	± 0.02	± 0.02	± 0.1

* - At 50°C

Refractive Index

Oils of different types exhibited different refractive indices; the values for oils of the same type were close. This indicates that refractive index can be used in the preliminary identification of oils and fats. There was hardly any change in refractive indices after 90 days of exposure to atmospheric light and oxygen (Tables 1 and 9) suggesting that atmospheric oxygen and light do not significantly affect refractive index and that the parameter is less useful in the determination of the rate of deterioration of oils and fats during storage. Of the three sunflower-oils studied, the refractive index value for Alizeti was lower than the standard recommended by FAO/WHO (Anon. 1993) and TBS. This is probably attributed to the nature of the fatty acids present since refractive index decreases with the molecular weight of the fatty acids. It can also be related to its lower iodine value since refractive index decreases with unsaturation. The lower refractive index value for Flora as compared to that of Afya for sunflower oils can be related to its higher FFA content since the presence of FFA appreciably lowers the refractive index of an oil or fat (Cocks 1966). Also, low refractive index for Flora can apparently be related to its high proportion of fatty acids of low molecular weight suggestive of its higher saponification value. The refractive index for Mpishi oil was slightly above the level recommended by FAO/WHO (Anon. 1993) and TBS. For sunflower oils, Afya brand had the highest refractive index. The refractive index of the Soya bean oil (Marhaba)(1.468) was greater than the average value for coconut oil (1.448); their respective iodine values were 130 and 9.

Saponification value

Saponification value gives a measure of the average length of the fatty acid chains which make up a fat. Thus Flora, Alizeti and coconut oils had saponification values above their respective Codex Alimentarius standards (Anon. 1993) and the recommendation of TBS for such edible oils (Table 3). Such high values in Flora and Mafuta ya Nazi oils can be attributed to the presence of high FFA content (Hui 1992).

Iodine value

Except for Alizeti, iodine values for all the oils were within the standards recommended by FAO/WHO (Anon. 1993) and TBS. Sunflower oils had high iodine value (128) suggesting that they were rich in unsaturated fatty acids (Hui 1992). The low iodine value (60) for Alizeti may have contributed to its greater oxidative stability during storage. Oxidative and chemical changes in oils during storage are characterized by a decrease in the total unsaturation of the oil and an increase in FFA contents (Perkins 1992). The iodine value (104) of the cottonseed oil (Okay) compares quite well with the values reported for similar oils in the USA (100-112), Brazil (105.5), China (104.7), Russia (104.2) and India (106.4)(Bailey 1948). The iodine value (126) for the Soyabean oil (Marhaba) agrees favourably with the values recommended by FAO/WHO (Anon. 1993) and TBS for Soyabean oil.

Acid value

Oils varied in their acid content (Table 4). This could be caused by their natural variations in moisture contents as well as the variations in the refining and deodorization processes used. Coconut oil had the highest initial acid value. The acid values for Afya, Alizeti and Marhaba were within the levels recommended by both FAO/WHO (Anon. 1993) and TBS (Table 4). Values for Mpishi, Flora and Mafuta ya Nazi were higher than the maximum level recommended by both FAO/WHO and TBS. The acid value for Okay was within the FAO/WHO (Anon. 1993) standard but higher than the TBS standard (Table 4).

Free Fatty Acid content

Oils varied in their FFA content (Table 5) possibly because of variation in moisture contents, refining and deodorization processes used. The highest initial FFA content (2.54 % as oleic acid) was observed in coconut oil. Flora and Mafuta-ya-Nazi are likely to show a noticeable acidity since their FFA values calculated as oleic acid can be above 0.5% (Egan *et al* 1981). This is also true for Mpishi after being exposed to atmospheric oxygen and light for more than 60 days. The variation could be attributed to inadequate refining and decolorization and the presence of soaps formed from the reaction of FFA with metal salts usually present in the edible oils (Perkins 1992). The three oils can be considered to have lower smoke point and may require more alkali refining to lower their FFA content (Bailey 1948).

Peroxide value

The initial peroxide values ranged between 1.6 and 24.0 meq/kg-oil. The highest value was found in Flora (24 meq/kg). The values for Alizeti, Mpishi, Mafuta ya Nazi and Okay were within the FAO/WHO (Anon. 1993) standards for edible vegetable oils. The values for Afya, Flora and Marhaba were above the maximum value set by FAO/WHO. Peroxide values increased during storage (Table 6, 7 and 8). The rate of peroxidation was different for the different oils and was related to the kind of treatment to which the oils were subjected. Oils not exposed to air and light had very little increase in peroxide, while those exposed to both atmospheric oxygen and light showed large increases in peroxide value. Increases in peroxide values were highest for Soya bean oil and sunflower oils (Alizeti excluded) followed by cottonseed oil and lastly coconut oil. It has been recommended by FAO/WHO (Anon. 1993) and TBS to add synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and propyl gallate (PG) to enhance the storage property of oils. The changes observed in the current study suggest that these antioxidants were not being added to the locally manufactured oils.

Tocopherol content

Vitamin E (tocopherol) contents ranged from 4 to 100 mg/100 g of oil (Table 3). The highest value was found in the Soyabean oil (Marhaba) and the lowest was in coconut oil. The average values were 45 mg/100-g for sunflower oil, 28 mg/100 g for palm oil, 4 mg/100 g for coconut oil and 87 mg/100 g for Okay. For the sunflower oils, Afya had the highest tocopherol content (72 mg/100 g) while Flora had the least content (13 mg/100 g). The tocopherol contents in Afya, Marhaba and Okay were above the standard recommended by TBS and FAO/WHO (Anon. 1993), whereas those for Flora, Mafuta ya Nazi and Mpishi were far below this value. The value for Alizeti was within the standard value recommended by FAO/WHO (Anon. 1993) and TBS.

CONCLUSION

Prior to storage, the physicochemical characteristics of the locally produced edible vegetable oils largely conform to both the international standards set by FAO/WHO (Anon. 1993) and the local standards set by TBS. Depending on the mode of storage, the physicochemical properties changed significantly with storage time; with storage the quality of the oils deteriorated. The highest changing property was that of peroxide in oils exposed to atmospheric oxygen and light; oils kept in tightly sealed containers and stored in the dark (absence of light) exhibited little change. Therefore, in order for the local edible vegetable oils to keep their characteristics, they should be stored in airtight, non-transparent containers. It is also recommended that synthetic antioxidants be used during production in order to enhance storage stability of the oils.

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