QUALITY ASSESSMENT OF EDIBLE SUNFLOWER (*Helianthus annuus*) OIL FROM SMALL SCALE PROCESSORS; A CASE STUDY OF MOROGORO REGION TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD SCIENCE OF THE SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

ABSTRACT

A study was carried out to assess sunflower oil quality. A total number of 18 small scale sunflower oil processors in Morogoro region were interviewed face to face using structured questionnaire to collect information on processing practices including registration of processors, access to training and packaging availabilities. Two batches of processed oil were sampled according to the European Oil and Protein Meal Industry (FEDOIL) procedures and subsequently assessed for physico-chemical properties (refractive index, colour, specific gravity, moisture content, acid value, peroxide value, iodine value and level of impurities) as per either International Standards (ISO) or IUPAC methods. The data was subjected to analysis of variance and mean differences were tested for significance at $p < 0.05$. Results indicated that an alarming number of processors 89 % were unregistered. Furthermore, 72 % of sunflower oil processors receive no training to enable them acquire skills important for their operations. All 18 processors use plastic containers for packaging and 89 % prefer to use 5 liters containers. It was revealed that 78 % of all small scale processors do not label their final products. Physico-chemical parameters analyzed were within the standard limits of FAO/WHO and the Tanzania Bureau of Standard except the insoluble impurities and peroxide values, which had the highest values of 1.233 % (m/m) and 16.597 (meq/kg) respectively. Despite of these results sunflower oil from small scale processors in Morogoro region is of good quality. Government should facilitate quality enhancement and enforce food laws among small scale sunflower oil processors. Willingness for change among processors attitudes on food quality is needed.

DECLARATION

I, Yohana Nanai Goshashy, do hereby declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

29th October 2014

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DEDICATION

This work is dedicated to my mother Sofina and father Nanai.

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In developing countries, urbanization, economic development and market globalization as well as increased industrialization have led to dietary and lifestyle changes (FAO, 2008). This has often been accompanied by unhealthy dietary patterns and inadequate physical activities to maintain an optimal energy balance and a healthy weight. The net outcome has been the increased prevalence of diet-related chronic diseases such as coronary heart disease and cancer risk in all socio-economic groups worldwide (Hu *et al.*, 1999). As there is a link between saturated fats and heart disease; this has led to preference in hydrogenated oils has been on the decline (Fellows and Axtell, 2012). In Tanzania there are indications of rising demand for sunflower oil due to health consciousness by consumers (Fellows and Axtell, 2012). Refined oil does not meet its growing demand and consequently consumers prefer locally produced oil *vis a vis* imported refined oils that are more expensive (Dietz *et al.*, 1998). The small scale sunflower oil processors contribution to the national oil demand is 40 % (RLDC, 2008). It is however unclear and uncertain whether there would be a tangible support to the small scale processors either directly from the government or institutions engaged in quality improvement (Dietz *et al.*, 1998). There is a feeling that the government has weak capacity to inspect the quality of imported foods as well as price regulations and control as reported by Sertse *et al.* (2011).

Registration of small scale sunflower oil processors is done through the Local government for taxation purposes and subsequently a Certificate of hygiene is secured from the Ministries of Health (Dietz *et al.*, 2000). Most consumers demand to have oil that is fresh and free from chemicals and other contaminants (Fellows and Axtell, 2012). Studies by Rab *et al.* (2008) show that sunflower oil processed by small scale processors is more accepted and welcomed by consumers so long as it is endowed with familiar taste and smell. Fats and oil packages are important factor in protecting the product from being spoiled by dirt, infestation of insects, rodents or microorganisms, loss and/ or gain of moisture, odour and flavour during handling (Abdellah and Ishag, 2012). Rancidity spoilage can be due to light and heat exposure, moisture, presence of certain metals, enzymes as well as microbes (O'Brien, 2004).

1.1 Problem Statement

Sunflower oil in particular has a high demand in rural and urban areas in Tanzania. The locally processed oil is insufficient to meet the high demand countrywide (Dietz *et al.*, 2000; RLDC, 2008). This results into consumers neglecting the oil quality aspects by consuming whatever comes on their way. Small- scale processors in Tanzania constitute a significant sub sector within the economy yet succumbing to competition from large processors. Importers of edible sunflower oil oftentimes use misleading labeling in which case crude oil may be labeled refined (Hamilton, 2010).

Some of small scale's oil processors lack organization and system for monitoring and control of sunflower oil quality. Lack of publicity for their products is also a major constraint in consumer health protection (Ruvuma Commercialization and Diversification of Agriculture - RUCODIA, 2007). More people are engaged in unregistered small scale food processing enterprises. This scenario renders the processors invisible to food quality regulators (Wiemer *et al.*, 1989; Dietz *et al.*, 2000). Some processors may extract or produce oil products in their backyard to earn additional income. The National Food Law requires all processors to be registered (Axtell and Noble, 2002). Small scale processors that do fail to adhere to the aforesaid procedures are frequently threatened by Health officers. It is reported by Dietz *et al.* (1998) that small scale sunflower oil producers lack understanding of the quality requirements by consumers. They get little opportunities for customer opinion for quality control of their products. Lack or inadequate packaging materials and packages for small scale sunflower oil processor lead retailers and consumers' to think that locally produced oil are of low quality compared to imported brands (Dietz *et al.*, 2000; Fellows and Axtell, 2012). Small scale oil processors find it difficult to fetch for trained and experienced technical staff as well as proper oil filters (Dietz *et al.*, 1998; Mpagalile *et al.*, 2008). Lack of skilled personnel can affect consumers, sunflower oil small scale processor as well as quality of the product produced.

1.2 Problem Justification

Rural Livelihood Development Company (2008) reported that one of the requirements for safety of unrefined sunflower oil from small scale processors is distribution and sale shortly after it has been expressed or extracted. The Tanzania Food and Drug Authority (TFDA) do not guarantee the quality of unrefined oil especially if stored for a long time after processing and packaging (Dietz *et al.*, 2000). The common practice by many small scale sunflower oil and traders is displaying for sale packaged sunflower oil along roadside the whole day. Abdellah and Ishag (2012) reported that exposure of oil to sunlight and high temperatures lead to its oxidation and quality loss acceleration. Locally processed sunflower oil to a great extent is packed in containers without labels that provide vital information on processing date, shelf stability and other oil quality attributes. Dietz *et al.* (2000) reported that in Tanzania, 90 % of registered food processors are on a small scale level implying that most processed food products marketed countrywide are from the small scale sector. Limited studies have been reported on quality aspects and marketing strategies of sunflower oil processed by small scale processors, hence this study was carried out to evaluate quality of sunflower oil produced by small scale processors.

1.3 Main Objective

The aim of this study was to examine the essential quality attributes of sunflower oil processed by small scale processors in Morogoro region.

1.4 Specific Objectives

1. To identify edible sunflower oil small scale processors and registration status in Morogoro Region.
2. To assess the extent of training and access to services from the government and its affiliated organs that focus on oil processing and quality enhancement.
3. To determine the availability of packaging materials and identify packaging practices by small scale sunflower oil processors in Morogoro Region.
4. To determine the physicochemical properties of the sunflower oil from small scale processors in Morogoro region after filtration and settling of the extracted oil.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sunflower Producers

Oil seeds in Tanzania include groundnut seeds 40 %, sunflower seeds 36 %, sesame seeds 15 %, cotton seeds 8 % and palm 1 % (The Agribusiness Innovation Center of Tanzania, 2012). Production of sunflower oil seeds in Tanzania is predominantly done by small scale farmers owning one to three acres (Match Maker Associates limited, 2012). However, there are also medium to large scale farmers with more than a thousand acres of sunflower. The crop is grown all over Tanzania but more than 50 % is cultivated in Dodoma (22.5 %), Kilimanjaro (13.2 %), Arusha and Manyara (13.1 %) Singida (8.9 %) (RLDC, 2008).

The production of the plant and the composition of the resulting oil depends on the growing conditions especially the temperature (Rab *et al.*, 2008). Sunflower is able to grow in warm to a moderate semi-arid climate region. The climate in which sunflower is grown have effects on seed oil fatty acid composition. For example, fatty acid composition in temperate sunflower oil is 55-75 % linoleic acid and oleic acid 15-25 % (high linoleic acid makes the oil prone to rancidity) while the protein content is 15-20 % (FAO, 2010).

In addition to sunflower having triacylglycerides that are the mainly oil, it provides a relatively high amount of vitamin E (tocopherols and tocotrienols) and sterols in diet (Foster *et al.*, 2009). It is also reported by Suliman *et al.* (2013) that sunflower oil is known to contain high levels of tocopherol (935 ppm) as natural antioxidants hence, increase its shelf stability, although Gornas *et al.* (2006) found that high peroxide value decreases tocopherol levels. Table 1 shows the increase in sunflower oil production in Tanzania from 1999 to 2007.

Table 1: Sunflower oil production in Tanzania from 1999-2007

Year	Sunflower oil production (in tons)
1999 – 2000	11,560
2000 – 2001	19,409
2001 – 2002	25,056
2002 – 2003	26,986
2003 – 2004	21,325
2004 – 2005	89,614
2005 – 2006	88,753

Source: RLDC (2008)

2.2 Raw materials for Sunflower Oil Extraction

Mature harvested crops contain most oil and it is easily extracted. Under-ripe seed materials give a lower oil yield and are difficult to process while the over- ripe ones are easily bruised hence, allowing enzyme action which facilitate rancidity (Fellows and Axtell, 2012; FAO, 2010). The Oil seeds must be properly dried before storage and cleaned to do away with sands as well as dust. Winnowing and sorting can be done to remove stones or contaminated seeds with moulds which can cause aflatoxin (common in groundnuts). Finally, before oil pressing decortication is important to obtain high amount of oil and to reduce material bulk to be processed (Swetman, 2008). Efforts should be made in order to have some degree of control over the supply of raw materials, to ensure that the seeds are well stored and Sunflower oil processors have trustworthy suppliers (Schumacher, 2007; Swetman, 2008).

2.3 Sunflower Oil Processing

There is considerable variation in the oil content of crops. Sunflower contains 25- 40 % oil content. The amount of oil produced depends to some extent on the variety and climate, but mainly it is related to the extraction efficiency of the process. The main governing factors of extraction efficiency are the pressure applied during extraction; the higher the pressure the higher the oil yield. The crude oil is usually subjected to traditional refining stages (Fellows and Axtell, 2012). Oil extraction is done mechanically using either a ram press or expellers (Plate 1) (RUCODIA, 2007). Extraction can also be done by the use of solvent when complex practice is done (Bachmann, 2001). Solvent extraction plants use hexane as a solvent to extract oil from oilseed cake. These plants are expensive and only suitable for large volumes which justify the capital cost of plants and equipment. Before filtration is effected clarification removes contaminants such as fine pulp, water, and resins. Oil is transferred to a holding tank prior to filtration under pressure through special filter cloths (Swetman, 2008).

A big challenge to oil handling in small scale processors in developing countries is how to extend the shelf life by preventing rancidity to occur. Technologies available are not reliable for such purposes and processors lack either the technical knowhow or the required financial capability to purchase, apply and sustain those (Oyekunle *et al*, 2012). Studies by Budryn *et al.* (2011) revealed that majority of edible oils are unstable when exposed to oxygen and light and hence can easily be oxidized. It has been reported that oxidative rancidity can be affected by temperature as well as storage conditions (Ngasapa and Othman 2001; Abdellah *et al.*, 2012). Findings by Abdellah *et al.* (2012) indicated that improperly stored oil have high peroxide values amounting to 19 meq/kg.

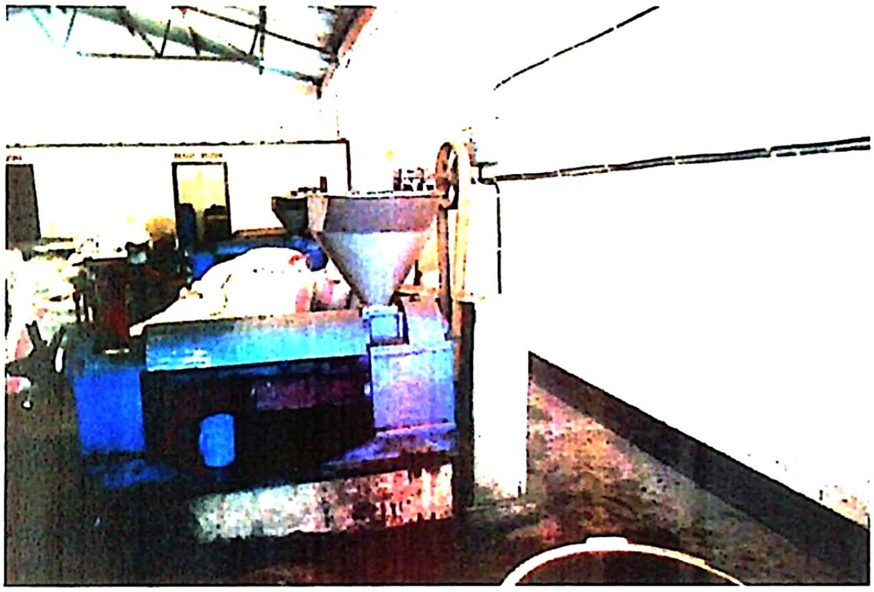

Plate 1: Expeller machine in one of the small scale processors' in Morogoro

2.4 Quality Assurance of Sunflower Oil

Consumers in most countries are demanding the best quality foods and their expectation to government is to assure such products (Robertson and Lupien, 2008). The products should meet consumer's perception of good quality and value for money. Hence, quality is considered as a major component of marketing mix (RLDC, 2008). Small scale sunflower oil processors need to meet national and international standards if they are to export their commodities. However, a study by Ngassapa *et al.* (2012) revealed that they do not meet the quality specifications. That is why they need to have quality assurance system in place since quality specifications for export oil are higher compared to crude oil (Fellows and Axtell, 2012). Most of small scale sunflower oil processors do not have a quality assurance system in place instead they have been solving problems as they arise (Dietz *et al.*, 1998; Fellows and Axtell, 2012). Ideally the quality checks should be on oilseeds, processing conditions, oil quality, packaging and storage conditions.

The attributes of crucial importance that have to be controlled are moisture content, colour, flavour, odour, clarity and fill weight/ volume (Practical Action, 2009).

Table 2: Physical characteristics and composition of sunflower oil

Characteristics	Typical	Range
Specific gravity (25°C)	-	0.915 to 0.919
Refractive index (25°C)	-	1.472 to 1.475
Iodine value	133	125.0 to 136.0
Saponification number	-	88 to 194
Unsaponifiable number	-	0.3 to 1.3
Titre (°C)	-	16.0 to 20.0
Melting point (°C)	-	-18 to -20
Solidification point (°C)	-17	-

Source: O'Brien (2004)

2.4.1 Moisture content

Measurement of moisture content of oilseeds is useful to prevent hydrolytic reaction of water with a fat or triglyceride which break it down to form diglyceride and a free fatty acid also support fungal growth during storage (O'Brien, 2004; Fellows and Axtell, 2012). The breakdown of fat and oil to fatty acid is facilitated by presence of high moisture content and microorganisms as reported by Abdellah and Ishag (2012).

2.4.2 Impurities

Foreign material in a finished product is usually caused by a malfunctioning polish filter, precipitant of metal salts, polymerized oil from dead spaces in lines and inadequate tank cleaning (O'Brien, 2004). Foreign matter reduces oil and protein yields, adversely affect oil, and increases wear and damage to the processing equipment. Stems, pods, leaves, broken kernels, dirt, small stones, and extraneous seeds are the typical components of the foreign material found in sunflower oil (O'Brien, 2004; Dimic *et al.,* 2012). On the other hand, it has been reported by Brevedan *et al.* (2000) that turbidity of unrefined oil is due to the presence of waxes and gums. Other findings by Rab *et al.* (2008) pointed out that about 30 % of sunflower seeds contain hulls covered by waxes which are extracted with the oil during processing, resulting into turbidity. The study indicated that pressing by a screw press or expeller resulted into residual fat content between 7 and 15 % depending on the pressing conditions. On the other hand, Dimic *et al.* (2012) indicated that up to 10 % of impurities and 32 % of the hulls led to poor sensory and chemical properties of the oil.

2.4.3 Odour and Flavour

Fats and oils easily absorb odours and flavours from other foods, spices, solvents, gases, chemicals, paints, and any other odoriferous or flavourful materials. Therefore, extreme care must be exercised to protect the fat and oil products at all times after deodorization including storage, handling, and transportation of bulk liquid or packaged products (O'Brien, 2004). It was reported that many small scale processors produce their products at the back yards to earn their living (Dietz *et al.*, 2000; Sertse *et al.*, 2011) hence, increasing the chances of contamination of the final products.

2.4.4 Filtration

Oil is filtered and quality is assured through maintenance of cleanliness and regular checks to ensure that the filter press is in good condition (Fig.1). Pre-coating, filtering and cleaning is done to help protect filter screen and improve flow rate (O'Brien, 2004; Fellows and Axtell, 2012). It was reported by Mpagalile *et al.* (2008) that many small scale oils processors do not have their own filters but depend on other processors or large scale. Filtering sunflower oil by gravity (Plate 2) through the use of clear fine piece of cloth was a method reported by Axtell and Noble (2002), although the process requires the processors to let the oil to stand and then filter.

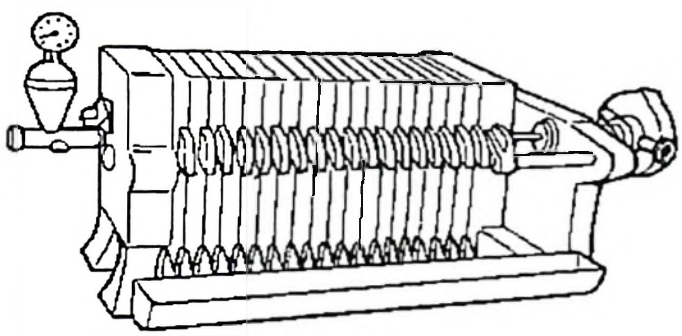

Figure 1: Typical filer press that use a pump
Source: Axtell and Noble (2002)

Plate 2: Alternative way of filtering in one of the processing facilities

2.4.5 Packaging

The majority of small scale sunflower oil processors use inadequate and unattractive packaging materials and packaging approach (Dietz *et al.*, 2000; Fellows and Axtell, 2012). Sunflower oil quality and stability is maintained by choosing suitable packaging (Kucku and Caner, 2005; Shafqatulla *et al.*, 2011). If incorrectly stored, oil rapidly goes rancid and develops an unpleasant odour and flavour. Factors that cause rancidity are moisture, bacteria and enzymes, light, heat, air and some types of metals including copper (Swetman, 2008). Other challenges that face small scale processors as indicated by Fellows and Axtell (2012) include improper sealing by hand where by the volume filled to the package rely on judgment by operators. The process also may introduce air that will accelerate oil oxidation. Since recycled bottles are used, there is no proper package inspection.

2.4.6 Labeling

'Label' is anything such as a tag, brand, mark, pictorial, or a descriptive matter, printed, written, stamped, perforated and impressed or attached to a container of any food packages (The Federation of Oil Seeds and Fats Association, 2011). Important information found on the label include: manufacture date, best before, batch number, ingredients, nutritional information and storage conditions. Many small scale sunflower oil processors do not label their products and since they are also unregistered this does not ensure consumers that the oil they eat is safe (Dietz *et al.*, 2000). Pre-packaged foods should be labeled as per FAO (1985).

2.4.7 Hygiene

Tanzania's food laws require that those who process any food should be registered by TFDA and should be given Certificate of Hygiene. Report by Dietz *et al.* (2000) indicated that many small scale food processors had registered to avoid harassment from the Ministry of Health and Social welfare. It is important that the processing buildings be well designed, constructed in a good location, routinely inspected to ensure that floors and walls possess no cracks as well as proper cleaning of equipment and processing areas or rooms, have good lightning and excellent ventilation (Fellows and Axtell, 2012). The building should be clean all the time although many personnel's prefer cleaning down at the end of day this is usually done in a rush and hence less effective (Fellows *et al.*, 1995). It is essential for personnel to be trained to keep the equipment clean throughout the day and waste removed as they accumulate. Personnel play a critical role in developing, implementing and maintaining sanitation process in a sunflower oil small scale mill (Warriner, 2011). It is important to involve them in developing sanitation programs.

2.4.8 Training of Personnel

Unavailability of technology, machines, maintenance and services was reported by Dietz *et al.* (2000) whereby, small scale processors were lacking institution or individuals to provide technical advice. Study by Mpagalile *et al.* (2008) indicated that about 60 % of sunflower oil processors have used new ideas and knowledge and there was more testing of the ideas among processors other than sunflower famers. Furthermore, the study indicated that only 15 % of employees were graduates and 20 % out of these reported to have training or skills needed by firm operations. Personnel without the necessary skills operate in small scale sunflower oil mills mainly due to the fact that oil pressing is laborious and involves many tedious or manual work which is unattractive to educated employees (Kipene *et al.*, 2013). However, some small scale sunflower mill owners are afraid of employing employees with skills and technology as they may demand high payment (Fellows and Axtell, 2012).

2.4.9 Quality Assurance and Legislation

With regard to quality assurance, Dietz *et al.* (2000) reported that small scale processors lack quality assurance system have inadequate storage facilities, lack of raw materials inspection, good hygiene practices and inefficient system of obtaining customer feedback. However, results by Mpagalile *et al.* (2008) indicated that some sunflower oil processors have built storage facilities, filter rooms and sanitary systems. They also reported to be unaware of International Standards (ISO) or Tanzania Bureau of Standards (TBS) specifications (Table 3) and those who were aware claimed the existence of bureaucracy in obtaining certification mark (Mpagalile *et al.*, 2008; Salisali, 2011). It was also indicated that small scale processors get inefficient support of the government as several activities of the sub sector are distributed in more than one ministry (Dietz *et al.*, 2000). However, study reported by Mpagalile *et al.* (2008) found the involvement of the government through support by Small Industries Development Organization (SIDO) training programmes.

Table 3: The recommended Physical and chemical properties of crude vegetable oil as per FAO /WHO and Tanzania Bureau of Standards

Moisture content (% m/m)	Specific gravity	Insoluble Impurities (% m/m)	Acid value %	Free fatty acid %	Peroxide value (mgKOH/g Oil)	Refractive index (at 25°C)	Iodine value (g/100g)
Codex Standards for the sunflower oil (CODEX-STAN 210 - 1999) FAO/WHO							
0.2	0.918-0.923	0.05	4	1.5	Up to 15	1.461-1.471	118-141
Tanzania Bureau of Standards (TBS) TZS 50: 2011							
0.2	0.918-0.923	0.05	5	2	10	1.464-1.480	188-194

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

This study was carried out in Morogoro region which consists of Morogoro urban, Morogoro rural, Kilombero, Ulanga, Mvomero and Kilosa districts.

3.1.1 Socio-economic Activities in Morogoro Region

The region is dominated by Agriculture and related activities such as small scale farming, cattle keeping, plantation and estates. The growth of capital in rural and urban areas has led to the emergence of activities such as manufacturing (e.g. sunflower oil processing, carpentry and welding). Other activities include; traditional fishing, mining (at Ulanga and Matombo) and provision of services- offices, hotels and petty trading (Morogoro Regional Commissioner's office, 1997).

3.2 Study Design

Morogoro region small scale sunflower oil processors (Appendix 3) were selected for this study which involves a survey and laboratory work. Structured questionnaire was used for the former part and laboratory analysis for the later part. Oil attributes were analytically tested and characteristics of processors observed to determine the product quality. Simple random sampling was used in sampling of the oil products from processors whereby individual batches produced had equal chances of being selected. Filled questionnaires were collected by the researcher at the end of visit ready for analysis. The region has a population of 2.22 million people (National Bureau of Statistics, 2012). Districts that were involved in this study included: Morogoro urban, Morogoro rural, Mvomero, Kilosa and Gairo.

3.2.1 Data Collection by the Survey Method

A survey was carried out by interviewing small scale sunflower oil processors using structured questionnaire with open and closed ended questions (Appendix 4). The questions sought to obtain information on Good Manufacturing Practices, Good Hygienic Practices, registration status and storage facilities. Data obtained from structured questionnaires was supplemented by factory observations and discussion with the management. Samples of oil were collected from the small scale processors for laboratory study.

3.2.2 Analysis of Survey Data

Data on survey obtained by use of structured questionnaires was statistically analyzed by SPSS statistical package (SPSS 16.0). Frequencies and percentages for variables were subjected to cross tabulation. χ^2 values were computed to determine association between categorical data at $p \leq 0.05$.

3.3.1 Oil Sampling Procedure for Physicochemical Quality Evaluation

Samples of sunflower oil were randomly selected from eighteen small scale processors in Morogoro region. According to SIDO Morogoro region there are twenty two Sunflower oil processors in the region whom they communicate to and provide advice. The study involved eighteen small scale sunflower oil processors who were actively operating. Sampling process was effected after filtration and oil settling ready for packaging. From each processor two batches were sampled. Selected samples were analyzed in the laboratory for physical parameter and chemical analysis. Samples were taken early August from small scale processors and started laboratory analysis in September, 2013.

3.3.2 Oil Sampling Procedure and Sample Size Determination

Sample size was determined by using the international standards guidelines for sunflower oil analysis. The guidelines stipulate that sampling from a lot or sub lot with packages $\leq$ 25 at least 1 package or unit is drawn.

If a lot or sub lot contain >25 and ≤ 100 packages 5 % or at least 2 packages is drawn and > 100 at maximum 10 packages or units should be drawn. For volumes < 50 liters minimum sample drawn should be 3 liters, ≥ 50 and ≤ 500 liters minimum sample drawn should be 5 liters (FEDOIL, 2008). During sampling of edible Sunflower oil, asceptic sampling was maintained; samples were kept in clean and sterile opaque containers. The drawn oil samples from each lot (plastic barrel of oil) were mixed thoroughly before sampling by shaking and then packed in 500 ml sampling containers that were light proofed by covering each with aluminium foil and tight fitted screw caps to prevent air ingress. The samples were refrigerated until required for physicochemical analysis as per FAO (1999) described hereunder. During analysis either International Standards (ISO) or IUPAC methods were adopted as indicated in sections 3.3.4 and 3.3.5 including their respective subsections. All analysis was done at the Government Chemistry Laboratory Agency (GCLA) in Dar es Salaam Tanzania.

3.3.3 Sample Preparation

All samples were brought to room temperature before analysis. Clean disposable spoon were used for drawing samples for analysis.

3.3.4 Physical Analysis

3.3.4.1 Moisture content

Moisture content was determined by oven drying method at 105°C in accordance with procedure stipulated by ISO 662: 1998. The dried cool metal dishes in desiccators were weighed and its weight recorded as W_1. A sample of 5 g of the sunflower oil was measured in a previously dried cooled metal dish and its weight recorded as W_2. The samples were dried in an oven at 105 °C for 1 hour. Dried samples were cooled in desiccators and weight measurement upon cooling was recorded as W_3. The test for each sample was carried in duplicate.

$$\% \text{ moisture content } (m/m) = \frac{W3-W2}{W2-W1} \times 100 \quad \text{.....(1)}$$

Where, W1= the weight of empty dry metal dish

W2= the weight of sample and dish before drying

W3= the weight of dried sample and dish

3.3.4.2 Refractive index

The refractive index of Sunflower oil samples was determined at 20 °C using an Abbe refractometer as per IUPAC 2.102. Prior to measurement, the instrument was calibrated using distilled water at the specified temperature. A drop of oil sample was placed on the prism and tightly closed with another prism followed by adjusting of the instrument lighting to obtain the distinctive reading for refractive index. All refractive index readings at temperature (T1) other than 20 °C were corrected by using the formula:

R=R1+K (T1-T) ....(2)

Where R= reading of the refractometer reduced to the specified temperature

T (20 °C)

R1= reading at T1 and K= Constant for oil (Abbe Refractometer used)

0.000385 (Food and Safety Standards Authority of India, 2012)

3.3.4.3 Specific gravity

The Specific gravity was measured by gravimetric procedures using a 10 ml pycnometer as per International Union of Pure and Applied Chemistry (IUPAC) 2.101. The empty pycnometer (density bottle) was first measured and its weight (W_1) recorded. Then the same pycnometer was filled with distilled water at 20 °C weight measured and recorded as

W_2. The same pycnometer was filled with oil and had its weight (W_3) recorded under the same temperature conditions.

$$\text{Density of distilled water} = \frac{\text{weight of distilled water (W2} - \text{W1)}}{\text{Volume of distilled water used (10 ml)}} \quad ....(3)$$

$$\text{Density of oil samples} = \frac{\text{weight of oil (W3} - \text{W1)}}{\text{Volume of oil used (10 ml)}} \quad ....(4)$$

Where, W1= weight of empty pycnometer

W2= weight of pycnometer and distilled water

W3= weight of pycnometer and oil

$$\text{Specific gravity (relative density)} = \frac{\text{density of oil}}{\text{density of distilled water}} \quad ....(5)$$

3.3.4.4 Oil Colour

Colour was analyzed by physical visualization method as indicated by Alander *et al.* (2013).

3.3.4.5 Insoluble impurities

Insoluble impurities were measured by gravimetric method as per ISO 663: 1999. Whatman filter papers No.1 were dried in an oven set at 105°C for 1hour then cooled in desiccators. Their individual weights measured and recorded as (W1). Exactly 20 g of sample were weighed (W2) and dissolved in 40/60 petroleum ether and then filtered through the pre weighed Whatman filter paper and followed by drying at 105°C for 1 hour to attain constant weight. Dry filter paper with insoluble impurities was weighed as W3 and recorded. Insoluble impurities were calculated using the following expression.

$$\text{Insoluble impurities (m/m)} = \frac{\text{W3} - \text{W1}}{\text{W2}} \text{X 100} \quad ....(6)$$

Where, W1 = Empty dry Whatman filter paper

W2 = weight of sample dissolved

W3 = dry Whatman filter paper and impurities

3.3.5 Chemical Analysis

3.3.5.1 Acid value

Acid value was measured by titrimetric procedure as per ISO 660: 1996. Exactly 1g of sample was placed in a 250 ml conical flask and dissolved in 50 ml of neutral diethyl ether- ethanol (95 % ethanol) in a 1:1 ratio. The oil solution was titrated against 0.1N NaOH in the presence of phenolphthalein (POP) indicator. The endpoint was realized when a faint pink colour was observed against a white background created by use of white paper. The 0.1 N NaOH titre volumes were recorded. Acid value was calculated as follows:

$$\text{Acid value} = \frac{V \times 5.61 \times N}{W} \quad \text{.......... (7)}$$

Where, V= titre of 0.1 NaOH in mls

N= normality of NaOH= 0.1 N

W= sample weight in gram

3.3.5.2 Free fatty acid

Free fatty acid was analyzed according to procedure as per IUPAC 2.201. Exactly 1 g of oil sample was placed in a 250 ml conical flask and mixed well with 50ml of diethyl ether. The mixture was dropwise titrated against 0.1N potassium hydroxide in the presence of phenolphthalein indicator. The titre volume was recorded when a pink colour appeared.

$$\text{Free fatty acid was expressed as \% oleic acid} = \frac{28.2 \times V \times N}{W} \quad \text{.......... (8)}$$

Where, V= titre volume of 0.1N KOH

N= concentration of 0.1N KOH

W= weight in g of the sample

3.3.5.3 Peroxide value

Peroxide value was determined by titrimetric procedure as per ISO 3961: 1998 and results expressed as milliequivalents of peroxide per Kg of sample (meq/kg). Exactly 1.0 g of the sunflower oil sample was transferred into a 250 ml erlenmeyer flask followed by addition of 50 mls of glacial acetic acid/Iso-octane solutions in a 3:2 ratio. The mixture was gently swirled and 0.5 ml of freshly prepared saturated potassium iodide solution added and the mixture was allowed to stand in a dark room for 1 minute. This was followed by addition of 30 ml of distilled water by rinsing the ground glass stopper and gentle swirling. The liberated iodine was titrated against 0.1 N sodium thiosulphate standard solutions with vigorous shaking until the yellow colour disappeared. Then 0.5 % of soluble Starch indicator was added the mixture changed to violet. Endpoint was determined following titration when the colour of the mixture changed from violet to colourless. The volume of titrated 0.1 N sodium thiosulphate was recorded. Test samples were analyzed concurrently with a blank. Peroxide value was computed using the following expression:

$$\text{Peroxide value}\left(\frac{meq}{kg}\right) = \frac{(V - Vo)\,C}{m} X\,100 \qquad (9)$$

Where, m= mass in g of the test portion

V= volume in mls of 0. 1N sodium thiosulphate solution used for test portion

Vo= volume in mls of 0. 1N sodium thiosulphate solution used for blank

C= concentration of the sodium thiosulphate = 0.1N

Where, V= titre volume of 0.1N KOH

N= concentration of 0.1N KOH

W= weight in g of the sample

3.3.5.3 Peroxide value

Peroxide value was determined by titrimetric procedure as per ISO 3961: 1998 and results expressed as milliequivalents of peroxide per Kg of sample (meq/kg). Exactly 1.0 g of the sunflower oil sample was transferred into a 250 ml erlenmeyer flask followed by addition of 50 mls of glacial acetic acid/Iso-octane solutions in a 3:2 ratio. The mixture was gently swirled and 0.5 ml of freshly prepared saturated potassium iodide solution added and the mixture was allowed to stand in a dark room for 1 minute. This was followed by addition of 30 ml of distilled water by rinsing the ground glass stopper and gentle swirling. The liberated iodine was titrated against 0.1 N sodium thiosulphate standard solutions with vigorous shaking until the yellow colour disappeared. Then 0.5 % of soluble Starch indicator was added the mixture changed to violet. Endpoint was determined following titration when the colour of the mixture changed from violet to colourless. The volume of titrated 0.1 N sodium thiosulphate was recorded. Test samples were analyzed concurrently with a blank. Peroxide value was computed using the following expression:

$$\text{Peroxide value}\left(\frac{\text{meq}}{\text{kg}}\right) = \frac{(V - Vo)\,C}{m} X\,100 \quad \ldots\ldots (9)$$

Where, m= mass in g of the test portion

V= volume in mls of 0. 1N sodium thiosulphate solution used for test portion

Vo= volume in mls of 0. 1N sodium thiosulphate solution used for blank

C= concentration of the sodium thiosulphate = 0.1N

3.3.5.4 Iodine value

Iodine value was determined by titrimetric procedure described by Wijis method ISO 3961:1996. The oil sample in cyclohexane was treated with a known excess Iodine monochloride solution in glacial acetic acid solution. The excess Iodine monochloride was treated with potassium iodide and the liberated iodine estimated by titration with sodium thiosulphate. Exactly 0.32g of the sunflower oil was transferred into a 500 ml glass stoppered flask followed by addition of 25 ml solution of a mixture of cyclohexane and glacial acetic acid in (a ratio of 1:1). The content was well mixed followed by addition of exactly 25 ml of Wijis reagent (Wijis reagent a mixture of 10 ml iodine monochloride in 1800 ml glacial acetic acid) gently swirled and left in dark for 1 hour. After standing in a dark room for one hour, 20 ml of potassium iodide was added then the content was mixed with 100 ml of distilled water by stopper rinsing. The liberated iodine was titrated against standard 0.1 M sodium thiosulphate until the yellow colour become pale. Addition of 3 drops of starch solution to the content was done and colour changed to blue. Titration was continued until the blue colour changed to colourless. The volume of sodium thiosulphate titre was recorded. This was done concurrently with blank.

$$\text{Iodine number} = \frac{12.69\, C\, (V1 - V2)}{M} \quad \text{...} (10)$$

Where, V1= Volume in ml of sodium thiosulphate solution used for blank test

V2= Volume in ml of sodium thiosulphate solution used for the test portion

C= concentration of sodium thiosulphate solution in moles per liter (0.1 M)

M= weight (g) of the portion sample used for analysis.

3.4.2 Analysis of Data from Laboratory Experiments

Data obtained from laboratory analysis for each variable was subjected to two way analysis of variance using Gen Stat statistical package to determine if there was significant difference in the physical- chemical properties of sunflower oil from various processors. Difference between means was tested by Duncan's Multiple Range Test at $P < 0.05$. Significant means for quality attributes between the processors were compared by national and international oil standards with a view of ascertaining compliance with respect to quality attributes.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Characterizations of Small Scale Sunflower oil Processors in Morogoro

The study has revealed that there are two categories of small scale sunflower oil processors in Morogoro region (Table 4). Those who are able to purchase oilseeds from farmers in bulk and their operations are commercial. The second category comprise of few small scale processors who are unable to purchase oilseeds in bulk. According to the investigation, processors annual production had no influence on registration. All processors use expeller machines to press sunflower seeds.

The processors, who are incapable of having bulk seeds of their own, offer oilseeds pressing services to the rural famers and few in urban to obtain oil for domestic use. A fee of 150/= Tanzanian shillings is charged a reduced fee when seed cake is left to the owner of the expeller machine. Although it have been indicated that undergoing medical checkup had no significant ($p > 0.05$) effect on registration the majority of the processors (89 %) are unregistered and do not undergo regular medical checkup (Table 5). For example, 50 % of processors who were not registered did not undergo medical checkups and thereby leaving 44 % of the unregistered processors who undergo medical checkups.

This scenario contradicts the food law that requires processors to undergo medical checkup before registration and do it on routine basis after registration. Compliance failures are probably attributed to avoiding harassment from health officers during inspection as reported earlier by Dietz *et al.* (2000). For example, 18 small scale sunflower oil processors in this study failed to show evidence of being inspected by the Municipal or District health officers. Despite of the situations explained; undergoing medical checkups had no influence ($p > 0.05$) on registration of small scale sunflower oil processors in Morogoro Region.

Table 4: Relationship between processors annual production and being registered

Annual production Litres	Registered n	Registered %	Unregistered n	Unregistered %	Total n	Total %
300	1	5.55	0	0.00	1	5.55
870	0	0.00	1	5.55	1	5.55
4160	0	0.00	1	5.55	1	5.55
5200	0	0.00	1	5.55	1	5.55
6200	0	0.00	1	5.55	1	5.55
6400	0	0.00	1	5.55	1	5.55
10400	0	0.00	2	11.10	2	11.10
12000	0	0.00	2	11.10	2	11.10
30000	0	0.00	1	5.55	1	5.55
46900	0	0.00	1	5.55	1	5.55
60000	0	0.00	1	5.55	1	5.55
105000	0	0.00	1	5.55	1	5.55
130000	0	0.00	1	5.55	1	5.55
186000	1	5.55	0	0.00	1	5.55
190000	0	0.00	1	5.55	1	5.55
200000	0	0.00	1	5.55	1	5.55
Total	2	11.10	16	88.80	18	99.9≈ 100

$\chi^2_{0.05\,(d.f=15)} = 18.0^{n.s}$

n= number of processors

Table 5: Relationship between being registered and undergoing medical check up

Registered	Undergoing medical checkup					
	Yes		No		Total	
	n	%	n	%	n	%
Registered	2	11.1	0	0	2	11.1
Not registered	7	38.9	9	50	16	88.9
Total	9	50	9	50	18	100

$\chi^2_{0.05\,(d.f = 1)} = 2.26^{n.s}$

n= number of processors

4.2 The Extent of Training and Access to Services from the Government

The results of the present study has shown that 72 % of small scale sunflower oil processors in Morogoro received no training to impart skills necessary for processing operations (Table 6). According to this observation availability of relevant training on Good Manufacturing Practices had a significant effect ($p < 0.05$) on urging small scale sunflower oil processors to undergo training.

Processors claimed that there has been little government involvement in the sector's development. In a previous study by Dietz *et al.* (2000), "inter- ministerial involvement" has been the cause for decline in efficiency. Mpagalile *et al.* (2008) reported similar discrepancy whereby government is only concerned with financial matters and not operational matters that affect product quality. Hence, food quality issues by all stakeholders and particularly the government have not been given appropriate attention. For example, all processors in the study, none was aware of the concept and principles for Hazard Analysis Critical Control Points (HACCP) in a food processing facility. For those who have attended training, only 28 % practiced Good Manufacturing Practice (GMP) which is a set of regulations, codes and guidelines for processing safe and quality food by manufacturers. Good Manufacturing Practice include: buildings, equipment and utilities as "means for good operation." In this study it has been noted that buildings are located in residential areas, poorly designed for Good Hygiene Practices and yet having walls and floors with cracks. Similar observations have been reported by Fellows and Axtell (2012).

Table 6: Relationship between being trained and types of courses attended

Are you trained	Type of course trained					
	GMP		No course attended		Total	
	n	%	n	%	n	%
Yes	5	27.8	0	0	5	27.8
No	0	0	13	72.2	13	72.2
Total	5	27.8	13	72.2	18	100

$\chi^2_{0.05\,(d.f=1)} = 18.0^{**}$

n= number of processors

Secondly high quality raw materials, trained experienced skilled workers and standard operating procedures in accordance with Good Manufacturing Practices are the basic requirements. All processors were having no efficient documentation system and this hampers traceability of Good Manufacturing Practices. For example, no record was observed in any premises showing routine inspection by the Tanzania Food and Drugs Authority. Different responses were given on the cleaning schedule of the premises as summarized in Table 6 and only 39 % of the premises have installed running water for cleaning operations. Hence, presence or absence of installed running water has no significant ($p > 0.05$) influence on cleaning schedule.

It was also noted that 28 % of processors do not use any cleaning aids to remove soils from surfaces (Table 8). Results in this study revealed that type of cleaning aid was significantly ($p < 0.05$) influenced by its nature. Furthermore, the personnel who manage these food enterprises do so without the required skills and knowledge.

Table 7: Relationship between cleaning schedule and presence of installed running water

Cleaning schedule	Presence of installed running water					
	Yes		No		Total	
	n	%	n	%	n	%
Daily	5	27.8	10	55.6	15	83.3
Once a week	1	5.6	0	0	1	5.6
Monthly plan	2	11.1	0	0	2	11.1
Total	8	44.5	10	55.6	18	100

$\chi^2_{0.05\,(d.f=2)} = 4.7^{n.s}$

n= number of processors

Table 8: Relationship between type of cleaning aids and its nature

Type of cleaning aids	Nature of the cleaning aids					
	Alkaline		Neutral solution		Total	
	n	%	n	%	%	%
Detergents	1	5.6	0	0	1	5.6
Liquid soap	7	38.8	0	0	7	38.8
use of hot water& soap	2	11.1	0	0	2	11.1
Caustic soda	3	16.7	0	0	3	16.7
Use water only	0	0	5	27.8	5	27.8
Total	13	72.2	5	27.8	18	100

$\chi^2_{0.05\,(d.f=4)} = 18.03^{**}$

n= number of processors

The study showed that 50 % of those who plan the cleaning schedule are supervisors, 33 % of them are primary and secondary school leavers with no profession and experiences (Table 9). According to the observations, individuals' profession in small scale sunflower oil processors had no significant ($p < 0.05$) influence on planning the cleaning schedule. On the other hand this may be a challenge as to why graduates are not found in these small scale processors despite the reasons given by them that graduates lack practical skills (Mpagalile *et al.*, 2008). Subsequent studies by Fellows and Axtell (2012) revealed that, skilled personnel demand relatively high remuneration impending fear for such trained personnel quitting jobs and reemployed by potential competitors. Hence, small scale food processors are scared of hiring trained personnel.

According to this study, it is envisaged that consumers' awareness on food quality may indirectly promote or stimulate small scale processors to initiate training. It is also possible for processors who are aware of food quality to launch such trainings. For example, it was observed that processors at Kipera- Mlali village in Mvomero district had more access to training on sanitation and Good Manufacturing Practices not withstand being in a rural setting since the form of ownership is cooperative. On the contrary small scale owners in urban area are not trained. The former category of processors was advantaged by being a cooperative movement *vis a vis* the latter group whose operations are private ownership. Lack of monitoring and control by the food regulatory authority could contribute to untrained personnel since training and having skilled personnel in a food processing is mandatory. However, the results of this study have shown that type of courses trained have an influence on attending the training (Table 6).

Table 9: Relationship between professionals and planners of the cleaning schedule

Professionals	Planers of the cleaning schedule							
	Manager		Supervisor(s)		Operators		Total	
	n	%	n	%	n	%	n	%
No professionals	1	5.6	6	33.3	3	16.7	10	55.6
Technical colleges	1	5.6	0	0	0	0	1	5.6
business person	0	0	3	16.7	2	11.1	5	27.8
Retired Teachers	1	5.5	0	0	1	5.6	2	11.1
Total	3	16.7	9	50	6	33.3	18	100

$\chi^2_{0.05}$(d.f =6) = 8.17 ^{ns}
n= number of processors

4.3 Packaging

It was found that all processors use plastic containers as packages, whereby 94 % buy industrial packages while 6 % use recycled packages from larger scale processors (Fig. 2). Observations in the present study suggest that there is improvement compared to the former findings by Dietz *et al.* (2000). The most preferred size of package by processors was the 5 liters containers and this capacity was preferred by 89 % of the respondents. The smallest package size used was 10 liters. The results of this study showed that 11 % of processors were using these containers (Fig. 3). Lack of packaging containers for storing oils before and after filtration was observed among many processors. Plastic barrels and few drums used were not of food grade (Plates 3 and 4). These observations contradict suggestions made by Kucku and Caner (2005); Shafqatulla *et al.* (2011) that quality oil and its stability depend on suitable selection of the packages and packing materials. In rural areas where owners of expeller machine offer services of pressing oilseeds, they do not have packaging containers instead their clients are responsible for bringing oil storage containers which are difficult to monitor their cleanness and hygiene. Majority of these processors continued using manual sealing; owners need to find alternative sealing methods which minimize contamination. Furthermore, 72 % of processors packages were not labeled (Table 10). Similar findings have been reported earlier (Practical Action, 2009; Fellows and Axtell, 2012). Although some processors claimed that labels are expensive, they however admitted the importance of labeling as proper means for products identification and safety. Product labeling practice was significantly ($p < 0.05$) influenced by available styles notably incorporation of a bar code which is definitely an expensive style for adoption.

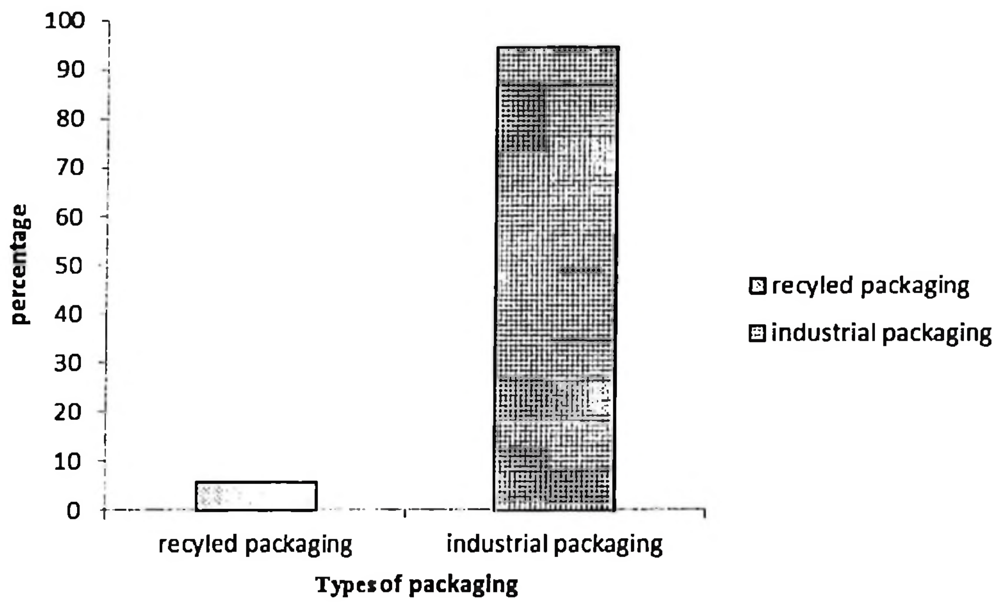

Figure 2: Types of packaging used by Morogoro small scale sunflower oil processors

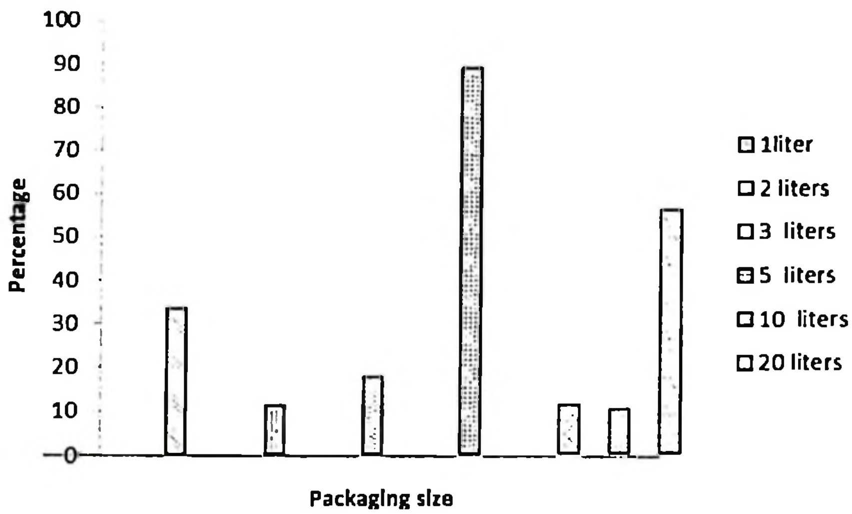

Figure 3: Size of packaging used by Morogoro small scale sunflower oil processors

Table 10: Labeling and the type of labels used by small scale processors

Labeling	Type of labeling					
	With bar code		Without labeling		Total	
	n	%	n	%	n	%
Yes	3	16.7	1	5.6	4	22.2
No	2	11.1	12	66.7	14	77.8
Total	5	27.8	13	72.2	18	100

$\chi^2_{0.05(d.f=1)} = 5.72$**

n= number of processors

4.4 Physical Properties of Sunflower Oil from Small Scale Processors

The mean values for sunflower oil physical properties are summarized in Table 11. The means for these properties encompass samples selected from 18 small scale oil processors as discussed hereunder.

4.4.1 Moisture content

The mean moisture content for the sunflower oil indicated in Table 11 show insignificant difference ($P > 0.05$) among processors. The moisture content range was 0.020 % as minimum and 0.145 % as maximum which are within the FAO/WHO (1999) and Tanzania Bureau of Standards (2011) allowable limits (Table 3), although there is no value stated for unrefined sunflower oil by either of these two regulatory authorities. In previous studies by Ngassapa and Othman (2001); Abdellah and Ishag (2012) variation in moisture content for stored sunflower oils were reported. If the moisture content is not controlled as recommended by Practical Action (2000) hydrolysis of oils tend to be accelerated.

4.4.2 Specific gravity

The results of this study have shown that specific gravity of sunflower oil ranged from 0.920 to 0.927 (Table 11). These values fall within the FAO/WHO (1999) and Tanzania Bureau of Standards (2011) (Table 3). Specific gravity for unrefined sunflower oils has no value specified by the Tanzania Bureau of Standard.

4.4.3 Insoluble Impurities

Presence of insoluble impurities in food affects the product appearance and consumers acceptability. Neither the FAO/WHO nor Tanzania Bureau of Standard has documented specifications for insoluble impurities for unrefined sunflower oil. In this study however, it has been shown that the insoluble impurities ranged from 0.163 % to 1.715 %. The amount obtained is far above the FAO/WHO (1999) as well as the level stipulated by the Tanzania Bureau of Standards (2011) for refined sunflower oil which is 0.05 %.

Presence of insoluble impurities in sunflower oil may be due to failure to use filter press. According to Mpagalile *et al.* (2008) many processors did not have filter press so as to improve oil quality. Although many of processors in this study were having filter press, they were not being used due to relatively high cost for maintenance and services. Hence, pieces of clothes and plastic sieves found in use as substitutes for filtration by small scale sunflower oil processors were similar to observations reported by Axtell and Noble (2002). The observed poor hygiene practices and bad manufacturing practices (Plate 3) among processors may also contribute to the presence of insoluble impurities in oil.

Table 11: Physical properties of unrefined sunflower oil from small scale processors in Morogoro region

Processor(s)	Moisture % (m/m)	Specific gravity	Insoluble impurities % (m/m)	Refractive Index at 20°C
1	0.049	0.924	0.479	1.473
2	0.043	0.924	1.233	1.473
3	0.05	0.921	0.504	1.473
4	0.023	0.922	0.559	1.472
5	0.043	0.925	0.581	1.473
6	0.06	0.923	0.794	1.472
7	0.02	0.926	0.679	1.473
8	0.048	0.925	0.426	1.472
9	0.029	0.921	0.386	1.472
10	0.043	0.922	0.417	1.472
11	0.087	0.924	0.328	1.472
12	0.026	0.927	0.743	1.473
13	0.145	0.922	0.369	1.472
14	0.1	0.92	0.222	1.472
15	0.091	0.927	1.715	1.472
16	0.072	0.922	0.189	1.473
17	0.066	0.922	0.163	1.473
18	0.112	0.922	0.408	1.473
Std. Error	±0.016	±0.001	±0.128	±0.0002

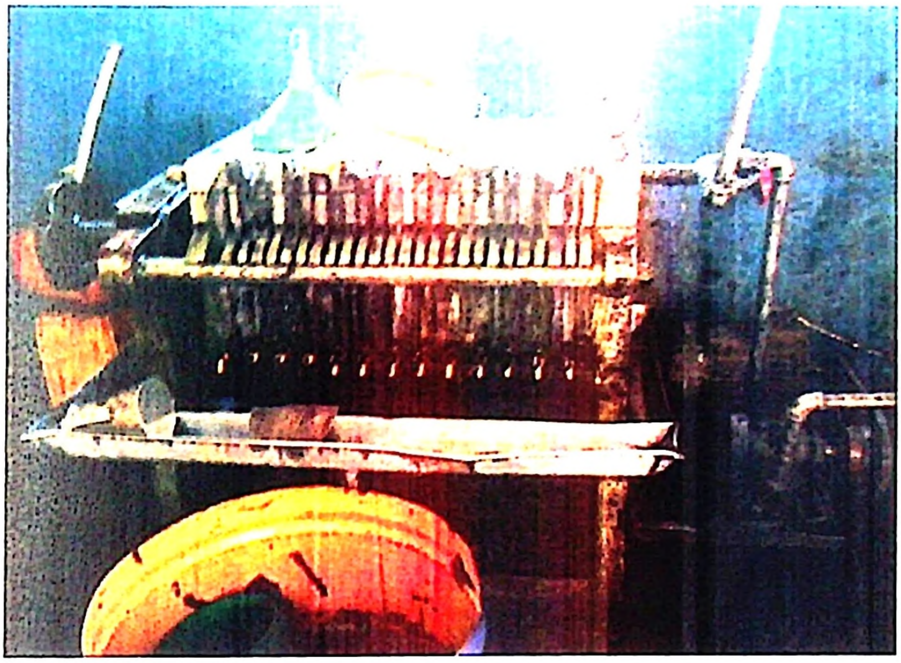

Plate 3: Filter press, use of plastic sieves and drums in one of the processors

For example, it was observed that some processors store raw materials, finished products and packaging materials in the same store and thereby increasing the possibility for cross contamination. Before packaging the oil into retail containers there are chances of dust contamination from unprocessed oilseeds packed in sacks. Furthermore, the majority of the processors do not clean seeds prior to pressing for oil. Although one processor had a blower that reduces chaffs and dust from the oil seeds, it was wrongly located at the entrance of the processing plant that allows dust flow in to the processing plant and thereby contaminating the oil. Nevertheless, the recorded impurities in sunflower oil from Morogoro small scale processors is far better by being lower than the impurities reported by Dimic *et al.* (2012) of up to 10 % in processed oil.

4.4.4 Refractive index

The mean refractive indices for oil from small scale processors more or less ranged from 1.472 to 1.473. These observations suggest that similar variety of sunflower oil had the same refractive index and hence, concurs with the idea of identifying oil by use of refractive index (Ngasapa *et al.*, 2012). The tolerable refractive index ranges by FAO/WHO (1999) as well as Tanzania Bureau of Standards (2011) are 1.461-1.471 and 1.464-1.480 respectively.

4.5 Chemical Properties of Sunflower oil from Small Scale Processors

4.5.1 Acid value

The mean sunflower oil acid values ranged from 0.065 mg KOH/g Oil to 0.194 mg KOH/g Oil (Table 12). The values are within both FAO/WHO (1999) and Tanzania Bureau of Standards (2011) specifications that is 4 mg KOH/g oil and 5 mg KOH/g oil respectively. This suggests that after oilseed pressing, settling and filtering the acidity development in sunflower oil was relatively low. Similar value of 0.11 mg KOH/g was reported in studies by Othman and Ngassapa (2010). Even though, a moderate high acidity value of 0.6 mg KOH/g was reported by Abdellah *et al.* (2012) in a later study, it is suggestive to the idea that there is low deterioration by acidity in processed oil.

4.5.2 Free fatty acid

The mean values of free fatty acid in sunflower oil ranged from 0.131 % to 0.387 % (Table 12). The values conform to the FAO/WHO and Tanzania Bureau of Standards tolerance levels. Previous studies by Ngassapa and Othman (2001); Abdellah and Ishag, (2012) showed that free fatty acid is the result of enzymatic hydrolysis mediated by lipases. The values obtained in this study promises quality product if temperature is properly controlled by processors during storage.

Table 12: Chemical properties of unrefined sunflower oil from small scale processors in Morogoro region

Processor(s)	Acid value (%)	Free fatty acid (%)	Peroxide value (meq/kg)	Iodine Value
1	0.194	0.387	15.748	127.657
2	0.147	0.294	8.973	126.944
3	0.113	0.226	5.677	125.33
4	0.123	0.246	11.376	130.812
5	0.082	0.163	6.429	128.238
6	0.132	0.264	7.889	133.371
7	0.081	0.162	10.012	127.687
8	0.104	0.208	4.123	129.243
9	0.138	0.275	15.447	132.675
10	0.15	0.299	13.071	138.9
11	0.109	0.218	9.726	130.242
12	0.132	0.264	16.597	136.589
13	0.109	0.218	8.945	131.05
14	0.183	0.366	3.472	132.851
15	0.111	0.223	13.851	129.25
16	0.065	0.131	6.798	129.995
17	0.139	0.278	6.649	129.681
18	0.138	0.275	13.943	129.892
Std.error	±0.014	±0.028	±1.714	±0.598

4.5.3 Peroxide value

Peroxide values of unrefined oil from small scale sunflower oil processors ranged from 3.472 to 16.597 (meq/kg) (Table 12). Only 16.7 % of processors in this study has peroxide values slightly above the FAO/WHO upper limit of 15 (meq/kg) although the Tanzania Bureau of Standards placed no specification value for Peroxide values of unrefined sunflower oil. Contrast to these findings studies by Ngassapa *et al.* (2010); Abdellah *et al.* (2012) indicated high level of peroxide values 19 (meq/kg) than the FAO/WHO (Table 3). The contributing factors affecting oxidative stability being elevated temperature as well as storage conditions. Previous report by Gornas *et al.* (2006) indicated that high peroxide values in sunflower oil reduce tocopherol levels. Subsequent studies by Foster *et al.* (2009); Othman and Ngasapa (2010) revealed the presence of tocopherol as a natural antioxidant in sunflower oil that increases its shelf life.

It was reported by Akhtar *et al.* (2012) that sunflower oil with no antioxidant spoil much more easily during storage. The variation among processors in this study was insignificant ($P < 0.05$). The observed increase in peroxide value may be due to handling and production practices by small scale processors. During seed pressing the crude oil is collected in open plastic dishes with much aeration, the oil is then filtered and placed in open plastic barrels which continue to support aeration. When oil is packed in a package it is displayed on roadside or outside the processing buildings for buyers to see, the practices that accelerate oxidation. Similar observations on marketing methods of these products have been reported by Dietz *et al.* (2000); Budryn *et al.* (2011) who observed that the practices accelerate oil quality deterioration. This suggests lack of good marketing system, unwillingness of processors in changing the way of marketing their products and/ or insufficient government support to the oil processing sector.

4.5.4 Iodine value

The iodine number for sunflower oil ranged from 125.3 to 138.9 (Table 12). The values are within the FOA/WHO limits of (118-141) and Tanzania Bureau of Standards limits of (188-194) specifications. There was a significant difference ($P < 0.05$) among processors (Appendix 1) with respect to the mean iodine values for oil. These means were significantly different at $P< 0.05$ following separation by Duncan's Multiple Range Test. (Appendix 2)

Iodine number measures the level of unstauration of fatty acids, the higher the number the greater the degree of unsaturation (Carman, 2007; Babalola and Apata, 2011). Study by Kulp (2000) indicated the effect of climate on iodine values. Sunflower seeds grown in a cool region are of higher iodine value than that in drought area. For example, Ali *et al.* (2009) reported that sunflower from drought stricken regions contain high level of unsaponifiable matter with decreasing iodine values. An iodine value on itself does not determine stability of the oil but rather indicate the type of fatty acids and its inherent stability (Gunstone, 2011).

Plate 4: Use of open plastic barrels (some not food grade) is a common practice among small scale processors before packaging

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Small scale sunflower oil processors in Morogoro region fall in two categories namely large and small scale oil seed transactions. Whereas those in urban areas within the first category, their operations are highly commercialized and seeds are purchased in bulk, the second category are those in the rural areas who also provide oil pressing services to consumers at a negotiable price. As many processors do not undergo medical checkups and are unregistered, it renders them invisible to the TFDA. Quality adherence was also hampered by lack of relevant training on oil processing operations as observed in this study.

Despite failures in the general quality conformity, it was interesting to note that there was an improved packaging practice whereby most processors pack oil in industrial plastic packages. The small scale sunflower oil processers also deserve credit for having packaged oil conforming to the physico-chemical standards set by TBS and ISO under the umbrella of the FAO/WHO. Although there were some processors whose products had elevated insoluble impurities, this may be due to failure to use filter press and lack of skilled personnel. Peroxide value was also noted as being slightly higher in oil samples from some processors suggesting that temperature elevation and exposure to sunlight were probable the causative factors. Some processors were lacking food grade barrels for oil storage and thus preempting risks for auto degradation before packaging.

5.2 Recommendations

As the registration status among small scale sunflower oil is at a rudimentary stage, there is need to remind the regulatory bodies like the TFDA and TBS to initiate alternative means for inducing quality assurance. These approaches may include use of affordable media notably radio, newspapers and posters. During national events and /or commemorations, aspects on quality assurance should be highlighted and learnt since willingness to learn and change is lacking among some processors. It is through such efforts that knowledge as well as skills may be imparted. In addition to these voluntary approaches, visits on the processing facilities ought to be encouraged with a view of either 'on the spot' training or regulation enforcement. Enforcement ought to include penalties and even forced closure in conformity with prevailing statutory codes of practice.

Understandably, small scale processors have a culture of independence and tendency to push back on regulations. Despite the already constrained availability of access to direct government involvement in assisting processors, actions by the regulatory bodies are indeed an indirect government involvement. Such involvement need to be augmented with access to loans at reasonable interest rates so that facilities like oil clarifiers and allied quality enhancement can be acquired. Processing and packaging facilities are intertwined. Much as there is an existing practice of using sub-standard packaging materials and especially those used for oil storage notably plastic barrels, access to renewed infrastructure and training will guarantee improved processed sunflower oil that will meet rural and urban demand at reasonable price. Further research is needed to assess and improve current processing, storage practices, as well as quality monitoring. Such research ought to focus on premises hygiene and all GMP. The forecasted impact will be an improved marketing, distribution and consumer protection.

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APPENDICES

Appendix 1: Analysis of variance for physicochemical properties of sunflower oil

Variable : Moisture content

Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0	0	0.01	0.9089
processor	17	0.04	0.002	0.97	0.5275
Error	17	0.04	0.002		
Non additivity	1	0.1	0.009	4.52	0.0493
Residue	16	0.03	0.002		
Total	**35**	**0.08**			

Variable : Specific gravity

Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0.00	0.00	0.08	0.7842
processor	17	0. 00012	0.000006	2.04	0.0755
Error	17	0.000085	0.000005		
Non additivity	1	0.00	0	0	
Residue	16	0.00	0		
Total	35	0. 0002			

Variable : Insoluble Impurities

Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0.14	0.143	2.63	0.1235
processor	17	4.98	0.293	5.39	0.0006
Error	17	0.92	0.054		
Non additivity	1	0.06	0.055	1.02	0.3284
Residue	16	0.87	0.054		
Total	35	6.05			

Variable : Refractive index					
Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0.00	0.000	0.23	0.6344
processor	17	0.000006	0.0000003	1.61	0.1667
Error	17	0.000004	0.0000002		
Non additivity	1	0.00	0.000	2.87	0.1094
Residue	16	0.00	0.000		
Total	35	0.00001			

Variable : Acid value					
Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0.00	0.002	0.99	0.3329
processor	17	0.04	0.002	1.19	0.3644
Error	17	0.03	0.002		
Non additivity	1	0.01	0.005	3.19	0.0932
Residue	16	0.03	0.002		
Total	35	0.07			

Variable : Free fatty acid					
Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0.01	0.007	0.99	0.3329
processor	17	0.15	0.009	1.19	0.3644
Error	17	0.12	0.007		
Non additivity	1	0.02	0.021	3.19	0.0932
Residue	16	0.10	0.006		
Total	35	0.28			

Variable : Peroxide value					
Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	10.79	10.788	0.46	0.5048
processor	17	569.26	33.486	1.44	0.2295
Error	17	394.98	23.234		
Non additivity	1	5.08	5.078	0.21	
Residue	16	389.90	24.369		
Total	35	975.03			

Variable : Iodine value					
Source	Degree of freedom	Sum of square	Mean square	F -value	prob
replication	1	0.80	0.800	0.26	0.6175
processor	17	382.82	22.519	7.29	0.0001
Error	17	52.54	3.090		
Non additivity	1	1.46	1.455	0.46	
Residue	16	51.08	3.193		
Total	35	436.16			

Appendix 2: Duncan's multiple range test

Value of iodine from ascending to descending

Processors	Means
10	138.9 a
12	136.6 ab
6	133.4 bc
14	132.9 bcd
9	132.7 cd
13	131.1 cde
4	130.8 cde
11	130.2 cde
16	130.0 cde
18	129.9 cde
15	129.5 de
17	129.4 cdef
8	129.2 cdef
5	128.2 ef
7	127.7 ef
1	127.7 ef
2	126.9 ef
3	125.3 f

109 ENDIF

110 SET [IN=*]

Appendix 3: List of Small scale sunflower oils processors in Morogoro region

S/No	Name of Processor	Contact person	District
1	Charles Anosisye Msanvu Shule	Charles Anosisye 0754 497700	Morogoro urban
2	Sido Sunflower oil Machine	Simon Mayauyau 0753 250035	Morogoro urban
3	Sokwe Sunflower oil Machine- Gairo	Hugho Gedmson 0754351785	Kilosa
4	Abdul Sunflower oil Machine – Ungu Rd Gairo	Abdul Msita	Kilosa
5	Kisuva Sunflower oil Machine - Ungu Rd Gairo	Pascal Makau 0764237762	Kilosa
6	Sunfree Mbuyuni Gairo	Dickson Maile 0713632171	Kilosa
7	VEKI General Supplies Kihonda Mbuyuni	Goodluck Elias 0712978867	Morogoro urban
8	SALIS OIL Kihonda Sido	Ramadhani Yahaya 0754 769699	Morogoro urban
9	VEKI General Supplies Kihonda Magorofani	George Lutumo 0767 370180	Morogoro urban
10	Fulwe Sunflower oil mill	Elikana Semu Lenga 0766302296	Morogoro rural
11	Sunflower Production and Value addition Kihonda sido	Mr. Seleman 0757 653906	Morogoro urban
12	Mlali processing and marketing cooperative Kipera - Mlali	Adventina Kawamala 0714002851	Mnvomero

Cont. Appendix 3: List of Small scale sunflower oils processors in Morogoro region

S/No	Name of Processor	Contact person	District
13	Catherine Pure Sunflower oil Processing- Kichangani	Enock Yela 0784401614	Morogoro urban
14	KKKT Mtibwa Suflower mill- KKKT Mtibwa	Ombeni George 0717 739000	Mnvomero
15	Nyagawa Sunflower Mill Madizini B- Turiani	Emmanuel Nyagawa 0717 673419	Mnvomero
16	Mustafa Sunflower Mill Kimamba mjini	Ramadhani Rajab 0714459844	Kilosa
17	KKKT Kimamba Sunflower oil Mill Kimamba mjini	Ester Lameck 0716 034527	Kilosa
18	Japhet J Mamkwe Ironga - Msalabani	Ms Mamkwe 0786 638030	Kilosa

Appendix 4: Questionnaire

Introduction.

You are asked to respond to questions in this questionnaire which are strictly confidential and will be used for study purposes only. Please you are asked to fill it to facilitate the intended learning at the Sokoine University of Agriculture.

SMALL SCALE SUNFLOWER OIL PROCESSOS IDENTIFICATION:

Processors Name.. Code No.........

Date of Interview..

Researcher's Name..

Name of Person interviewed..

His/her position in a particular Processor...

Processors' Address P.O. BOX..............Tel/Mob..................

Email...

District..........................Street..

Region..

ENTERPRISE'S CHARACTERISTICS

1. Number of Employees......................
2. Type of Employees

   (i)Number of Administrative Employees........

   His/ her Professional.................................

   (ii)Number of Technical employees........................
3. His/ her Professional (tick the appropriate) (a) Technical college (b) VETA (c) SIDO (d) university Food science.
4. Annual volume produce (i)50 gallons/ drums (ii) 10 Tones (iii) 5000 Liters of oil
5. Is the enterprise registered as Small scale processor by TFDA? YES/NO (tick one).

   If YES, state the registration number and dates............................

   If NO, give brief reasons..

GOOD HYGIENIC PRACTICES

6. How often do you clean your small scale sunflower oil processing establishment? (tick the appropriate) (i) daily (ii) once weekly depending on available activity (iii) a month plan (iv) others
7. Who plan the cleaning schedule(tick the appropriate) (i) Manager (ii) Quality Assurance officer (iii) Supervisor (iv) others
8. Do you have installed running water in your oil processing plant? (tick the appropriate) YES/NO. If YES what is the source of it (tick the appropriate) (i) Municipal source (ii) well water (iii) reservoir tank (iv) others sources
9. Do you use any aid in cleaning to remove soils and oil residues on different surfaces in your processing plant? (i) detergents (ii)liquid soap (iii) hot water (tick the appropriate) (iv) combination of hot water and detergents/soap
10. What is the nature of the cleaning solution used in your processing plant? (i)Alkaline (ii) acidic (ii) sequestering and chelating agent (iv) others.
11. Do you have hand washing facilities installed in your sunflower oil establishment YES/ NO
12. Do employees wash their or hands before processing oil is effected? YES/NO If YES, where in particular (i) the wash room (ii) in the toilet (iii) washing basin in processing area
13. Do the hand washing facilities contain (i) hot (ii) running water
14. Is your employees undergo medical checkup? YES/NO (tick one).

    If YES, (i) when seeking registration (ii) when newly employed (iii) when
    they get sick (tick the appropriate)
15. How often the routine medical checkup is done (i) after six months (ii) annually (iii) when they fall sick
16. What measures are taken when an employee fall sick? (i) stop to work (ii) stop work and examined by doctor (iii) stop working, do medical checkup and return to work upon medical approval (iii) others
17. What are the protective gears provided to the employees (i) protective clothes (ii) caps/ hair net (iii) gumboots (tick the appropriate)

18. What are the procedures for employees who were sick to resume work(i) attending hospital and having doctor approval for fitness (ii) when she/he fell physically fit to work (iii)approval by quality control officer or supervisor
19. Do you have records of medical checkup for employees and accident? YES/NO (tick one). If YES, how many accidents occurred the past six months (i) none (ii) one to three (iii) more than five(tick the appropriate)
20. Is there a specific employee(s) who work or stationed in the storage room for raw materials or other stores (i) Store keeper available (ii) operator in processing take his/her needs before work resume or when need arise (iii) anybody who are available can assist.
21. Do you and the employees attend any training on Quality processing? (i) Quality management system (ii) Sanitation (iii) Good hygiene Practices and Good Manufacturing Practices (tick the appropriate)
22. Who organized the training? (i) government institutions (ii) non government organization (iii) own initiative through cooperatives/association (tick the appropriate)
23. Are you a member of any association YES/NO (tick one). If YES, (i) the association for financial services (ii) cooperatives (iii) if others

GOOD MANUFACTURING PRACTICE

24. How often the clean the equipment used for sunflower oil processing is done? (i) Cleaning before processing (ii) cleaning after processing (iii) cleaning before and after processing (tick the appropriate).
25. Are employees trained on equipment sanitary YES/NO (tick one).

   If YES, (i) cleaning starts with detergent application/wash of equipment

(ii)pre rinse of the equipment (iii) sterilization of the equipment

26. Do you label your label your final products? (i) with label with date product produced and expire (ii) batch number (iii) net weight
27. Is activities separated in your oil processing plant YES/NO (i) there is raw materials receiving areas (ii) storage area for raw materials, finished products and packaging separately (iii) separate processing area (iv) finished products and packaging stored together

28. Are you aware of hazard analysis critical control points? YES/NO (tick one).

If YES, (i) expensive to apply (ii) used sanitation and processing (iii) effective way of controlling and minimizing hazards and risks (iv) others

STORAGE FACILITIES

29. Do you have storage facilities in your establishment? YES/NO (tick one).

If YES, (I) available for raw materials only (ii) available for sunflower oil and packaging (ii) a storage room available for both raw materials(sunflower seeds), sunflower oil and packaging. (tick the appropriate).

30. Is the size of your storage enough for your activities? (i) enough for storing packaging materials only (ii) raw materials (ii) finished products
31. Are you aware of any raw oil standards? YES/NO (i) TBS (ii)ISO (iii)EAC (iv) others
32. Does your oil meet TBS specifications? YES/NO (tick the appropriate) (i) my products conform to TBS standards (ii) my product possess a bar code.(iii) EAC Standards
33. What type of packaging material do you use to pack your products?(i) plastic (ii)glass (iii) metal (iv) others
34. Where do you get your packaging materials?(i)Buy from packaging industries (ii) Buy re used package from market (iii) recycled plastic from larger processors (iv) others
35. What size of the containers that you use as packaging(i) 1liter (ii)2 liter (iii) 3liter (iv)5 liters (v) 20 liters
36. Cleaning of the packaging is done by (i) use of cold water (ii) hot water only (iii) hot water and detergent and rinsed with hot water (iv) others
37. Wastes and byproduct is expose from the processing plant (ii) through selling the seedcake to livestock keepers (ii) burning (iii) buries in a pit (iv) as fertilizer to farmers
38. How long does your processed oil stay in shelf before being sold?(i)1-2 days (ii) 1 week (iii) a month (iv)5 months