EFFECTS OF TEMPERATURE ON THE PHYSICOCHEMICAL PROPERTIES OF TRADITIONALLY PROCESSED VEGETABLE OILS AND THEIR BLENDS

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ABSTRACT

The quality and stability of traditionally processed palm, sunflower and sesame oils and their blends as affected by temperature were evaluated by analyzing their physicochemical properties which included acid, saponification, peroxide, iodine values and refractive indices.. The initial quality of traditionally processed oils studied was found to be within the specifications of TZS and Codex requirements. The results further indicate that the quality of both unblended and blended traditionally processed vegetable oils deteriorate significantly at elevated temperatures ($p < 0.05$). However, the blends showed relatively better quality and stability than the unblended ones whereby the formulations of palm oil (PO) and sesame oil (SSO) appeared to be more stable than those of PO and sunflower oil (SO). This work suggests that blending of traditionally processed PO, SO and SSO improves the quality and stability of these oils.

Keywords: Palm, sunflower, sesame oil, blends, traditionally processed, phydicochemical properties.

INTRODUCTION

Traditionally made edible vegetable oils that are unrefined are good sources of natural antioxidants, vitamin E, polyunsaturated fatty acids and minerals which are very important for human health (FAO and WHO 2002, Hunter and Cason 2006). Edible oils and fats which are mainly traditionally processed in Tanzania include palm, sesame, coconut and sunflower oils. Among other oil seeds, palm tree nuts have highest oil content of about 46-67% (RLDC 2008). However, due to the poor quality of grinding machines, almost about 60% of oil is not extracted from the seeds (Sulle and Nelson 2009). Since palm tree require specific climatic condition which are found in few parts of Tanzania and the fact that there is no substantial production of oil from sesame seed, sunflower oil becomes a most important vegetable oil produced in Tanzania (Rural Livelihood Development Company, RLDC 2008). According to the Tanzania Standards (TZS), the oil obtained by mechanical pressing or by solvent extraction should be pure without any particles, sediments, foreign matter or any contamination (RLDC 2008). However, due to unhygienic production processes, traditional processed oil do not meet international quality standards (RLDC 2008, Sulle and Nelson 2009).

The physicochemical changes taking place at the high temperature of the frying process and the compounds formed in deteriorated frying oil have been extensively studied showing that deep frying tends to increase the foaming, colour, viscosity, density, amount of polymeric and polar compounds and free fatty acid content of frying oil (Andrikopoulos *et al.* 2002). The reactions during the frying/cooking process and storage conditions depend on factors such as the original quality of the oil, type of oil, concentration of antioxidants and oxygen.

Other factors such as the initial content of the free fatty acids, temperature, moisture content, presence of polyvalent metal ions and unsaturated fatty acid content also affect the oxidative stability and overall quality of oil during food preparation process and storage time (List *et al.* 2005). A number of traditionally processed vegetable oils including palm, sesame and sunflower oils are marketed in Tanzania and used in various food preparations including deep-frying. Despite their use in food preparations, the quality and stability of these traditionally made vegetable oils have not been systematically investigated. This paper reports the quality and stability of traditionally processed palm, sesame and sunflower oils and their blends including parameters such as refractive index, saponification value, iodine value, acid value and peroxide value at elevated temperature.

MATERIALS AND METHODS

Oil Sampling, Reagents and Equipments

Three types of traditionally processed palm (*Elaeis guineensis*), sesame (*Sesamum indicum*) and sunflower (*Helianthus annuus*) oils were purchased from the local producers in Kyela District, Mbeya Region (palm oil), Kondoa District, Dodoma Region (sunflower oil) and Masasi District, Mtwara Region (sesame oil). The sampling and storage were conducted as described by TZS 1979b and 2001. The samples were transported to the Chemistry Department, University of Dar es Salaam for storage and analysis. Analytical grade reagents were used. All glassware were cleaned with liquid soap, rinsed with distilled water and then dried before use.

Preparation of Oil Blends, Storage and Treatment Conditions

Oil blends were prepared by mixing palm oil with sunflower or/and sesame oils at a ratio of 3:1, 1:1 and 1:3 (w/w) for binary blends and 1:1:1, 2:1:1, 1:2:1 and 1:1:2 (w/w) for ternary blends. The mixtures were magnetically stirred for 20 minutes to allow homogenization. The oils and their blends were heated at 120 °C (reflecting frying temperature) by a heating mantle for 3 hours every day for 60 days. The heated and unheated control samples were sealed and stored in the dark for the same number of days. Sampling for analysis was performed once after every 10 days for the 60 days of storage time.

Analyses of Physicochemical Properties

The samples were analyzed at Chemistry Department, University of Dar es Salaam, Tanzania.

Acid Value (AV)

The acid values (AV) represent the degradation of the oil quality resulting from the hydrolysis of triacylglycerol as well as further decomposition of hydroperoxides. AV was determined as per TZS 1979b and 2001 protocols. A drop of phenolphthalein (POP) indicator (1% solution in alcohol) was added to 50 ml ethanol-ether mixture (1:1 v/v). To this mixture, 10 g of unblended sesame and sunflower oil samples were added whereas 20 g of palm oil and its blended samples were weighed into a flask followed by addition of 50 ml of neutralized *iso*propanol and then boiled on hot plate for 5 minutes. The duplicate mixture was then titrated against 0.1 N KOH solution until a pink colour that persisted for about 30 seconds was formed. The procedural blank test was also carried out in parallel with the AV determination.

Saponification Value (SV)

The TZS 561:2001 procedure for determination of saponification value (SV) was adopted. To 2 g of each sample in a conical flask 25 ml of alcoholic potassium hydroxide was added. The flask was then connected to a reflux air condenser and heated on electric heating mantle for 1 hour. The sample was heated gently but steadily until it was completely saponified as indicated by the appearance of clear solution. After the flask and condenser have cooled, they were washed with little water followed by addition of POP indicator to duplicate samples and then titrated against 0.5 N Hydrochloric acid. The blank test was carried out in parallel with the SV determination.

Peroxide Value (PV)

Peroxide value (PV) is a measure of the peroxides contained in a sample of fat, expressed as mill-equivalent of peroxide per 1000 g of the material. It is one of the most important chemical constants for appraising the degree of deterioration of oils. TZS 2001 and 1979b were adopted for determination of PV, in which 5 g of each sample was weighed into a 250 ml flask followed by addition of 30 ml of the acetic acid-chloroform (3:2 V/V) solution and the flask swirled until the sample was dissolved in the solution. A 0.5 ml of saturated potassium iodide was added and swirled for 1 minute followed by 30 ml of distilled water. A duplicate titration with 0.01 N sodium thiosulphate solution was carried out with constant and vigorous shaking until the yellow colour has almost disappeared. Thereafter, about 0.5 ml of starch indicator solution was added and titration continued until the blue colour just disappeared. The blank test was also carried out in parallel with the PV determination.

Iodine Value (IV)

Iodine value is an indication of the degree of unsaturation in the oils and fats and is a measure of vulnerability to the oxidation. The higher the iodine value (IV), the more the vulnerability of the oil to oxidation. Wijs' method as described in TZS 1979b and 2001 for determination of IV was adopted. 0.4 g of each sample was weighed into a clean dry 500 ml. 25 ml of Wijs solution (a solution containing iodochloride in glacial acetic acid) was added, the glass stopper replaced and the flask swirled for intimate mixing and then left to stand in the dark for 30 minutes (for sesame and sunflower oil) and 1 hour for palm oil and the blends. Then 15 ml of potassium iodide solution and 100 ml of water were added in sesame and sunflower oil samples while in palm oil and blends 20 ml of potassium iodide and 150 ml of water were added. The liberated iodine was titrated with 0.1 N sodium thiosulphate until the colour of the solution was straw yellow followed by addition of one millilitre of starch solution and the titration continued until the blue colour formed disappeared after thorough shaking with the stopper on. The experiment was carried in duplicates and the blank test was carried out simultaneously under similar experimental conditions.

Refractive Index (RI)

The refractive indices (RI) of the oils and fats were measured by a refractometer at constant pressure. The TZS 1979b and 2001 protocols were followed. An Abbe refractometer connected to a thermostatically controlled (at 40 °C) water bath with a circulating pump was used. Two drops of each sample were placed on the lower prism. The prism was closed, tightened firmly with the screw-head and allowed to stand for 1-2 minutes after which the determination of RI was done. Ethanol was used for cleaning the prism of the refractometer.

Data Analysis

Duplicate samples of pure oils and blends were analyzed and the mean values calculated for each physicochemical parameter determined. Mean and standard deviations of acid value (AV), saponification value (SV), peroxide value (PV), Iodine value (IV) and refractive index (RI) were calculated using MS excel. Instat statistical package was used for multiple comparison with one way ANOVA/t-test to establish the significant difference within one type of oil, across various oil types and their blends as compared to the control samples to statistically establish the effect of temperature ($\alpha = 0.05$).

RESULTS AND DISCUSSIONS

Acid Value (AV)

The AV for unblended palm oil (PO) was found to be 4.47% palmitic acid while those of sunflower oil (SO) and sesame oil (SSO) were found to be 0.42% and 2.03% Oleic acid, respectively. The unblended PO, SO and SSO should have maximum values of free fatty acid (FFA) of 5% palmitic acid, 1.5-2.5 and 0.3-0.35 FFA % oleic acid as quality requirements for Tanzanian Standards, respectively (Table 6) (TZS 2004, 1979a and 1979b). The Codex specification recommend that the unblended SO and SSO should have maximum FFA content of 2% oleic acid. Thus, the initial FFA values of unblended traditionally processed PO and SO except SSO were found to be within the range of standard requirements.

From the change in mean acid values obtained (Table 1), temperature appears to have significant effect ($p < 0.05$) on the FFA content of unblended PO, SO and SSO. The unblended SO appeared to be highly affected by temperature by showing the highest increase of FFA content compared to PO and SSO. This could be attributed to high degree of unsaturation in SO compared to other oils. The increase of FFA upon heating under the stated conditions was significantly lower than for the samples stored in the air tight-dark conditions. The reason behind the observed trend could be due to the fact that the triglycerides and FFAs would be undergoing further chemical reactions giving degenerate products which could not be detected as oil acidity. Among other oils, SSO showed the highest stability which could be contributed by the presence of high content of natural antioxidants such as sesamin, sesamolin, sesamol and γ-tocopherol that could be retarding formation of FFA through oxidative pathway.

In addition, temperature had significant effect ($p < 0.05$) on the change of mean AV for both binary and ternary blends (Table 1). For the binary blends, the results showed lower increase of FFA content of samples that were heated at 120 °C compared to the increase of the FFA content of the corresponding unheated samples. Again the disparity is attributed to FFAs in the former treatment undergoing further chemical reactions giving degenerate products, hence could not be detected as oil acidity. The blends of PO:SO (1:3) and PO:SSO (1:3) were highly affected by temperature due the high content of the unsaturated oils (SO and SSO) which are less stable at elevated temperatures compared to the saturated one (PO). For the blends stored in the dark, the PO:SO:SSO (1:1:2) blend showed the highest stability by showing the small change in FFA followed by PO:SO:SSO (1:2:1) and PO:SO (1:1). Again the reason for the stability of these blends could have been attributed by the high degree of unsaturation of SO and SSO which retards hydrolysis of triglycerides.

Table 1: Mean ± SD AV change after 60 days of storage time

SAMPLE	D	H
PO	$4.01 \pm 0.03^{a,b}$	$0.51 \pm 0.103^{a,b}$
SO	$0.27 \pm 0.26^{a,b}$	$0.55 \pm 0.01^{a,b}$
SSO	$0.19 \pm 0.02^{a,b}$	$0.23 \pm 0.02^{a,b}$
PO:SO (3:1)	$2.97 \pm 0.02^{a,b}$	$0.23 \pm 0.02^{a,b}$
PO:SO (1:1)	$1.58 \pm 0.04^{a,b}$	$0.24 \pm 0.04^{a,b}$
PO:SO (1:3)	$1.18 \pm 0.02^{a,b}$	$0.54 \pm 0.01^{a,b}$
PO:SSO (3:1)	$3.9 \pm 0.01^{a,b}$	$0.39 \pm 0.01^{a,b}$
PO:SSO (1:1)	$2.61 \pm 0.01^{a,b}$	$0.45 \pm 0.01^{a,b}$
PO:SSO (1:3)	$1.73 \pm 0.11^{a,b}$	$0.83 \pm 0.11^{a,b}$
PO:SO:SSO (1:1:1)	$1.39 \pm 0.006^{a,b}$	$0.62 \pm 0.01^{a,b}$
PO:SO:SSO (2:1:1)	$2.08 \pm 0.023^{a,b}$	$0.29 \pm 0.02^{a,b}$
PO:SO:SSO (1:2:1)	$1.09 \pm 0.001^{a,b}$	$0.2 \pm 0.02^{a,b}$
PO:SO:SSO (1:1:2)	$1.03 \pm 0.003^{a,b}$	$0.11 \pm 0.01^{a,b}$

a *= Mean values in the same row are significantly different,* $p < 0.05$
b *= Mean values in the same column are significantly different,* $p < 0.05$

D *= Samples stored in air tight-dark condition for 60 days*

H *= Samples heated at 120 °C for 3 hour per day for 60 days*

Saponification Value

The initial saponification values (SV) recorded for unblended PO, SO and SSO were 200.33, 186.13 and 193.66 mg KOH/g oil, respectively. TZS and Codex standard requirements specify that the SV of unblended PO, SO and SSO should range between 194-1202, 188-194 and 185-193 mg KOH/g oil, respectively (Table 6). The initial SV showed that traditionally processed PO and SSO were within the range of specified standard requirements while SO was out of the specified range. The mean SV for unblended PO, SO and SSO were significantly affected by temperature ($p < 0.05$) by showing different SV change after 60 days of storage time. SSO has shown to be the most stable oil than others due to the smaller SV change under this treatment (Table 2). The results showed that the increased SV of unblended PO, SO and SSO exposed at elevated temperature are significantly lower than the SV of the same samples stored in the dark. This may be attributed to transformation of fatty acids to carbonyl compounds which reduces the FFA content in the oils and hence lowering the SV.

The effect of temperature was also significant on the mean change of SV of all the blends (Table 2). Thus, the results showed the mean SV change of heated blends to be significantly lower than those observed for the air tight-dark stored oil. Again this could be due to chemical reactions giving degenerate products other than FFAs. The binary blends of PO and SSO appeared to be more stable than the PO and SO blends treated and stored under the same conditions, the stability being ascribed to high amount of the natural antioxidants in SSO which retard the formation of free fatty acids. Among all the binary blends, PO:SSO (1:3) formulation exhibited the highest stability whereas PO:SO (3:1) was the least stabel. The SV of ternary blends which were heated at 120 °C for 3 hours per day for 60 days showed an increase which was observed to be significantly lower than the SV of samples stored in air tight-dark conditions. The dissimilarity is ascertained again to FFAs in the former treatment having undergone further chemical reactions giving degenerate products. PO:SO:SSO (1:1:2) blend was significantly stable over the others due to high amount of SSO which is known to have large quantity of natural antioxidants, followed by PO:SO:SSO (1:2:1) blend containing substantial amount of highly unsaturated SO contributing to its stability against hydrolysis.

Table 2: Mean ± SD SV change after 60 days of storage time

SAMPLE	**D**	**H**
PO	29.53 + 0.55[a]	26.81 + 0.33
SO	29.61 + 0.07[a]	28.2 + 0.06
SSO	17.16 + 0.04	15.66 + 0.06
PO:SO (3:1)	26.85 + 0.48	23.3 + 0.47
PO:SO (1:1)	23.25 + 0.05	22.83 + 0.45
PO:SO (1:3)	22.16 + 0.06	21.63 + 0.04
PO:SSO (3:1)	23.29 + 0.01	22.57 + 0.22
PO:SSO (1:1)	18.23 + 0.07	17.6 + 0.1
PO:SSO (1:3)	16.08 + 0.5	14.26 + 0.31
PO:SO:SSO (1:1:1)	26.86 + 0.04	25.61 + 0.02
PO:SO:SSO (2:1:1)	27.1 + 0.43	26.39 + 0.06
PO:SO:SSO (1:2:1)	19.44 + 0.11	16.13 + 0.02
PO:SO:SSO (1:1:2)	18.87 + 0.34	15.99 + 0.03

a *= Mean values in the same column are not significantly different, $p > 0.05$*

D *= Samples stored in air tight-dark condition for 60 days*

H *= Samples heated at 120 °C for 3 hour per day for 60 days*

Peroxide Value

Initial PVs of unblended PO, SO and SSO were found to be 0.19, 8.64 and 4.36 meq O_2/kg, respectively. This indicated that the traditionally processed PO, SO and SSO have a good PV since they were within the TZS and Codex Standard which require that a good quality oil should have a maximum PV of 10 meq O_2/kg (Table 6). The mean change of PV of unblended PO, SO and SSO were significantly affected by temperature ($p < 0.05$; Table 3). For the unheated samples, the PV increase of PO was lower than those of SO and SSO indicating that PO is significantly oxidatively stable oil than the others. Since linoleic and linolenic acids are the most readily oxidized components of oil, the oxidative stability of PO could be due to the low linoleic acid content (7.5-10.9%) as compared to the estimated amounts present in SO (53-68%) and SSO (45%) (Martin 1995). The PV increase for the heated samples was significantly lower compared to those stored in air tight-dark condition except for PO. The low PV of the heated samples could be explained by the fact that peroxides are unstable compounds towards high temperatures, transforming them to carbonyl compounds as previously reported by Serjouie *et al.* 2010 for refined oils.

Table 3: Mean ± SD PV change after 60 days of storage time

SAMPLE	D	H
PO	2.57 ± 0.24^{a,b}	29.2 ± 0.03^{a,b}
SO	91.74 ± 0.01^{a,b}	37.52 ± 0.22^{a,b}
SSO	34.97 ± 0.02^{a,b}	30.75 ± 0.08^{a,b}
PO:SO (3:1)	14.24 ± 0.01^{a,b}	26.82 ± 0.09^{a,b}
PO:SO (1:1)	39.24 ± 0.14^{a,b}	31.41 ± 0.04^{a,b}
PO:SO (1:3)	57.3 ± 0.001^{a,b}	37.23 ± 0.01^{a,b}
PO:SSO (3:1)	5.31 ± 0.02^{a,b}	27.77 ± 0.02^{a,b}
PO:SSO (1:1)	11.67 ± 0.03^{a,b}	28.57 ± 0.02^{a,b}
PO:SSO (1:3)	13.73 ± 0.08^{a,b}	29.02 ± 0.05^{a,b}
PO:SO:SSO (1:1:1)	21.45 ± 0.15^{a,b}	29.06 ± 0.07^{a,b}
PO:SO:SSO (2:1:1)	29.71 ± 0.03^{a,b}	33.84 ± 0.1^{a,b}
PO:SO:SSO (1:2:1)	52.26 ± 0.42^{a,b}	30.72 ± 0.02^{a,b}
PO:SO:SSO (1:1:2)	26.44 ± 0.24^{a,b}	30.09 ± 0.02^{a,b}

***a** = Mean values in the same row are significantly different, $p < 0.05$*
***b** = Mean values in the same column are significantly different, $p < 0.05$*
***D** = Samples stored in air tight-dark condition for 60 days*
***H** = Samples heated at 120 °C for 3 hour per day for 60 days*

The effect of temperature on PV was also observed on the blends. Binary blends of PO:SO were significantly affected ($p < 0.05$) by high temperature than those of PO:SSO (Table 3). The results indicate that the blends of PO and SSO have relatively higher stability than the corresponding blends of PO and SO stored under the same storage condition whereas the PO:SSO (3:1) blend appeared to be more stable followed by PO:SSO (1:1). The PV increase of PO:SO blends at elevated temperature appeared to be significantly lower than those stored in the dark except for PO:SO (3:1) due to the high content of PO which was relatively stable at elevated temperature than SO. The lower increase of PV of these blends indicates SO to be unstable oil at elevated temperature, transforming easily to carbonyl compounds, causing its blends to have low PV compared to the corresponding blends stored in air tight-dark condition. Such trend appears to be different from the blends of PO:SSO in which the PV increase was significantly higher than those observed in the blends stored in the dark. For the ternary blends, the PV increase for PO:SO:SSO (1:1:1) PO:SO:SSO (2:1:1) and PO:SO:SSO (1:1:2) was found to be significantly higher than the increase observed in the air tight-dark conditions due to the increased amount of PO and SSO respectively, used in the formulations (Table 3). The PV increase for PO:SO:SSO (1:2:1) blend was significantly lower than those stored in the dark due to increased amount of SO used. Generally, the blends which contained large amounts of PO showed the highest stability whereas the blends which contain large amount of SO showed the least stability when heated or stored in air tight-dark conditions.

Iodine Value

The IV of unblended PO, SO and SSO at the initial time of storage were found to be 61.91, 142.96 and 89.86 (g I_2/ 100 g oil), respectively. According to TZS and Codex standard, unblended PO, SO and SSO should have an IV of 56.0-59.1, 110-143 and 104-120 g I_2/100g oil, respectively (Table 6). PO was found to have higher IV while SSO was found to have lower IV compared to the standard requirements. On the other hand, SO was found to have an IV which is within the TZS and Codex standard requirements.

Table 4: Mean ± SD IV change after 60 days of storage time

SAMPLE	D	H
PO	16.14 ± 0.59	8.15 ± 0.01
SO	30.4 ± 0.02	22.35 ± 0.06
SSO	21.73 ± 0.04	16.8 ± 0.06
PO:SO (3:1)	23.12± 0.011	15.33 ± 0.16
PO:SO (1:1)	26.9 ± 0.10	21.74 ± 0.17
PO:SO (1:3)	27.81 ± 0.011	21.93 ± 0.05
PO:SSO (3:1)	19.58 ± 0.05^{a}	10.98 ± 0.029
PO:SSO (1:1)	19.73 ± 0.01^{a}	11 ± 0.08
PO:SSO (1:3)	20.71 ± 0.024	12.74 ± 0.128
PO:SO:SSO (1:1:1)	28.18 ± 0.05^{b}	12.57 ± 0.18
PO:SO:SSO (2:1:1)	28.4 ± 0.29^{b}	11.84 ± 0.25
PO:SO:SSO (1:2:1)	19.4 ± 0.001	14.48 ± 0.101
PO:SO:SSO (1:1:2)	17.5 ± 0.01	13.09 ± 0.04

a &b = Mean values in the same column are not significantly difference, p > 0.05

***D** = Samples stored in air tight-dark condition for 60 days*

***H** = Samples heated at 120 °C for 3 hour per day for 60 days*

The mean change of IV for unblended PO, SO and SSO were significantly affected at elevated temperature ($p < 0.05$) than when stored in air tight-dark conditions. SO was indicated to be the most vulnerable to oxidation (Table 4). The IV increase at elevated temperature could be attributed to destruction of double bonds in the oils upon heating. Temperature also had significant effect on IV for both binary and ternary blends ($p < 0.05$) by showing significant lower IV change for the heated samples compared to the unheated blends (Table 4). This could be due to the effect of high temperature causing destruction of π-bonds and hence decreasing the degree of unsaturation. For the ternary blends of PO with SO and SSO, the results indicated the blend with high ratio of PO to have lower IV change than those with high ratio of SO and SSO at elevated temperature. The increased IV of PO upon blending could be due to an increase of the predominance of unsaturated fatty acids (PUFA) providing an imminent information that blending has significant influence on IV by improving the saturation/unsaturation ratio of PO (saturated oil) by blending it with SO and SSO (unsaturated oils).

Refractive index

The initial RI of unblended PO, SO and SSO were found to be 1.4575, 1.4665 and 1.4605, respectively, all being within the TZS and Codex standard requirements which range between 1.4589-1.4592, 1.464-1.480 and 1.4662-1.4655 for unblended PO, SO and SSO, respectively (Table 6).

The mean change of RI for unblended PO, SO and SSO exposed to elevated temperature appeared to be insignificantly higher ($p > 0.05$) than those of oils stored in the dark condition (Table 5). Nevertheless, the results indicate unblended PO to be the most stable oil against elevated temperatures since it showed the smallest change of RI after 60 days of storage time. The variation could be attributed to the degree of unsaturation (7.5 – 10.9%, 53.0 – 68.0% and 45% for PO, SO and SSO, respectively).

All blends were also insignificantly affected by high temperature ($p > 0.05$). Thus, the mean RI increase of the blends at elevated temperature appeared to be insignificantly higher than the increase observed in the blends stored in dark condition. Generally, the binary blends of PO and SSO showed higher stability compared to the corresponding blends of PO and SO kept under the same storage condition. This stability may be attributed to the high amount of natural antioxidants in SSO. PO:SSO (3:1) blend showed the highest stability at elevated temperature compared to the other blends due to the large amount of PO while PO:SO (1:3) blend was highly affected by temperature due to the large amount of SO. For the ternary blends, PO: SO:SSO (1:1:1) and PO:SO:SSO (2:1:1) blends were insignificantly affected by high temperature ($p > 0.05$) showing high stability over the other blends. PO:SO:SSO (1:2:1) was found to be the least stable due to the increased amount of SO in the formulation. These results suggest that RI measurements could be used in the initial identification of quality of oils and fats, but less important in the determination of the deterioration of oils and fats upon heating or during storage.

Table 5: Mean ± SD RI change after 60 days of storage time

SAMPLE	D	H
PO	0.0008 ± 0.002	0.002 ± 0.00011[a]
SO	0.0008±0.002	0.0037 ± 0.0002[a]
SSO	0.0008 ± 0.0007	0.0022 ±0.0005[a]
PO:SO (3:1)	0.0012 ± 0.002	0.0027 ± 0.00023
PO:SO (1:1)	0.0012 ± 0.0005	0.003 ± 0.0001
PO:SO (1:3)	0.0013 ± 0.0005	0.0034 ±0.0005
PO:SSO (3:1)	0.0007 ± 0.0002	0.002 ±0.0002
PO:SSO (1:1)	0.0007 ± 0.0002	0.0022 ± 0.0005
PO:SSO (1:3)	0.0005 ± 0.0005	0.0023 ± 0.0005
PO:SO:SSO (1:1:1)	0.0009 ± 0.0002	0.002 ±0.00023
PO:SO:SSO (2:1:1)	0.0008 ± 0.0004	0.002 ± 0.0004
PO:SO:SSO (1:2:1)	0.0012 ± 0.00016	0.0035 ± 0.0004
PO:SO:SSO (1:1:2)	0.0009 ± 0.0002	0.0024 ± 0.0002

a *= Mean values in the same column are significantly different, $p<0.05$*

D *= Samples stored in air tight-dark condition for 60 days*

H *= Samples heated at 120 ºC for 3 hour per day for 60 days*

Table 6: Recommended TZS and Codex Standards for unrefined vegetable oils studied (TZS 1979a; TZS 1979b; TZS 2004)

Vegetable oil	RI at 40 °C	SV mg KOH/g oil	IV Wijs	AV KOH max	PV meq. O_2/kg, max
Palm	1.4589-1.4592	194-1202	56-59.1	10	10
Sunflower	1.464-1.480	188-194	110-143	3.0-5.0	10
Sesame	1.4655-1.4662	185-193	105-120	0.6-0.75	10

CONCLUSIONS

In general, the results of this study indicated that traditionally processed vegetable oils (PO, SO and SSO) in Tanzania meet the recommended TZS and Codex standards at the initial stage though most of them were found to be at the margins of the specification requirements. The unblended oils were found to have poor stability upon heating as well as with prolonged time of storage than the blended oils. This work has also revealed that blends which contain PO and SSO have higher thermal stability than the blends of PO and SO. This could have been contributed by the large amount of natural antioxidants such as sesamin, sesamol and γ-tocopherol present in SSO.

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REFERENCES

Andrikopolous NK, Kalogeropoulos N, Falirea A and Barbagianni MN 2002 Performance of Virgin Olive Oil and Vegetable Shortening During Domestic Deep- frying and Pan-frying of Potatoes. *Int. J. Food Sci. Technol.,* **37**:177-190.

FAO and WHO 2002 Human Vitamin and Mineral Requirements, Rome.

Hunter JG and Cason KL 2006 Fat in your Diet. Home & Garden Information Center (HGIC)

4050, The Clemson University Cooperative Extension Service http://www.clemson.edu/extension/hgic/food/nutrition/nutrition/dietary_guide/hgic4050.html. Retrieved on 11/09/2011

List GR, Wang T and Shukla VKS 2005 Storage, Handling and Transport of Oils and Fats. Bailey's Industrial Oil and Fat Products.

Martin C 1997 Comparative Study of Edible Vegetable Oils and Fats Marketed in Dar es Salaam. *M.Sc.Dissertation*, University of Dar es Salaam, Tanzania.

Rural Livelihood Development Company 2008 Sunflower Sector, Market Development Strategy.

Serjouie A, Tan CP, Mirhossein H and Man YBC 2010 Effect of Vegetable-based Oil Blends on Physical Chemical Properties of Oils During Deep-fat frying. *Am. J. Food Technol.*, **5**: 310-323.

Sulle, E and Nelson, F 2009 Biofuels, Land access and rural livelihood in Tanzania, IIED, London.

TZS 50 1979a UDC 665.347.8 Tanzania Standard Sunflower Seed Oil – Specification. *Tanzania Bureau of Standards*.

TZS 51 1979b Tanzania Standard Oils and Fats-Sampling and Test Methods Part 1: Sampling and Chemical Tests. *Tanzania Bureau of Standards.*

TZS 51 1979c UDC 665.337.4 Tanzania Standard Sesame Seed Oil- Specicication. *Tanzania Bureau of Standards.*

TZS 559 2004 (E) ICS 67.200 Tanzania Standard Palm Olein – Specification. *Tanzania Bureau of Standards*

TZS 561 2001 Tanzania Standards, Sampling and Test Methods for Palm Oil and Palm Oil Products. *Tanzania Bureau of Standards.*