QUALITY AND SAFETY OF PEANUT BUTTER PROCESSED BY SMALL AND MEDIUM ENTERPRISES IN DAR ES SALAAM REGION

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A DISSERTATION SUBMITTED IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD QUALITY AND SAFETY ASSURANCE OF SOKOINE UNIVERSITY OF AGRICULTURE MOROGORO, TANZANIA.

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ABSTRACT

The aim of this study was to assess the quality and safety of peanut butter processed by Small and Medium Enterprises (SMEs) in Dar es Salaam region. Samples for peanut butter were collected randomly from 33 SMEs selected from the list provided by Small Industries Development Organization (SIDO). Production knowledge and challenges facing these SMEs were assessed using pretested structured questionnaire and checklist. Chemical composition and microbiological qualities were evaluated using AOAC (2005) and ISO (2005 and 2017) methods respectively. The results showed that protein content ranged from 4.68 to 21.28 %, fat 33.16 to 66.44 %, carbohydrate 13.65 to 51.40%, calcium 332.19 to 668.64 mg/kg, magnesium 1723.01 to 2553.63 mg/kg, acid value 0.10 to 3.49 mg KOH/g, and peroxide value 8.32 to 45.84 mEqO_2/kg.The results showed that 69.7% of samples tested positive for AFB1 (0.70 to 380.80 μg/kg) while 84.8% tested positive for total aflatoxins (B1, B2, G1 and G2) (0.70 to 425.63 μg/kg) of which 46.6% had higher levels than the limit 15 μg/kg established by TZS 844:2014 standard. *Escherichia coli* and *Salmonella* were not detected in all samples. The results showed that, 30 (91%) of peanut butter SMEs were aware of safety and quality requirements and 31(94%) had access to potable water. Majority of them lack permits, licences and facilities for quality monitoring system. However, high levels of aflatoxin pose a threat to the safety of these products hence, regulatory bodies should strictly monitor the Good Agricultural, Manufacturing and Hygienic Practices throughout the peanut butter supply chain.

DECLARATION

I, Zena Chijoriga, 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 to any other institution.

Zena Chijoriga **Date**

(MSc. Food Quality and Safety Assurance)

The above declaration is confirmed;

Prof. Lyimo, M. **Date**

(Supervisor)

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DEDICATION

I dedicate this dissertation to my family, my lovely children Virginia, Vitas, VivanEliab and baby Vianca whom I was pregnant for her during the beginning of my research and gave birth to her by the time I was writing my dissertation. Their patience, strength, support and the love I have for them enabled me to complete this study.

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ABBRIVIATION AND ACRONYMS

$AgNO_3$	Silver Nitrate
AIDS	Acquired Immunodeficiency Syndrome
AOAC	Association of Official Analytical Chemists
AV	Acid Value
AV	Anisidine Value
a_w	Water Activity
Ca	Calcium
CAC	Codex Alimentarius Commission
CFR	Code of Federal Regulations
CFU	Colony Forming Unit
$CuSO_4$	Copper Sulphate
FAO	Food and Agriculture Organization of the United Nations
FCL	Food Chemistry Laboratory
FLD	Florescence Detector
g	gramme
GAP	Good Agricultural Practice
GDP	Gross Domestic Product
GHP	Good Hygienic Practice
GMP	Good Manufacturing Practice
H_2SO_4	Sulphuric Acid
HCl	Hydrochloric Acid
HIV	Human Immunodeficiency Virus
HPLC	High Performance Liquid Chromatography
IAC	Immunoaffinity Column
IARC	International Agency for Research on Cancer

ICP	Inductively Coupled Plasma
ISO	International Organization for Standardization
ITDG	Intermediate Technology Development Group
Kg	Kilogram
KOH	Potassium Hydroxide
LQD	Limit of Detection
M	Molarity
MEA	Malt Extract Agar
$mEqO_2/Kg$	mill equivalents of oxygen per kilogram
Mg	Magnesium
mg/kg	milligramme per kilogram
min	minutes
ml	millilitre
MPN	Most Probable Number
MS	Mass Spectrophotometer
$Na_2S_2O_3$	Sodium Thiosulphate
NaCl	Sodium Chloride
NaOH	Sodium Hydroxide
^oC	Degree Centigrade
PUFA	Polyunsaturated Fatty Acids
PV	Peroxide Value
QC	Quality Control
SADCAS	Southern African Development Community Accreditation Services
SIDO	Small Industries Development Organization
SME	Small and Medium Enterprise

SO	Standard Operation
SOP	Standard Operating Procedure
SPE	Solid Phase Extraction
TB	Tuberculosis
TBS	Tanzania Bureau of Standards
TFDA	Tanzania Food and Drugs Authority
TM	Technical Method
TZS	Tanzania Standard
µg/kg	Microgram per kilogram
µL	Micro Litre
URT	United Republic of Tanzania
USDA	United States Department of Agriculture
UV	Ultra Violet
WED	Women Entrepreneurship Development

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Peanut butter is a food paste made primarily from ground dry roasted peanuts or groundnuts (*Arachis hypogaea*) and blended with non-peanut ingredients (sugar, molasses, hydrogenated vegetable oil, mono and diglycerides and salt). It is a popular food product worldwide and is mainly used as a sandwich spread, sometimes in combination (peanut butter and jelly sandwich) (Odu and Okonwo, 2012). Peanut butter has been frequently associated with food illness in which initial contamination is traceable to food handlers. *Escherichia coli*, *Staphylococcus aureus*, *Yesinia enter-colitiia, Salmonella spp*, yeasts and moulds have been used to assess the microbiological safety and sanitation conditions during processing and keeping quality of peanut butter product (Consumer report, 2009).

The basic raw material for peanut butter is groundnuts (peanuts) which is prone to aflatoxin contamination produced by toxigenic fungi; therefore, making peanut butter requires great care in the choice of raw materials as this has a bearing on the final quality and safety of the product (Horn, 2005; Craufurd *et al*., 2006; Mutegi *et al*., 2009, Intermediate Technology Development Group (ITDG), 2012; Monyo *et al*., 2012). Peanut butter may be more contaminated than the groundnut grains because unlike the grains, it is nearly impossible to make an informed decision on the quality of peanut butter visually (Samwel *et al*., 2016). To protect consumers from the harmful effects of aflatoxins, most governments have established regulations (FAO, 2004). However, unlike the developed nations, the enforcement of these regulations in developing countries is challenged by several factors, including unavailability of relevant analytical facilities and lack of skilled personnel (Matumba *et al*., 2015).

1.2 Problem Statement and Justification

Peanut butter being potentially hazardous food, it does not have indicative signs of molds so one cannot tell whether the nuts used to produce were moldy, insect damaged, or otherwise contaminated (Samwel *et al*., 2016). Peanut suppliers are required to provide certificates of analysis assuring lots delivered do not exceed specified limits for pathogens or foreign material (Grocery Manufacturers Association, 2016), perhaps, this is a big challenge for small and medium enterprises of these products due to the high risk of microbial, physical and chemical contamination at various point of production that lack quality supervision. These challenge contaminations can pose serious health problems to consumers.

Small and Medium Enterprises in Tanzania including peanut butter SMEs have been growing very fast and most of them have extended their markets by participating in different exhibitions such as “Nanenane” and Saba saba national trade fair. Currently, there is an increased number of entrepreneurs especially women who have been involved in small and medium food processing enterprises including peanut butter processing. Majority of these SMEs operate in the informal sector and are not registered by food quality authorities though their products are increasingly consumed and sold locally. However, due to challenges facing the SME processors including inadequate knowledge, poor raw and packaging materials, lack of appropriate equipment and technology, inconsistent in product quality and limited shelf life, the overall quality and safety of these products is questionable (Mukantwali, 2014). In addition, there is a gap in the knowledge as well as limited data on the quality of peanuts and its products especially the peanut butter which is widely consumed locally. On knowledge point of view, there is no scientific data on quality of peanut butter processed and marketed by SMEs in Tanzania. The assessment of quality and safety of food is important in human health.

Preservation of the chemical and sensory quality is one of the main problems in the peanut industry. Storage stability of peanut butter is the main concern for consumer acceptability due to its high polyunsaturated fatty acids (PUFA) (Li *et al*. 2013). Therefore, this study was carried out to assess the quality and safety of peanut butter processed by small and medium enterprises and the findings will serve as useful information for consumers and government regulators.

1.3 Objectives of the Study

1.3.1 General objective

The general objective was to assess the quality and safety of peanut butter processed by small and medium scale processors in Dar es Salaam region.

1.3.2 Specific objectives

i. To assess production knowledge and challenges facing peanut butter SMEs in Dar es Salaam region.
ii. To determine the chemical composition of peanut butter processed by SMEs in Dar es Salaam region (moisture, fat, acid value, ash, peroxide and anisidine values, protein, carbohydrate, salt, magnesium and calcium).
iii. To evaluate the microbiological quality of peanut butter processed by SMEs in Dar es Salaam region.
iv. To determine the level of aflatoxins contamination of peanut butter processed by SMEs in Dar es Salaam region

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Food industry is one of the largest branches of industries in Tanzania which is made up of micro, small, medium and large processors (Kimambo, 2005; Ruteri and Xu, 2009). There is no universally accepted definition of SMEs (Olomi, 2005 and Khan, 2010). According to Tanzania SMEs Policy and definition of SMEs that classified SMEs into: micro enterprises (1 to 4 workers), small enterprises (5 to 49 workers), medium enterprises (50 to 99 workers), large enterprises-(100+ workers) (Msemo, 2013). SMEs play an important role in food processing industry for the economies of developing countries (Wignaraja, 2003; World Business Council for Sustainable Development, 2004; and Rodriguez *et al*., 2007).

Groundnut or peanut (*Arachis hypogea Linn*) is a plant which belongs to the family of Fabaceae (Eke-Ejiofor *et al*., 2012). Botanically, groundnut is a legume although it is widely identified as a nut and has similar nutrient profile with tree nuts (Ros, 2010). In Tanzania, it is mainly grown in Dodoma, Tabora, Shinyanga, Singida, Mtwara, and Mwanza regions by smallholder farmers (eleven varieties of groundnuts have been released to date and Pendo and Johari are very popular) (Bucheyeki *et al*., 2010).

2.2 Composition of Peanuts /groundnuts and Peanut Butter

Peanut constitutes a major annual oilseed crop and a good source of protein containing high lysine content, which makes it a good complement for cereal (Okaka, 2005) .Groundnut, contains high quality edible oil (50%), easily digested protein (25%) and carbohydrate (20%) (Taru *et al.*, 2008; Muhammad – Lawal *et al*., 2012).

Groundnut seeds are source of vitamin E, folacin, calcium, zinc, iron, phosphorus, niacin, magnesium, potassium, riboflavin, and thiamine (Surendranatha *et al*., 2011). The availability of calcium, magnesium, phosphorus is a good indication that the groundnut is rich in minerals for bone formation. Calcium is involved in blood clotting, muscles contraction and in certain enzymes in metabolic processes (Ayoola *et al*., 2009). The proximate biochemical composition of mature groundnut seeds per 100 g edible portion is moisture (6.5 g), protein (25.8 g), lipids (49.2 g), carbohydrate (16.1 g), dietary fibre (8.5 g),calcium (92 mg), magnesium (168 mg), phosphorus (376 mg) and iron (4.6 mg) (USDA, 2010). Peanut butter contains a minimum of 90% peanuts; sweeteners and salt can be added to enhance flavor while small amounts of stabilizers are used to prevent oil separation (Akhtar *et al*., 2014). Peanut butter is rich in variety of minerals; it contains sodium, potassium, phosphorus, iron, zinc, copper, magnesium, aluminium, barium, and strontium in a good amount (Özcan and Seven, 2003).

2.3 Peanut Butter Processing

The production of high quality, flavourful and wholesome peanuts begins at the farm level. Raw material management is critical to the overall performance of any manufacturing concern. The availability of the raw material in the right quality and quantity will determine to a reasonable extent the availability, quality and quantity of the resultant output (Akindipe, 2014). The composition and quality of the peanut crops is affected by climatic variations and subjected to loss during harvesting, storage and handling techniques due to insect, bird, and rodent infestation, microbial activity, and mechanical damage, physical changes such as weight loss or shrinkage (Lolayo, 2002). Reception of peanut that is used for processing is the most critical stage that requires different quality checks including color, aroma, taste, texture, insect damage, and foreign particles, broken and, mouldy grains, under size grains and moisture so as to ensure selection of best peanuts available for processing (Aslam *et al*., 2012).However ,peanut butter is processed in the same way as roasted peanuts up to the dry roasting stage, at which peanuts are finely ground into a paste and vacuum packaged (Mutegi *et al*., 2009).

The overall quality of nut spread is related to the quality of nut paste which is used as the main ingredient. The quality of nut paste is influenced by raw kernel quality, processing conditions such as roasting temperature and time, and storage conditions (Tomlins, 2007). Roasting is an important unit operation step involved in the peanut manufacturing industry for the production of different peanut products, the development of roasted flavour and aroma not only depends on the type of peanuts and techniques applied during the process but also on temperature and time combinations (Shakerardekani *et al*., 2011). When the peanuts are roasted at temperatures over 85 °C, final moisture content of 6% or lower is attained. Peanut butter is produced from roasted peanuts with moisture content of 1% (i.e. aw of 0.2 to 0.3); the extremely low water activity in peanut butter prevents growth of spoilage and pathogenic microorganisms (Ma *et al*., 2009).

According to Code of Federal Regulations (CFR), peanut butter is defined as creamy spread, mainly composed of peanut paste and stabilizer. It may also contain sweetener, salt, emulsifier and other ingredients (CFR, 2010b) Differences in manufactured peanut butter reflect variations in product formulations and processing conditions. A typical peanut butter consists of 90% peanut paste, 1-5% hydrogenated vegetable oil, 1-6% sweetener, 1-1.5% salt, 0.5-1.5% emulsifier (APV, 2008). Natural peanut butter, a popular product among some consumer groups, does not contain stabilizer, is less firm, and flows more easily than stabilized commercial peanut butter. Peanut butter without stabilizer exhibits oil separation problems, coupled with the formation of a hard layer of peanut solids at the bottom of the container due to settling (Aryana *et al*., 2000). Stabilizers commonly used in commercial peanut butter include hydrogenated canola and cottonseed oils (Aryana *et al*., 2003). Use of these stabilizers results in a firm but spreadable peanut butter that does not exhibit oil separation over time.

2.4 Peanut/Peanut Butter Utilization

Peanuts can be eaten as straight food (raw), used in recipes, made into solvents and oils, used in make-up, medicines, textile materials, peanut butter, as well as many other uses (Filaherty, 2013). Popular confections made from peanuts include salted peanuts, peanut butter (sandwiches, peanut candy bars, peanut butter cookies, and cups), peanut brittle, and shelled nuts (plain/roasted) (Filaherty, 2013). Peanuts are also used as major ingredients in the formulation of complementary food with other cereals such as sorghum, corn, and millets because of their high protein and omega 6 fatty acid content (Iro *et al*., 1995).

Peanuts and its derivatives are often classified as street food which satisfies essential need of the urban population by being affordable and available (Donkor *et al*., 2009). The production and sales of peanut and its product (peanut paste) serves as a major source of livelihood to the women in Northern Ghana (Millar and Yeboah, 2006) where it is publicized on tables for consumers to buy, likewise in Tanzania as it has been observed from women who were selling leaf vegetables together with fine grounded raw and roasted peanuts and peanut paste along the main road at Mbezi Mwisho bus stand in Dar es Salaam region (Field survey, 2017). Roasted salted peanuts are one of the most commonly (popular confection) consumed products around the world (Nepote *et al*., 2009) as well as peanut paste, especially at places where poverty is at the highest peak (Omer *et al*., 2001).

Peanut butter is used mainly as a sandwich spread, and owing to its high lipid and protein contents, it has become a major constituent of ready-to-use therapeutic food in treating malnutrition in children and AIDS patients, particularly in the developing world (Manary, 2006; Ndekha *et al*., 2009). Peanut butter, a smooth paste obtained after grinding roasted peanuts (*Arachis hypogaea*) is traditionally an important product used for cooking purposes in many homes in rural Tanzania. The paste is used in preparation of side dishes and is also cooked with vegetables, pearled sorghum and maize to make a variety of dishes.

2.5 Quality and Safety Attributes of Peanut and peanut butter

Moisture content is one important quality factor to the peanut industry (Kandala *et al*., 2008). Moisture content is important both before and after processing. It is central to colour, flavour and textural development of the final product through several chemical reactions, heat transfer and drying which occur during roasting (McDaniel *et al*., 2012), as it affects the stability, quality, and texture of roasted peanut products (Lee and Resurreccion, 2006). Therefore, moisture control is critically important in preventing food borne illness such as Salmonella contamination in low- moisture products (International Commission on Microbiological Specifications for Foods, 2005). Peanuts and peanut butter are considered nutritious, as they contain proteins, oils, fatty acids, carbohydrates, and minerals (Settaluri *et al*., 2012). This, ironically, makes them a rich medium for fungal growth and aflatoxin contamination (Barberis *et al*., 2012). Peanut butter quality problems include those associated with food safety such as *Salmonella* outbreak and physicochemical attributes deterioration (Burnett *et al*., 2000).

Peanut paste and peanut butter have high oil contents and are thus susceptible to developing rancidity and off-flavours through lipid oxidation.. Lipid oxidation is one of the most common testing for measurement of oxidative rancidity in oils and fats (Li *et al.*, 2013) and the peroxide value (PV) is a measure of the concentration of peroxides and hydroperoxides formed in the initial stages. Storage stability of various butter and spread using PV as indicator has been applied for oilseed butter from sunflower kernels (Muttagi *et al.*, 2014), peanut butter (El- Rawas *et al*. 2012) and shea butter (Honfo *et al*., 2011).

2.6 Microbial contamination of Peanut and Peanut Butter

2.6.1 Aflatoxins contamination

The major microbiological issue with nuts has been the control of mycotoxins produced by fungi such as *Aspergillus flavus* and *Aspergillus parasiticus.* Food contamination caused by aflatoxin could occur at any point along the value chain. Groundnuts (peanuts) are liable to fungal contamination during pre- and post-harvest processing, handling, storage and transportation, exposing them to the risk of contamination with aflatoxin (Polixeni and Panagiota, 2008; Mutegi *et al*., 2012). Peanut has proved to be a good substrate for the growth of *Aspergillus sp* and for the production of aflatoxins (Bakhiet and Musa, 2011). Aflatoxin produced by *Aspergillus sp* has immunosuppressive effects and epidemiological studies have shown a positive correlation between aflatoxin intake and the incidence of liver cancer (IARC, 2002). There are several types of aflatoxin in nature, among these, aflatoxin B1 and B2, G1 and G2 are the common and the most important which cause human disease. Aflatoxin B1 is the most ubiquitous form and the most toxic (Kamika and Takoy, 2011; Wild and Gong, 2010).

If raw groundnuts are contaminated with aflatoxins, there is high risk of exposure to the consumer through consumption of peanut butter processed from such groundnuts (Mutegi *et al*., 2012). Humans or animals with low immune system are more susceptible to infection from aflatoxin (Nigam *et al*., 2009). The coupling effect of some deadly infectious diseases such as hepatitis B/C, TB, HIV and consuming high levels of contaminated food have led to higher mortality among patients whose immune system were down due to aflatoxin infection.

Most countries have legislation setting maximum permissible limits for aflatoxins, which are in the low micrograms per kilogram for food matrices (FAO, 2004). Two types of limits exist, one for aflatoxin B1 (5 µg/kg) and the other for the sum of the four aflatoxins (B1, B2, G1 and G2 (5 µg/kg) (TZS 844:2014) respectively. The most frequently used analytical protocol for aflatoxins is High Performance Liquid Chromatography (HPLC) coupled with either fluorscence or mass spectrometric detection (Spanjer *et al*., 2008; Vega, 2005). Aflatoxins possess significant UV absorption and fluorescence properties, so techniques based on chromatographic methods with UV or fluorescence detection have always predominated. High Performance Liquid Chromatography using fluorescence detection has already become the most accepted chromatographic method for the determination of aflatoxin because it provides high selectivity, low limit of quantification (LOQ) and accurate analysis (Bao *et al*., 2010). Peanut butter is extremely complex consisting of carbohydrates, proteins, vitamins, phytosterols, poly/mono-unsaturated fatty acids and several inorganic ingredients. The extraction of the peanut butter with solvent will co-extract many of these constituents with the aflatoxins. The toxins from food matrices are solvent extracted and the extracts cleaned either by immunoaffinity column (IAC) or solid-phase extraction (SPE) columns prior to analysis. Therefore, a thorough sample cleanup protocol is required to eliminate these matrix components, especially when parts per billion level aflatoxins are to be quantitated (Countryman et al., 2009).

2.6.2 Bacteria contamination

Effective cleaning and sanitation of peanut butter lines are essential for preventing both initial and cross-contamination with microbial hazards such as *Salmonella* (U.S. Food and Drug Administration, 2009b; Grocery Manufacturers Association, 2009a, 2009b, 2010;International Life Science Institute Europe, 2011; Podolak *et al*., 2010; Scott *et al*., 2009).

Low-moisture foods, including nut butters, were once thought to be relatively microbiologically safe products with respect to foodborne illness risk because of their low water activity (generally less than 0.7) that do not permit the growth of foodborne microorganism (Danyluk *et al*., 2007). *Salmonella* cannot multiply on nuts or in nut products, however the organism can survive on and in these products, for an extended period (greater than one year), especially when held in cold storage (Danyluk *et al*., 2007). However the ability of *Salmonella* to survive in high fat content, low water activity foods like peanut butter has been demonstrated by large foodborne illness outbreaks in recent years (D'Souza *et al*., 2012). About 1.2 billion pounds of peanut butter are consumed annually in the United States. In 2008 to 2009, an outbreak involving *Salmonella typhimurium* in peanut butter led to a recall of over 3900 products by over 200 companies. More than 700 people became sick, 100 were hospitalized, and 9 people died from this outbreak (Grasso *et al*., 2010). *Escherichia coli* contamination in nut and nut products is also a concern as the presence of *E. coli* in nuts normally indicates that products have been handled poorly during processing. Manual de-shelling also increases the exposure to microbial contamination (Freire and Offord, 2002).

Table 1: Tanzania standard levels in peanut butter

S/N	Characteristic	Requirement
1.	Moisture, %, max	3.0
2.	Ash, %, max.	5.0
3.	Acid value, mg/KOH/g	4.0
4.	Salt as NaCl, %, max.	2
5.	Fat,%	45 - 55
6.	Yeast/Molds, max	10^3/g
7.	*Escherichia coli*	Shall be absent
8.	Total aflatoxin content, µg/kg, max.	15
9.	Aflatoxin B1, µg/kg, max.	5

Source: Tanzania Standard (TZS) 844:2014 Peanut butter Specifications.

2.7 Production Challenges and Quality of Peanut Butter Processed by SMEs in Tanzania

Tanzania has about three million SMEs contributing to about 23.4% of the total employment and 27% to the GDP (URT, 2012); indicating how important the sector is in employment creation in particular to those with low skill levels. However, SMEs face many challenges including; poor quality of products resulting from inferior technology, low capital and production skills, limited access to reliable information to enable selection of target markets, product development and technical skills, limited access to appropriate technology and financial resources to manage the business potential and limited access to business development services is still a major constraint to the development of SMEs (Fortune Africa, 2013).

According to Intermediate Technology Development Group, peanut butter became commercially popular in Tanzania and for the past five years women entrepreneurs assisted by the SIDO Women Entrepreneurship Development Programme (WED) in food processing have learned and excelled in the production of peanut butter and have been faced with some experienced common problems during peanut butter processing including; low individual production capacities of the peanut butter because of limited technology used (manual roasting, winnowing, and grinding) (ITDG, 2012). Most entrepreneurs use a hand grinder that can process one kilogram of kernels at a time and normally grinding has to be carried out two or three times. These technologies are certainly limiting for an entrepreneur who would like to grow. The problem of oil separation which discouraged peanut butter processors on how to prevent peanut oil from separating out of the peanut paste a few weeks after processing**.** The problem of packaging despite the good quality of peanut butter, its packaging is still inferior to that of imported products (ITGD, 2012).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

Dar es Salaam is the major commercial, administrative and industrial centre of Tanzania. The region has favorable economic and fiscal policies whereas its five different municipalities namely Temeke, Ilala, Kinondoni, Ubungo and Kigamboni have been seen to have communities with sustainable social and economic development through participatory resource mobilization and utilization thus enhancing the quality of social and economic services by using the existing resources and opportunities. The major economic activities in Dar es Salaam include; internal trade, manufacturing and tourism. (Dar es Salaam City Council, 2004).

3.2 Study Design

This study involved survey and laboratory work. A cross-sectional design was employed for the survey whereby information (data) were collected at a single point in time. Total of 33 peanut butter SMEs were selected from registered list provided by SIDO basing on criteria that most of the SMEs in Dar es Salaam have been normally trained by SIDO on entrepreneurial skills and this organization is entrusted in spearheading development of Small and Medium Enterprises (SMEs) in the country. Face to face interviews were conducted using structured questionnaire/ checklist to respond to the questions concerning production knowledge and challenges (Appendix 1). Characteristics of surveyed peanut butter SMEs are summarized in Appendix 2.

3.3 Sample Collection

A total of 33 peanut butter samples (one kilogramme each) were randomly collected from 33 peanut butter SMEs. Most of the samples were sampled and collected from the production lots not exceeding one week from the production date. It is important to note that these peanut butter SMEs' production was not continuous, the production per day was normally an average of 10 to 20 kg depending on market outlets to their customers and availability of raw materials particularly peanuts. The collected samples were coded and transported to the laboratory for analysis on the same day. Original packages containing the samples were kept in dark, dry and cool place in the laboratory. The parameters were tested within a week from the collection day.

3.4 Laboratory Work

Analysis for chemical, bacterial and aflatoxin levels of peanut butter samples collected in this research study was carried out at the Food Laboratory of the Tanzania Bureau of Standards in Dar es Salaam. Tanzania Bureau Standards food laboratory consisted of Food Chemistry and Food Microbiology sections which have been accredited by Southern African Development Community Accreditation Services (SADCAS) in most of its parameters on different matrices

3.4.1 Chemical composition

3.4.1.1 Moisture

Moisture content of the collected peanut butter samples was determined following AOAC (2005) procedures using official method no. 925.40. Approximately 10g of prepared peanut butter was weighed in tarred aluminium dish with a cover and evenly distributed. With cover removed, the dish and cover were placed in an air- dry oven (HERAEUS) maintained at 105 °C until constant weight and dried for 4 hours. Thereafter, the dishes were covered and placed in a desiccator for 30 min to reach ambient temperature. The moisture content (MC) was determined by the difference of weight before and after drying the sample in an oven as follows

$$\% \text{ Moisture} = \frac{(\text{M1} - \text{M2})}{(M1 - M)} \text{ x } 100$$

M_1 = mass in g of the dish with material before drying

M_2 = mass in g of the material with material after drying

M= mass in g of the empty dish

3.4.1.2 Ash

Ash content of the peanut butter samples was determined according to the AOAC (2005) procedures using method no. 950.49. Ash fraction was determined by the incineration of dried sample (3 g) into the dried crucible (pre-dried in the furnace) in a muffle furnace (Carbolite) at 550°C for 4 h. The ash was cooled in desiccator for 30 minutes and weighed. Percent residual weight in the crucibles was reported as the ash content in the sample and expressed as:

$$\% \text{ Ash } = \frac{(M2 - M)}{(\text{M1} - \text{M})} \times 100$$

M_2 = mass in g of the crucible with ash

M = mass in g of the empty crucible, and

M_1= mass in g of the crucible with the sample taken for the test.

3.4.1.3 Protein

Protein content was determined by Kjeldahl procedure (AOAC, 2005) using test method no. 950.48. Two grams of the prepared samples were weighed in Kjeldahl flasks, 0.5g anhydrous $CuSO_4$ and 10g of anhydrous Na_2SO_4 were added. The flasks were placed to the Kjeldahl digester (Gerhardt) and heated gently until frothing ceases. Thereafter, boiled briskly until the solution clears and then for at least 30 min longer. The digestion was for 4 h, cooled the solution and then transferred to Kjeldahl distiller (Vapodest) where 150 ml of water, 100 ml of NaOH were dispense automatically together with 50 ml of boric acid dispended in a receiving flask in which the distillate was collected. The distillation was for 15 min. Addition of two to three drops of mixed indicator followed and then titrated with standard solution of 0.25M H_2SO_4 to the endpoint. A blank was run under the same condition as with the sample. Protein percent was calculated according to the following equation:

Protein percent = Nitrogen percent (N %) x 5.46

3.4.1.4 Fat

The fat content was determined by AOAC (2005) with test method no. 948.22 using Soxtherm (Gerhardt) through extraction process by petroleum ether as solvent. About 2 g of the samples were weighed directly into extraction thimbles. The thimbles were covered with some cotton wool and placed into extraction flasks and fitted to the Soxtherm (Gerhardt). The extraction was lasted for two and a half hours.

Then, the solvent was completely removed under reduced pressure in a rotary evaporator and dry the flask containing the extracted oil at 105 °C in the air oven for an hour, thereafter cooled in a desiccator for 30 min and weighed. Fat percent was determined by weight difference of the extraction flask (weighed previously) and flask with the residue and expressed as follows;

$$\% \text{ Fat (g/100g)} = \frac{(\text{W2} - \text{W1})}{W3} \text{ x } 100$$

W_1= weight in g of the extraction flask

W_2 = weight in g of the flask plus the extracted oil

W_3 = weight in g of the sample taken for the test

3.4.1.5 Carbohydrate

Carbohydrate content was estimated by the difference of the other components using the following formula described by Mestrallet *et al*. (2004).

Carbohydrate content (%) = 100 – (moisture + protein + fat + ash)

3.4.1.6 Salt (as NaCl)

Salt content of the peanut butter samples was determined using general chemical procedure by Pearson-Mohr method as recommended by AOAC (2005).Ash fraction was obtained by the incineration of dried sample (2 g)into the dried crucible (pre-dried in the furnace) in a muffle furnace (Carbolite) at 550°C for 4h until grey ash obtained. Cooled in desiccator and wetted with 10 ml of distilled water then transferred to a conical flask whereby few drops of 5% potassium dichromate indicator were added and titrated with the 0.1M of Silver Nitrate ($AgNO_3$) solution to the appearance of permanent orange colour endpoint. Percent salt of the sample was calculated as follows;

$$\% \text{ Salt (NaCl) } = \frac{(\text{Vx } 0.005844)}{Sample\ weight\ (g)} \text{ x } 100)$$

V = volume in ml of the AgNO3 used (titre value).

1 ml 0.1 M $AgNO_3$≡ 0.005844 g NaCl

3.4.1.7 Acid Value

The acid value of an oil/fat is the number of potassium hydroxide required to neutralize the free acids resulting from the complete hydrolysis of 1g of the sample. About 10 g of the peanut butter was taken in a thimble and extracted oil with petroleum ether for 8 h in a soxhlet apparatus. Then evaporation of the solvent was completely done under reduced pressure in a rotary evaporator. The oil obtained in the extraction flask was dissolved with warm neutral alcohol solution and titrated with standard 0.1M of sodium hydroxide solution to a faint pink colour which persists for 10s. The acid value was therefore, determined using equation below:

$$\%\ \text{Acid Value (as oleic acid)} = \frac{(56.1\ \text{x VM})}{m}\ \text{x}\ 100$$

V = volume in ml of standard sodium hydroxide solution used (Titre value).

M = molarity of standard sodium hydroxide solution, and

m = mass in g of the sample taken for the test.

3.4.1.8 Peroxide Value

Indicators of lipid oxidation in peanut butter samples were measured by peroxide values (PV). PVs were quantified following the AOAC (2005) official method no. 965.33. Approximately 35g of peanut butter was extracted with petroleum ether through a thimble for 8 h in a Soxhlet extractor apparatus. The solvent was then removed using a rotary evaporator to recover peanut oil. Peroxide value was then determined on 5 g of oil by adding 30 ml of acetic acid chloroform (3: 2 ratio) swirled to dissolve then 0.5 ml of saturated potassium iodide solution, with occasional shaking for one min. This was followed by addition of 30 ml of distilled water and 0.5ml of 1% starch indicator then slowly titrated with 0.01 N of sodium thiosulfate ($Na_2S_2O_3$). Blank determination was also conducted which was then subtracted from sample titration. Peroxide Value was expressed as mill equivalents of peroxide per kilogramme of sample (meq peroxide/kg sample) and calculated using the formula:

$$\text{Pv (meq } 0_2\text{/kg} = \frac{\text{Volume in ml of } Na_2S_2O_3 \text{ (blank corrected) x (0.01 Normality of } Na_2S_2O_3 \text{ x 100}}{\text{g oil sample}}$$

3.4.1.9 Anisidine Value

Anisidine value of the peanut butter samples was determined following the procedure described by ISO 6885: 2016 (E). About one g of peanut oil sample (previously extracted as indicated in PV) was dissolved in10 ml of isooctane and made up to the mark of 50ml volumetric flask with the same solvent. In a test tube, 5ml of the test solution (unreacted test solution) was mixed with 1ml of glacial acetic acid. The tube was stoppered, well shaken and was kept in the dark for 8 min. Within a further 2 min, the solution was transferred to a clean, dry spectrometer cell. The absorbance of this solution (A_0) was measured at 350nm in a spectrophotometer (SPECTRO UV-VIS AUTO-UV-2602) after exactly 10 min. Again, in a test tube, 5ml of the fat solution (reacted test solution) was mixed with 1ml of p-anisidine reagent the tube was stoppered as well as well shaken and was kept in the dark for 8 min. Within 2 min, the solution was transferred to a clean, dry spectrometer cell. The absorbance of this solution (A_1) was measured at 350nmin a spectrophotometer after exactly 10 min. For blank, the absorbance (A_2) of the solution was measured at 350nm, where a mixture of 5ml of isooctane was added with 1ml anisidine reagent in a test tube which was stoppered, well shaken and kept in dark for 8 min.

The p-anisidine value was given by the formula:

$$AV = \frac{100QV}{m} \times [1.2(A_1 - A_2 - A_0)]$$

Where:

V is the volume in which the test sample was dissolved, in millilitres (V=50 ml);

m is the mass of the test portion (peanut butter oil), in grams;

Q is the sample content of the measured solution based on which the anisidine value is expressed in grams per millilitre (Q = 0.01g/ ml);

A_0 is the absorbance of the test solution after reaction with glacial acetic acid (unreacted test solution);

A_1 is absorbance of the fat solution after reaction with the p-anisidine reagent (reacted test solution);

A_2 is the absorbance of the isooctane after reaction with anisidine reagent;

1.2 is the correction factor for the dilution of the test solution with 1ml of the reagent or glacial acetic acid.

3.4.1.10 Mineral composition of SMEs peanut butter samples

Calcium and magnesium were determined by Inductively Coupled Plasma Mass Spectrometry (ICP–MS 7900). Three grams (3 g) of the sample was dry ashed in a muffle furnace at 550°C -600. The minerals were extracted from the ash by adding 10 ml of 1:1 HCl, heated until it started to boil and this was transferred quantitatively by filtering through whatman paper No. 100 to a 100 ml volumetric flask. The filtrate was diluted to the mark (100 ml) with distilled water, after that treatment, then the filtrate was collected in 10 ml vials through the 0.45 micro filter used a syringe and analysed by ICP– MS 7900.The mineral content of the samples were quantified against standard solutions of known concentrations and the blank sample (which were analysed concurrently).

$$\text{Mineral content of the sample}\left(\frac{mg}{kg}\right) = \frac{\text{Concentration of the sample} - \text{concentration of the blank x 100}}{\text{weight of the sample taken}}$$

3.5 Microbial analysis

3.5.1. *Escherichia coli*

Escherichia coli was determined according to the ISO 7251:2005 procedures. The enumeration of presumptive *E.coli* was based on Most Probable Number (MPN) three tubes technique by determining Most Probable Number of *Escherichia coli* per gram of the test peanut butter using the Buffered Peptone Water (BPW), Laurly Tryptose broth (selective enrichment medium), EC broth and Tryptone water by. The apparatus and media were prepared and sterilized and apparatus were also sterilized by autoclaving at 121^0C for 15 minutes. This was followed by sample dilution and inoculation whereby three replicates of twenty five (25) gram from each peanut butter sample were homogenized with 225 ml of Buffered Peptone Water (OXOID), from this 1 ml of the test sample (initial suspension) was transferred by use of sterile pipette to each of the three tubes of double strength and single strength (serial dilution i.e.10^{-1} to 10^{-3}) containing the selective enrichment medium. Thereafter, the contents were carefully mixed the inoculums and the medium followed by incubation at 37^oC for 48 h. After incubation time each dilution with tubes of positive results (showing gas formation or opacity), when either of these features was first observed were sub cultured them onto EC broth with sterile plastic loop and incubated at 44^oC for 48 h. On confirmation for the presence of *E.coli*; tubes with positive results (gas formation or opacity) from EC broth after incubation were inoculated in tryptone water and incubated at 44^oC for 48 h then indole test was followed whereby 0.5 ml of indole reagent was added to tubes of tryptone water incubated and observed the formation of red ring as positive results for *E.coli* presence. Positive, negative controls and blank test were tested concurrently.Results for the positive tubes were expressed in MPN/g (Presumptive *E.coli* per gram) by selecting three consecutive dilutions and compared with number of positive tubes from MPN Table (see Appendix III).

3.5.2 Yeast/Moulds

The enumeration of Yeast/Moulds was carried out according to procedures described by ISO 7954 (2005). Malt extract agar (MEA) enriched with lactic acid was used to determine the presence and the numbers of yeast and molds in the peanut butter samples. Three replicates of 25 gram from each peanut butter sample were homogenized with 225 ml of buffer peptone water (OXOID). Pour plating technique was employed into sterile petri dish whereby 1ml of the diluted peanut butter samples (initial suspension) was transferred by means of sterile pipette into the petri dishes of different serial dilutions (10^{-1} to 10^{-3}) which were then carefully mixed with molten agar (MEA) and allowed the mixture to solidify. After solidification, the agar plates were incubated at 30°C for 5 days. Yeast/Molds were identified by colony counting using colony counter device where by the number of yeast/molds per gram of sample were calculated from the number of colonies obtained on each plate and expressed as colony-forming units per gram of sample (CFU/g).

3.5.3 *Salmonella*

The presence or absence of *Salmonella* in peanut butter samples was detected by the procedures described by ISO 6579:2017. For each sample three replicates were carried out where by twenty five (25) grams of the samples were mixed with 225ml of Buffered Peptone Water (pre-enrichment- non selective liquid medium) and incubated at 30^{o}C for 24h. After incubation, 0.1 ml of the cultured sample obtained was inoculated into Rappaport Vassiliadis (RV) broth (enrichment selective liquid media) and incubated at 41.5 ^{o}C for 24h. The culture obtained inoculated on petri dishes containing two selective solid media (Xylose Lysine Desoxycholate and Brilliant Green Agar) for each replicate by stripping with a loop and incubated at for 37 °C for24 h. The detection of *Salmonella* was determined by observing the typical color of colonies characteristics on the two selective agar media used and expressed per 25 grams of sample.

3.6 Analysis of Aflatoxins

The determination of aflatoxins (B1, G1, B2, G2) was carried out by the Standard Operating Procedure (SOP) no. FCL/SO-TM/13 which followed Romer Labs procedures (EC-Directive EC/178/2010) for the purification of Aflatoxins in conjunction with High Performance Liquid Chromatography. The tested portions of 25g of fine ground peanut butter samples were extracted for 3 min by mixed in a covered high speed laboratory blender jar with 100 ml of 60% HPLC grade methanol (i.e. 60: 40 methanol; water). The extract was filtered using whatman No.1 into a 4 ml sample tube and diluted by adding 8 ml of phosphate buffer solution (12 ml), followed with clean up stage to a glass microfiber filter by placing the aflacolumn (AflaStar^{TM} R- Immunoaffinity column, Romer Labs, Austria) into the adapter. The flow rate did not exceed 3 ml/ min when the diluted extract was loaded and allowed to pass through the column and after the extract passed through the column, 10 ml of distilled water was passed twice where by the first rinse solution was to wash and the second rinse was applied direct to the column. In case of any remaining liquid slight pressure was applied.

The elution stage involved the placement of vials under the column for the collection of eluent by eluting the bonded aflatoxin without use of vacuum with 1ml of Acetonitrile (i.e. HPLC grade) by passing it through a column, the Acetonitrile was left on the column for a few seconds before elution to allow intensive contact with the gel. Slight pressure was applied on top of the column to remove any remaining liquid. Using micropipette, 400µL from the eluent was mixed with 600µL of derivatizing reagent (70:20:10; (Water) H_2O: (Trifluoroacetic acid) TFA: acetic acid) for derivatization. The mixture was conditioned at 65^{o}C for 15 min, allowed to cool and finally injected to High Performance Liquid Chromatography (HPLC- FLD) for analysis of aflatoxins. Calibration standards were prepared and were run with the QC (Quality Control) sample alongside with the peanut butter samples. Calibration curves were generated whereby the data were collected and analysed with the Agilent Chem Station software, and quantification was achieved by comparing the areas under the curve with those of authentic aflatoxin standards.

The sample concentration was calculated as follows:

Concentration of the sample (μg/kg) =

$$\frac{conc\ found\ \left(\frac{ng}{ml}\right) x\ 1ml\ x\ 100(ml) x2.5(dilution\ factor)}{4ml\ x\ weight\ of\ the\ sample\ taken\ (g)}$$

3.7 Statistical Data Analysis

Data from the laboratory analysis were analyzed using SAS (version 9.1) software statistical package. Analysis of Variance (one way ANOVA) was used to determine whether the values obtained from the SME peanut butter samples show any significant difference ($p<0.05$). Means were separated by Duncan Multiple Range Test (DMRT). Results were expressed as mean ± standard error of the mean and presented in tabular form. Data for field survey were analyzed by Statistical Package for Social Sciences (SPSS) version 16.0 using descriptive analyses namely percent and frequency distributions and were presented in tables.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Production Knowledge and Challenges Facing Peanut butter SMEs

4.1.1 Employee status and education level of peanut butter SMEs

Results shown in Table 2 indicate that, there was variation on number of employees and educational level of peanut butter SMEs identified. Majority 23 (70%) of the SMEs had up to four employees and 21 (64%) of these SMEs had technical education (i.e. SIDO/VETA). The findings of this study are in contrast with that reported by Yahya and Mutarubukwa (2015) that 93% of the SMEs owners are primary school-leavers. Education acts as a catalyst in acquiring and disseminating information that is needed for running day-to-day business operations. These findings justify what has been observed during survey whereby most of these SMEs were knowledgeable enough to what they have been on peanut butter processing despite of other production challenges. In order for SMEs to penetrate the international market, education and training is very important. According to Loewe *et al.* (2013) differences in education, training and work experience determine SMEs ability to upgrade. Apart from skills acquisition, the role of education especially at a tertiary level is to help the entrepreneur in promoting disciplines, identify options and make correct decisions.

Table 2: Employees status and educational levels of the peanut butter SMEs in Dar-es-Salaam region (N=33)

	Frequency
Number of employees	
0-4	23 (70%)
5-10	10 (30%)
Educational level attained	
Technical college and University	12 (36%)
Technical (SIDO/VETA)	21 (64%)

4.1.2 Possession of manufacturing permit and license by peanut butter SMEs

The biggest challenge Tanzania is facing with the private sector is that many enterprises operate informally (Mitumba, 2015). This observation is supported by the results shown in Table 3. Of the 33 peanut butter SMEs only 3(9%) had manufacturing licence and only 1 (3%) had TFDA permit and/or TBS. Majority reported inability to meet costs and requirements and being on process to apply for permit/licence respectively. Small and medium-sized enterprises (SMEs) play a critical role in economies around the world. To remain competitive, SMEs must be capable of delivering high quality products and services on-time and at a reasonable cost has to agree with the study by Musa (2008) who reported that no food production, processing, distribution company or organization can be self-sustained unless the issues of food safety and quality are properly recognized and addressed. In a bid to support this, these SMEs should be formally recognized by TFDA and TBS to ensure their products are being registered and certified by these authorities so as to assure quality and safety of their products. Quality awards offer significant publicity opportunities, particularly to the organizations that use its quality to achieve a marketing edge (Lee, 2002; Kontogeorgos and Semos, 2008). An award raises the profile of the organization and generates pride in the employees and also becomes a symbol of quality and business excellence (Lee, 2002).

Table 3: Possession of manufacturing permit and license by peanut butter SMEs in Dar-es-Salaam region (N=33)

	Frequency
Possession of manufacturing permit/license	
Yes	3 (9%)
No	30 (91%)
Possession of the TFDA permit	
Yes	1 (3%)
No	32 (97%)
Reason 1: Ability to meet the required costs	
Yes	13 (39%)
No	20 (61%)
Reason 2: Ability to meet the requirements	
Yes	7 (21%)
No	26 (79%)
Reason 3: being on process to apply for permit	
Yes	12 (36%)
No	21 (64%)
Possession of the TBS license	
Yes	1 (3%)
No	32 (97%
Reason 1: Ability to meet the required costs	
Yes	12 (36%)
No	21 (64%)
Reason 2: Ability to meet the requirements	
Yes	9 (27%)
No	24 (73%)
Reason 3: Being on process to apply for licence	
Yes	11 (33%)
No	22 (67%)

4.1.3 Quality and safety control measures and training status of the peanut butter SMEs

Table 4 shows results on quality and safety control measures by the peanut butter SMEs and their training status. It was observed that 30 (91%) of the SMEs were aware of the safety and quality requirements while 18(54%) cannot distinguish between quality and safety. Majority (87.9%) of these peanut butter SMEs rely on visual observations for quality check though these practices are not reliable and cannot be accurate and may result into variable quality during production.

The results showed that 20(61%) of the peanut butter SMEs had suitable area for storage of their raw materials and as it was observed during survey that most of them bought and use the raw materials once for their particular production. The study findings suggest that good storage of the raw materials contribute to the good performance of these studied peanut butter SMEs samples on chemical and microbial qualities. It was observed that, 21(64%) of the peanut butter SMEs had trained on Good Hygiene Practices and Good Manufacturing Practices. Observations in this study are similar to those reported by Bamidele *et al.* (2015) in previous study which revealed that respondents with good knowledge about food hygiene may have more positive attitude and good practice than those without knowledge. It is important to note that training must be applied as stringently to temporary personnel as well as permanent employees. Personnel must be trained on quality and food safety before being placed into positions that may affect the product (American Peanut Council, 2009). Agroprocessors also believed that improved storage conditions, better hygiene and training will help to improve the quality of their products (Goburdhun *et al*., 2010).

The study findings also reveal that the waste disposal management practised by these SMEs was suitable and emphasize that food waste, animal by-products and other waste materials can be a significant source of microbiological and physical contamination of food that is intended for human consumption. Such hazards could cause illness or injury to consumers and so must be prevented or minimised (Food Standards Agency, 2015).

The results of the present study in general revealed that record keeping was problems with all peanut butter SMEs (Table 4 and 5). The observations in this study suggest that there is need to train the peanut butter SMEs on aspects of record keeping and entrepreneurship skills in order to improve their performance. It has been observed from study conducted in Nigeria that lack of proper record keeping makes it impossible for owners of small businesses to do a critical assessment of their performance and therefore, calls for the maintenance of proper record keeping in enhancing their profitability and performance (Okoli, 2011).

Table 4: Quality and safety control measures and training status of peanut butter SMEs in Dar-es-Salaam region (N=33)

	Frequency
Awareness on safety and quality requirements	
Yes	30 (91%)
No	3 (9%)
Distinction between quality and safety	
Yes	15 (46%)
No	18 (54%)
Methods for monitoring product quality	
visual checks	29 (87.9%)
formal testing on quality and safety parameters	1 (3%)
others/both	3 (9.1%)
Keep inspection and testing records	
Yes	0 (0%)
No	33 (100%)
Suitable area for storage	
Yes	20 (61%)
No	13 (39%)
Waste disposal management	
Waste disposal facilities available	
Yes	28 (85%)
No	5(15%)
Waste disposal practices	
Burning	15 (45.5%)
Land filling	2 (6.1%)
As fertilizer/manure	6 (18.2%)
Selling for animal feed	4 (12.1%)
Others (combination)	6 (18.2%)
Attending training on quality and safety aspects	
Yes	21 (64%)
No	11 (36%)
Training on GHP and GMP	16 (48.5%)
Keep records for training	
Yes	2(6%)
No	31(94%)

4.1.4 Work place hygiene and personal hygiene practices

Food hygiene is the set of basic principles employed in the systematic control of the environmental conditions during production, packaging, delivery/transportation, storage, processing, preparation, selling and serving of food in such a manner as to ensure that food is safe to consume and is of good keeping quality. Various factors such as the general sanitary standards of the house, the proper use of sanitation facilities like latrines, hand-washing lavatories, refuse management systems, and dishwashing facilities affect food safety in food establishments (Ifeadike *et al*., 2014). From Table 5, it was observed that all thirty three (100%) peanut butter SMEs had no policy statement for hygiene on adherence in manufacturing of foods as per code of hygiene. To comply with the GMPs, all food processing and storage operations should be designed to facilitate maintenance and sanitation operations including the exterior of the operation, the structure of the building, and the interior facilities (American Peanut Council, 2009).The results of the present study identified some good hygienic practices exhibited by SMEs at the production site thus supporting observations reported by Malhotra *et al.* (2008).

The principle of food hygiene implies that there should be minimal handling of food items. Hand hygiene is not a new concept for prevention of microbial contamination of food in food industry (CDC, 2012). Food handlers are thus expected to observe proper hygiene and sanitation methods as the chances of food contamination largely depend on their health status and hygiene practices (Ifeadike *et al*., 2014). The findings of present study suggest strong indication of the good health status and good hygiene practices of peanut butter handlers/processors and agree with the findings reported by Hakim *et al*. (2014), although majority 27(82%) of the processors handled the peanut/peanut butter with bare hands but all 33 (100%) knew the importance of washing their hands so as to reduce the risk of food contaminations. Similar previous studies from USA (Pragle *et al*.,

2007) and Italy (Buccheri *et al*., 2007) also reported low use of hand gloves among food vendors in regular food processing or retailing except where sticky food items are processed, or when food vendors sustain injuries in their hands. In addition, it has been established over decades that foodborne outbreaks occur in food operations because of lapses in hand hygiene (Muinde and Kuria 2005; Greig *et al*., 2007).

The results of the present study revealed that majority of these SMEs in this study reported to wash their hands before handling, preparation and packaging and after visiting toilets. Moreover, hand wash facility availability, having training on food safety, knowledge on food safety and availability of potable water are the main factors influencing the health and hygiene of food handler (Lalit *et al*., 2015).The results in Table 5 also show that majority 23 (70%) of the peanut butter SMEs reported to use cold soapy water to wash their equipment and utensils while 31(94%) of the processors clean equipment/utensils with clean water only without soap. The findings of this study are similar to those reported by Musa and Akande (2003) who observed that respondents used soap and water for cleaning utensils.

Table 5: Work place hygiene and personal hygiene practices by peanut butter SMEs in Dar-es-Salaam region (N=33)

	Frequency
Policy statement for hygiene commitment in place	
Yes	
No	0(0%)
	33(100%)
Processing place is in clean condition	
Yes	30(91%)
No	3(9%)
Access to portable water at the processing place	
Yes	31(94%)
No	2(6%)
Hand washing facilities available	
Yes	20(61%)
No	13(39%)
Set cleaning plan	
Yes	
No	25(75.8%)
	8(24.2%)
Aware on importance of washing hands	
Yes	33(100%)
No	0(0%)
Washing hands before handling, preparations and packaging	
Yes	22(67%)
No	11(33%)
Washing hands after visiting toilets	
Yes	
No	26(78%)
	7(22%)
Wearing of clean and presentable clothes during processing	
Yes	19(58)
No	14(42%)
Product handling practices with bare hands	
Yes	27(82%)
No	6(18%)
Equipment/utensils cleaning	
Cleaning with warm soapy water	
Yes	7(21%)
No	26(79%)
Cleaning with cold soapy water	
Yes	23(70%)
No	10(30%)
Cleaning with water and no soap	
Yes	2(6%)
No	31(94%)
Keep detailed records for cleaning	
Yes	0(0%)
No	33(100%)

4.2 Chemical Composition

4.2.1 Ash

The results for the ash content of the collected peanut butter samples ranged from 0.26 to 7.00 %. Despite the fact that there was significant ($p < 0.05$) variation between ash mean values of peanut butter samples, statistical analysis showed that 93.9% of all the samples (i.e. 31 samples out of 33) were within the maximum acceptable limit of 5% for peanut butter as stipulated in TZS 844:2014 and only 6.1% did not meet the requirements (Table 6). The observed variations in ash content may have resulted from inferior processing activities particularly blanching, roasting and grinding of peanuts using hand tools resulted to variable particle size and presence of impurities including the remained skins attached to the peanuts (Plate 1) may possibly. The ash content values of peanut butter samples in this study are comparable to those reported by Özcan and Seven (2007), who recorded values of 1.86 to 5.5%.High ash content in food is an indication of high mineral content, although it may also be an indication of impurities in the samples (Ayoola *et al*., 2012).

Plate 1. Local processing practices of peanut butter (Source: Field survey, 2017)

4.2.2 Fat content

Table 6 shows the mean values of fat content in peanut butter ranging from 33.16 to 66.44%. Significant ($p < 0.05$) difference was found within fat content among SME peanut butter samples. Only 66.7% of the SME peanut butter samples in this study had mean fat content values which were within the requirements of 45 to 55% stipulated by TZS 844:2014 for peanut butter, the rest of the samples (33.3%) had fat content that exceeded and/or were below the requirements. The highest values of their fat content may be attributed to the oil added during processing and the lowest values probably were due to the nature of cultivars/varieties of peanuts used. Similar fat content values ranging from 37.9-56.3% were also reported in previous studies by (Dwivedi *et al*., 1996; Özcan and Seven, 2003; Yav *et al*., 2008; Önemli, 2012; Hassan and Ahmed, 2012; Chaiyadee *et al*., 2013; Mzimbiri *et al*., 2014; Chowdhury *et al*., 2015; Escobedo *et al*., 2015) who reported the variation of fat content in different cultivars under different environmental conditions

4.2.3 Protein content

The protein content in evaluated peanut butter samples ranged from 4.68 to 21.28%. Most of the SME peanut butter samples in this study were significantly ($p < 0.05$) different from each other in protein content. Variations of protein content in peanuts have been reported earlier for example Mbonwa (2013) reported 10.80 to 16.63% protein in selected cultivars of groundnuts whereas Ahmed and Young (2011) observed that the varieties of peanuts which are commonly grown around the world have an average protein content of about 25%. In addition, protein content (8.2 to 12.1%) were reported by McWatters *et al.* (2006). However, the values of protein content observed in the present study are in agreement with those reported by Nagaraj (2009) who observed that different varieties of peanuts have different protein content that is due to differences in their gene sequence, geographical location and season and/or method of cultivation. Protein quality of the peanut seed is strongly influenced by nodulation and symbiotic N fixation by symbiotic N fixing bacteria and the effect of higher levels of fertilization on nodulation (Basu *et al*., 2008).

4.2.4 Carbohydrate content

Carbohydrate mean values of the SMEs peanut butter samples in this study ranged from 13.65 to 51.40% (Table 6). There was significant difference ($p < 0.05$) in carbohydrate content between SME peanut butter samples with exception of few samples. These obtained values are similar to previous study reported by Ayoola *et al* (2012) that the carbohydrate content is slightly high, especially in the roasted groundnut, makes it a suitable source of nutrient and the carbohydrate content values for most of the samples in this study were found to be higher than previous studies of 15 to 26% reported by Boli *et al* (2013). Low carbohydrate content may be due to the variety of raw peanut used for the paste preparation (Asibuo *et al*., 2008).

Table 6: Proximate composition of SME peanut butter samples (%dry weight basis)

SME processor sample code No	Ash	Fat	Protein	Carbohydrate
PB1	2.55±0.01^{fgh}	49.69±0.36^{pq}	11.22±0.21^{ijk}	34.58±0.66^{g}
PB2	3.13±0.01^{d}	45.81±0.05^{s}	11.66±+0.24^{hi}	38.55±0.35^{d}
PB3	3.11±0.03^{d}	52.68±0.46^{kl}	13.65±0.13^{g}	29.92±0.31^{jk}
PB4	2.65±0.02^{efgh}	49.25±0.26^{q}	13.30±0.15^{g}	34.23±0.31^{g}
PB5	3.29±0.27^{d}	52.30±0.20l	13.40±0.32^{g}	29.51±0.33^{jkl}
PB6	2.50±0.01^{fgh}	55.54±0.05^{h}	6.75±0.14^{n}	33.10±0.14^{h}
PB7	2.51±0.12^{fgh}	46.87±0.20^{r}	11.39±0.11^{ij}	39.03±0.29^{d}
PB8	2.49±0.03^{fgh}	49.61±0.17^{pq}	13.17±0.33^{g}	34.00±0.44^{g}
PB9	2.07±0.03^{i}	51.01±0.13^{m}	11.74±0.09^{hi}	34.17±0.20^{g}
PB10	2.68±0.00^{efgh}	46.23±0.22^{s}	4.68±0.06^{o}	45.69±0.27^{b}
PB11	7.00±0.04^{a}	63.96±0.18^{b}	10.92±0.12^{kj}	17.80±0.13^{r}
PB12	1.49±0.18kl	57.59±0.10^{e}	8.55±0.16^{m}	31.95±0.36^{i}
PB13	1.41±0.15l	55.83±0.36^{gh}	13.22±0.39^{g}	29.43±0.41^{kl}
PB14	2.66±0.03^{efgh}	52.66±0.12^{kl}	11.62±0.16^{hi}	31.38±0.18^{i}
PB15	3.24±0.07^{d}	33.16±0.16^{u}	8.89±0.10^{lm}	51.40±0.05^{a}
PB16	0.26±0.01^{n}	57.37±0.11^{ef}	11.49±0.24^{ij}	29.70±0.20^{jkl}
PB17	2.72±0.01^{efg}	66.44±0.11^{a}	16.91±0.13^{c}	13.65±0.20^{s}
PB18	1.29±0.02l	56.84±0.09^{f}	9.36±0.13l	29.88±0.20^{jk}
PB19	2.51±0.03^{fgh}	50.47±0.06^{mn}	13.18±0.14^{g}	31.42±0.2^{1i}
PB20	0.36±0.00^{n}	60.18±0.05^{d}	10.67±0.20^{k}	22.08±0.26o
PB21	2.83±0.01^{e}	54.30±0.09ij	12.21±0.27^{h}	30.45±0.21j
PB22	2.44±0.07^{gh}	54.17±0.19^{j}	16.04±0.19^{d}	26.14±0.38^{m}
PB23	1.82±0.0^{3}j	53.06±0.31^{k}	8.73±0.14^{m}	35.86±0.41f
PB24	1.29±0.03l	52.54±0.33k^{l}	7.23±0.18^{n}	37.15±0.40^{e}
PB25	0.99±0.12^{m}	63.12±0.14^{c}	14.55±0.28^{f}	18.85±0.35^{q}
PB26	1.28±0.03l	56.16±0.11^{g}	21.28±0.02^{a}	19.75±0.11^{p}
PB27	2.75±0.22^{ef}	64.10±0.13^{b}	13.33±0.14^{g}	18.52±0.42^{qr}
PB28	1.67±0.04^{jk}	54.81±0.19^{i}	17.39±0.26^{c}	23.54±0.24^{n}
PB29	2.40±0.11^{h}	57.16±0.10^{ef}	19.20±0.08^{b}	20.06±0.15^{p}
PB30	1.79±0.02^{j}	44.32±0.15^{t}	8.94±0.25l^{m}	40.83±0.39^{c}
PB31	4.07±0.04^{c}	50.35±0.07^{no}	15.33±0.28^{e}	28.90±0.25l
PB32	1.81±0.02^{j}	52.34±0.07l	10.69±0.17^{k}	34.70±0.22^{g}
PB33	5.27±0.08^{b}	49.87±0.12^{op}	9.08±0.16l^{m}	34.76±0.32^{g}

Values are means ± standard error of the mean of triplicate determinations. Values in the same column having the same superscripted letters are not significantly different ($p > 0.05$) according to Duncan Multiple Range Test

4.3 Chemical Properties of the SME Peanut Butter Samples

4.3.1 Salt (NaCl)

The SMEs peanut butter analysed had a mean salt (NaCl) content values that ranged from 0.08 to 1.23 % (Table 7).These observations suggest that the salt content of all (100%) peanut butter samples fell within the requirements of maximum 2% as indicated in TZS 844:2014. Majority of the samples (PB 9, PB 11, PB 13, PB 15, PB 21, and PB 28) in this study did not differ significantly ($p > 0.05$) in salt (NaCl) content. Totlani (2002) reported that, salt is the main flavoring ingredient added to the peanut butter, and the amount added is between 1.5 to 2.0%.

4.3.2 Acid Value

The results for acid value showed that 10 (30.3%) of peanut butter samples did not differ significantly ($p > 0.05$) whereas 4 (12.1%) differed significantly ($p < 0.05$) from the rest (Table 7).The results in this study may suggest that the acid value variations in peanut butter samples were due to roasting process involved. The results showed that, all studied peanut butter samples fell within the requirements (4.0 mg/KOH/g) for in TZS 814:2014. The previous study by Ayoola *et al*. (2010), in examining the effect of peanut heat treatment on quality changes concerning acid value of peanut fat, found that fat extracted from peanuts subjected to roasting was characterized by a higher acid value compared to fat extracted from raw peanuts and according to Özcan and Seven (2003), acid value content of peanut butter of both varieties (i.e.ÇOM and NC-7) decreased according to the seed type.

4.3.3 Peroxide Value and Anisidine Value

The results of the present study showed that peroxide value of peanut butter samples ranged from 8.32 to 45.84 $mEqO_2/kg$ (Table 7). The peroxide value of the peanut butter samples differed significantly ($p < 0.05$) from each other with exceptional of few samples which did not differ statistically ($p > 0.05$).The findings for peroxide value in this study are in close agreement with those reported by Akubugwo and Ugbogu (2007) that fresh oils have peroxide value less than 10 mEqO_2/kg and values between 20 and 40 mEq O_2/kg results in rancid taste. Previous studies reported by Matsiko *et al* (2014) on peanut butter observed values of 8.50 mEqO_2/kg. The obtained values of PV in the present study are higher than maximum acceptable value of 10 mEqO_2/kg set by the Codex Alimentarius Commission (CAC, 2001). Peroxide value is used to monitor the development of rancidity through the evaluation of the quantity of peroxide generated in the product (initiation product of oxidation). The peroxide value is usually less than 10 per gram of a fat sample when the sample is fresh. Peroxide value decreases with an increase in temperature. Peroxide value is an indication of level of deterioration of oil (Akanni *et al*., 2005). Low peroxide values further confirms the stability of the oil and indicate the ability of the oil to resist lypolitic hydrolysis and oxidative deterioration. Oil separation leads to lipid peroxidation of peanut butter which develops off-flavour and results in rancidity (Gills and Resurreccion, 2000a) and this is the problem with natural peanut butter due to absence of stabilizer. However, Schorno *et al*. (2009) reported higher PV of natural peanut butter of longer grinding time and thus could be due to the greater exposure of lipid content susceptible to oxidation as a result of higher surface to volume ratio of the peanut butter particles. The higher peroxide values obtained in current study suggest that the grinding process could be the source for the increase of PV as it was obviously observed in this study because most of the peanut butter SME were using hand grinding machine which take much longer time.

The present study also revealed that the anisidine values for the tested peanut butter samples ranged from 0.43 to 27.37. The anisidine values obtained are in contrast with values (8.59 to 76.72) reported by Jerzewska (1991) suggesting the content of secondary products of oxidation and was statistically ($p < 0.05$) different between majority of the peanut butter SMEs samples as compared to twelve samples that were not significantly differ ($p > 0.05$) (Table 7). The variation for AV and PV from the analyzed peanut butter samples in this study as observed during visit was probably due to the poor quality and/or improper storage conditions of the raw materials as well as nature of the oils used as ingredients in peanut butter processing. Most of the SME peanut butter samples were natural peanut butter, adding only little amount of salt, oil as well as some little sugar (in some of the processors) and they did not use stabilizers (hydrogenated vegetable oils) at all due to scarcity and cost. Majority of the peanut butter SMEs used normal refined vegetable oils (such as sunflower oil, palm olein etc.) which they just buy from the local markets of which their quality is not guarenteed. The type of oils used might likely have already undergone oxidation prior to usage.

Table 7: Chemical properties of SME peanut butter samples

SME sample code	**Salt** (%)	**Acid Value** (mg KOH/g)	**Peroxide Value** (mEq O_2/kg)	**Anisidine Value**
PB1	0.20 ± 0.00^{n}	0.18 ± 0.01^{on}	26.96 ± 1.21^{h}	4.19 ± 0.15^{k}
PB2	0.73 ± 0.02^{g}	0.20 ± 0.03^{on}	9.05 ± 0.23^{uv}	3.07 ± 0.08^{l}
PB3	$0.30\pm0.01l^{m}$	0.18 ± 0.01^{on}	11.47 ± 0.22^{s}	0.50 ± 0.03^{qr}
PB4	$0.32\pm0.00l^{m}$	0.15 ± 0.01^{on}	45.84 ± 0.24^{a}	18.42 ± 0.15^{e}
PB5	1.23 ± 0.02^{a}	0.13 ± 0.00^{on}	23.35 ± 0.45^{j}	0.89 ± 0.12^{pq}
PB6	0.18 ± 0.01^{no}	0.56 ± 0.04^{jk}	17.10 ± 0.11^{q}	25.40 ± 0.18^{b}
PB7	0.56 ± 0.02^{hi}	0.40 ± 0.01^{m}	$21.75\pm0.44l^{m}$	0.95 ± 0.04^{op}
PB8	0.44 ± 0.02^{k}	0.14 ± 0.04^{on}	9.23 ± 0.13^{uv}	4.96 ± 0.10^{j}
PB9	0.08 ± 0.00^{p}	0.16 ± 0.01^{on}	41.13 ± 0.15^{c}	3.99 ± 0.03^{k}
PB10	$0.35\pm0.01l^{m}$	0.15 ± 0.01^{on}	23.21 ± 0.30^{jk}	2.42 ± 0.11^{m}
PB11	0.09 ± 0.01^{p}	0.88 ± 0.01^{h}	32.00 ± 0.56^{f}	4.90 ± 0.07^{j}
PB12	$0.78\pm.01f^{g}$	0.93 ± 0.02^{h}	42.52 ± 0.27^{b}	17.12 ± 0.26^{f}
PB13	0.08 ± 0.00^{p}	1.08 ± 0.04^{h}	19.08 ± 0.25^{o}	25.69 ± 0.34^{b}
PB14	1.07 ± 0.04^{b}	0.41 ± 0.01^{g}	25.16 ± 0.1^{6i}	0.43 ± 0.05^{r}
PB15	0.13 ± 0.01^{op}	0.43 ± 0.01^{m}	10.46 ± 0.16^{t}	1.17 ± 0.02^{o}
PB16	0.97 ± 0.03^{cd}	$0.10\pm0.01l^{m}$	23.21 ± 0.17^{jk}	0.63 ± 0.01^{pqr}
PB17	0.81 ± 0.03^{f}	2.61 ± 0.10^{d}	8.54 ± 0.18^{v}	5.78 ± 0.1^{1i}
PB18	0.48 ± 0.02^{kj}	0.15 ± 0.00^{on}	14.53 ± 0.13^{r}	27.37 ± 0.15^{a}
PB19	0.60 ± 0.01^{h}	3.49 ± 0.09^{a}	20.23 ± 0.31^{n}	3.40 ± 0.05^{l}
PB20	1.08 ± 0.01^{b}	$0.43\pm0.01l^{m}$	30.54 ± 0.29^{g}	4.32 ± 0.11^{k}
PB21	0.08 ± 0.00^{p}	0.55 ± 0.00^{jk}	9.54 ± 0.10^{fu}	4.03 ± 0.25^{k}
PB22	0.59 ± 0.02^{h}	2.41 ± 0.01^{e}	22.33 ± 0.28^{kl}	3.97 ± 0.36^{k}
PB23	$0.78\pm0.01f^{g}$	2.97 ± 0.07^{c}	9.91 ± 0.13^{tu}	1.88 ± 0.06^{n}
PB24	1.02 ± 0.00^{bc}	0.65 ± 0.01^{ij}	20.90 ± 0.21^{mn}	1.32 ± 0.02^{o}
PB25	0.96 ± 0.03^{cd}	3.36 ± 0.09^{b}	41.98 ± 0.21^{bc}	20.40 ± 0.14^{c}
PB26	0.42 ± 0.01^{k}	1.27 ± 0.01^{f}	11.44 ± 0.13^{s}	4.39 ± 0.14^{k}
PB27	0.97 ± 0.02^{cd}	0.64 ± 0.05^{j}	26.77 ± 0.18^{h}	4.04 ± 0.09^{k}
PB28	0.10 ± 0.00^{p}	3.35 ± 0.04^{b}	$22.09\pm0.07l$	1.81 ± 0.04^{n}
PB29	0.29 ± 0.01^{m}	0.75 ± 0.01^{i}	14.60 ± 0.12^{r}	25.39 ± 0.07^{b}
PB30	0.88 ± 0.06^{e}	2.71 ± 0.00^{d}	40.07 ± 0.22^{d}	19.26 ± 0.10^{d}
PB31	$0.36\pm0.02l$	0.23 ± 0.01^{n}	34.68 ± 0.18^{e}	9.84 ± 0.08^{h}
PB32	0.53 ± 0.04^{ij}	3.05 ± 0.01^{c}	18.08 ± 0.16^{p}	13.62 ± 0.08^{g}
PB33	0.91 ± 0.03^{de}	0.53 ± 0.01^{kl}	8.32 ± 0.16^{v}	5.39 ± 0.14^{i}

Values are means ± standard error of the mean of triplicate determinations. Values in the same column having the same superscripted letters are not significantly different ($p > 0.05$) according to Duncan Multiple Range Test

4.4 Mineral Content of Peanut Butter SMEs Samples

Peanut butter samples from the 33 SMEs were rich in magnesium and calcium. Magnesium content ranged from 1723.01 to 2553.63 mg/kg and Calcium from 332.19 to 668.64 mg/kg (Table 8). The results of the present study showed that about 60 % of the samples from SMEs did not differ significantly ($p > 0.05$) in Mg and Ca content. However, peanut butter samples from SMEs had significantly ($p < 0.05$) higher magnesium content than the rest (Table 8). These minor and major variations in mineral content of peanut butter samples could probably be due to differences in climatic conditions, soil structure and environmental temperature during maturation of peanut kernels used to make the peanut butter. Peanut butter is rich in variety of minerals. This is supported by the study reported by Özcan and Seven (2003) who found both peanut seeds and butter of ÇOM and NC-7 cultivars were rich in these minerals in good amount (11474.4 – 89377.9 mg/kg). Ayoola and Adeyeye (2010) stated that roasted groundnut used for peanut butter manufacturing was more advantageous in mineral content than the raw ones. The mineral content findings in the study also relates in some way with the study by Özcan (2006) who reported high amounts of these minerals determined as 644.56 mg/kg Ca and 1377.2 mg/ kg Mg.

Table 8: Mineral content of peanut butter SMEs samples (mg/kg) on dry weight basis

SME sample code	Magnesium	Calcium
PB1	2100.43±53.50^{fghi}	550.17±8.49^{cdefgh}
PB2	2169.94±83.46^{defghi}	502.94±12.72^{fghi}
PB3	2210.30±33.64^{cdefg}	488.95±8.52^{ghi}
PB4	2374.21±31.88^{abcde}	555.41±9.58^{cdefg}
PB5	2296.37±176.42^{bcdefg}	543.04±41.08^{defghi}
PB6	2553.63±23.91^{a}	616.29±6.05^{bcde}
PB7	2137.54±138.19^{fghi}	498.37±26.89^{fghi}
PB8	1889.37±47.97^{jkl}	380.65±23.95^{jkl}
PB9	2178.80±78.42^{defghi}	648.29±29.53^{bc}
PB10	2165.65±68.98^{defghi}	628.29±16.80^{bcd}
PB11	1967.71±64.29^{ijk}	549.26±29.41^{cdefgh}
PB12	2175.17±12.72^{defghi}	493.51±6.65^{cdefgh}
PB13	2106.17±37.31^{fghi}	533.15±19.58^{defghi}
PB14	2415.49±50.57^{abc}	447.12±13.27^{hijk}
PB15	2485.44±42.73^{ab}	598.38±16.54^{cdef}
PB16	2067.24±30.73^{ghi}	363.48±12.20^{kl}
PB17	2111.12±17.72^{fghi}	510.46±9.23^{fghi}
PB18	1972.56±55.85^{hij}	622.43±15.23^{bcde}
PB19	2185.09±60.80^{defghi}	444.25±9.75^{hijk}
PB20	2145.83±82.33^{efghi}	532.35±21.93^{defghi}
PB21	2455.69±75.11^{ab}	529.47±23.05^{defghi}
PB22	2265.01±63.78^{cdefg}	499.19±7.66^{fghi}
PB23	2089.84±43.68^{fghi}	600.04±6.70^{bcdef}
PB24	2312.32±42.79^{bcde}	437.25±2.81^{ijk}
PB25	2065.22±61.58^{ghi}	551.75±23.18^{cgh}
PB26	2099.12±85.27^{fghi}	668.64±16.65^{a}
PB27	1825.29±38.29^{kl}	469.52±19.30^{ghij}
PB28	1949.99±60.33^{ijk}	508.12±14.82^{fghi}
PB29	2097.15±49.74^{fghi}	516.76±8.80^{efghi}
PB30	2383.28±99.61^{abcd}	752.67±24.72^{a}
PB31	1964.10±85.76^{ijk}	332.19±144.11l
PB32	2167.16±55.36^{defghi}	547.07±13.11^{defgh}
PB33	1723.01±84.32l	471.31±28.25^{ghij}

Values are means ± standard error of the mean of triplicate determinations. Values in the same column having the same superscripted letters are not significantly different ($p > 0.05$) according to Duncan Multiple Range Test**.**

4.5 Microbiological Quality of the SMEs' Peanut Butter samples

Peanut butter and other nut butter products are usually regarded as microbiologically stable and safe for consumption owing to the inherent low water activity between 0.22–0.30 as it cannot support the growth and proliferation of bacterial pathogens (Rozalli *et al*., 2016). However the presences of *Escherichia coli*, *Proteus sp,* and *Salmonella sp* in peanut butter samples indicate the possibility of a microbial hazard and fecal contamination.

4.5.1 *Escherichia coli*

Escherichia coli is commonly used as surrogate indicator, its presence in food generally indicate direct and indirect faecal contamination (Clarence *et al*., 2009; Adebayo-Tayo *et al*., 2012a). *Escherichia coli* contamination in nut and nut products is also a concern as the presence of *Escherichia coli* in nuts normally indicates that products have been handled poorly during processing. Manual de-shelling also increases the exposure to microbial contamination (Freire and Offord, 2002). All of the peanut butter samples in this study were categorised as safe due to absence of *Escherichia coli* and they met the requirements for TZS 844:2014 and this might be attributed to the fact that these samples were still fresh from production and not exposed to contamination for a long time. Also suggesting that these peanut butter SMEs observed good hygienic as well as manufacturing practices during processing and handling of their products.

4.5.2 Yeast/Molds

It is clear from Table 9 that yeast/moulds were not present in twenty five (76%) peanut butter samples examined whereas eight (24%) samples showed low counts of between 0.85 to 1.33 $\log_{10}$ CFU/g. Statistical analysis showed that no significant difference ($p > 0.05$) between these SME peanut butter samples. However, the obtained results in all samples were lower than the acceptable limit of 3 $\log_{10}$ CFU /g of TZS 844:2014 and may not present any health hazard.

Table 9: Yeast/Molds count of the tested peanut butter from SME processors in Dar es Salaam region

SME sample code no	Yeast/Molds counts (Log_{10} CFU/g)
PB1	0.85[b]
PB2	*
PB3	0.85[b]
PB4	*
PB5	0.85[b]
PB6	*
PB7	*
PB8	*
PB9	0.85[b]
PB10	*
PB11	1.34[a]
PB12	*
PB13	*
PB14	*
PB15	1.26 [a]
PB16	*
PB17	*
PB18	*
PB19	*
PB20	*
PB21	*
PB22	*
PB23	*
PB24	*
PB25	*
PB26	*
PB27	1.00[b]
PB28	*
PB29	*
PB30	*
PB31	*
PB32	*
PB33	0.85[b]

Key: * = No growth

Each value is the mean ± standard error of the mean. Mean values in the column having same superscripts are not significantly different ($p < 0.05$) according to Duncan Multiple Range Test

Low counts of yeast/moulds observed in some of these SME peanut butter samples might have resulted from either poor processing conditions, using contaminated raw materials, inadequate knowledge on Good Manufacturing Practice (GMP) or probably the use of contaminated water during processing (Appendix 2) and this is in agreement with observations reported by Odu and Okonko (2012) that lack of Hazard Analysis and

Critical Control Points (HACCP) programs, coupled with inadequate understanding on Good Manufacturing Practices can lead to yeast and moulds contamination in food.

4.5.3 *Salmonella*

The presence of *Salmonella* was not detected in all peanut butter samples in this study. When assessed against the USDA acceptable microbial levels in peanut paste, these observations suggest that all peanut butter samples in this present study were classified as microbiologically acceptable (USDA, 2010).In general, high fat, less carbohydrate content and higher storage temperature (21 °C) are effective methods for reducing *Salmonella* population in peanut butter (Burnett *et al*., 2000, He *et al*., 2011). *Salmonella* cannot multiply on nuts or in nut products, however the organism can survive on and in these products, for an extended period (greater than one year), especially when held in cold storage (Danyluk *et al.*, 2007). It was speculated that cells of *Salmonella* clump or aggregate near the water phase and differences in the rate of inactivation was attributed to the differences in the size of the water and lipid droplets dispersed in the peanut meal (Burnett, 2000).

4.6 Aflatoxin Contaminations.

Twenty eight (84.8%) of the peanut butter samples were contaminated with total aflatoxin ranging from 0.70 to 425.63 µg/kg. It was observed that 46.4% of the contaminated peanut butter samples exceeded the maximum total aflatoxin level of 15 µg/kg while the rest (53.6%) met the maximum acceptable level as stipulated in TZS 844:2014.The Tanzania standard limit for aflatoxin B1 is 5 µg/kg in peanut butter meant for direct human consumption and in this study aflatoxin B1 (AFB1) had the concentration ranging from 0.70 to 380.80 µg/kg as detected in all twenty three (69.7%) samples whereby sixteen (69.6%) of the detected samples were above the limits and only seven (33.3%) samples complied with the requirements for TZS 844:2014. Significant difference ($p < 0.05$) in aflatoxin levels was observed among the peanut butter samples with exception of

AFGI of which there was no statistical difference ($p > 0.05$) between samples (Table 10). The differences in aflatoxin contamination found in this study might be due to the nature and/or handling practices of the raw materials used as well as the environmental conditions (hot and humid) prevalent in the processing area. In addition during the survey, it was observed that these peanut butter SMEs inspect the raw materials visually without testing the quality and safety of raw materials. However all these peanut butter SMEs did not have any records to assure the status of their raw materials. Few processors stored the peanuts for long before grinding as observed instead of grinding the roasted peanuts immediately after roasting. It was even observed that some of these peanut butter SMEs failed to clean the grinder after the previous peanut butter production, also cooling of roasted nuts on the floor and/or outside in the open area attributed the exposure of the nuts to polluted environment. These practices might have created conducive conditions for contamination of aflatoxin that might have affected the peanut butter. Higher total aflatoxin levels (26.6 to 853 μg/kg) in peanut butter have also been reported in Sudan with 90% of the samples exceeding the European Union maximum limit of 20 μg/kg (Elzupir and Amar, 2011). Variation in aflatoxin levels among groundnut and peanut butter samples ranging from 0.0 to 2377.1 μg/kg has been reported by Ndung'u *et al*. (2013).

Table 10: Aflatoxin contamination levels in peanut butter samples collected from SME processors in Dar-es-Salaam region (µg/kg)

SME sample code	AFG1	AFB1	AFG2	AFB2	TOTAL AFs
PB1	*	*	*	1.99± 0.21^{fg}	2.49±0.37^{qr}
PB2	9.54±1.85^{b}	72.18±2.41^{d}	4.21±0.70^{bcd}	15.46± 6.65^{c}	101.3±95.76^{d}
PB3	*	17.92±0.62^{e}	*	12.41± 0.27^{cd}	30.33±0.35^{f}
PB4	*	0.70±0.12^{m}	*	*	0.70±0.22^{r}
PB5	*	380.80±10.12^{a}	4.98±1.13^{b}	39.84± 2.14^{b}	425.63±31.25^{a}
PB6	*	6.88±0.07^{g}	2.17±0.11^{fg}	2.00± 0.06^{fg}	11.05±0.24^{klm}
PB7	*	4.38±0.19^{hij}	1.09±0.08^{g}	2.21± 0.07^{fg}	7.68±0.26^{mno}
PB8	*	9.98±0.14^{f}	3.25±0.13^{cdef}	2.27± 0.12^{fg}	15.50±0.38^{hij}
PB9	*	3.28±0.11^{ijk}	*	3.28± 0.19^{fg}	6.56±0.30^{nop}
PB10	*	7.08±0.71^{g}	4.87±0.08^{b}	*	11.95±0.78^{jkl}
PB11	*	282.28±0.99^{c}	*	45.47± 0.35^{a}	327.75±1.35^{c}
PB12	*	*	*	*	*
PB13	*	*	*	*	*
PB14	*	16.95±0.13^{e}	*	6.93± 0.05^{ef}	23.88±0.12^{g}
PB15	*	*	11.02±0.01^{a}	12.80± 0.16^{c}	23.82±0.16^{g}
PB16	*	1.56±0.15^{klm}	*	8.12± 0.14^{de}	9.68±0.06l^{mno}
PB17	*	*	3.31±0.23^{cdef}	*	3.431±0.22^{qr}
PB18	*	1.17±0.04l^{m}	3.11±0.03^{def}	5.21± 0.12^{efg}	9.49±0.13l^{mno}
PB19	2.98± 0.02^{d}	5.35±0.05^{hg}	3.56±0.04^{cde}	*	11.89±0.04^{jkl}
PB20	*	73.82±1.03^{d}	*	2.44± 0.25^{gh}	76.26±1.13^{e}
PB21	*	*	*	*	*
PB22	*	*	2.13±0.05^{fg}	5.05± 0.07^{efg}	7.18±0.06^{mno}
PB23	*	*	*	*	*
PB24	1.44±0.02^{de}	16.23±0.41^{e}	*	6.47± 0.35^{efg}	24.14±0.63^{g}
PB25	1.57± 0.06^{de}	5.29±0.12^{gh}	*	3.02± 0.10^{fg}	9.89±0.24l^{mn}
PB26	12.25± 0.34^{a}	5.96±0.20^{gh}	*	*	18.21±0.45^{h}
PB27	*	329.50±20.49^{b}	11.32±0.15^{a}	44.95± 0.56^{a}	385.80±1.17^{b}
PB28	6.18± 0.12^{c}	*	4.38±0.10^{bc}	3.16± 0.09^{fg}	13.72±0.13^{ijk}
PB29	*	1.11±+0.05l^{m}	1.54±0.24^{g}	3.09± 0.06^{fg}	5.74±0.28^{opq}
PB30	*	5.20±0.09^{ghi}	*	11.64± 0.28^{cd}	16.84±0.29^{hi}
PB31	2.44± 0.07^{de}	10.10±0.08^{f}	2.96±0.11^{ef}	1.40± 0.06^{fg}	16.90±0.25^{hi}
PB32	*	*	*	*	*
PB33	1.47± 0.04^{de}	2.98±0.12^{jkl}	*	2.30± 0.12^{fg}	6.76±0.25^{nop}

Key: * = Not Detected. Values are means ± standard error of the mean of triplicate determinations. Values in the same row having the same superscripted letters are not significantly different ($p > 0.05$) according to Duncan Multiple Range Test.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This research aimed on providing information on the quality and safety of peanut butter processed by SMEs in Dar es Salaam region. The study has enabled to conclude that the majority of the peanut butter samples processed by the selected SMEs had satisfactory chemical qualities and complied with the requirements stipulated in Tanzania Standard (TZS 844:2014). The results also revealed that the microbiological quality of peanut butter processed by these SMEs was generally very good. Also majority of these peanut butter SMEs had the required general knowledge towards quality and safety aspects and observed good hygienic as well as manufacturing practices during processing and handling of their products despite of several production challenges observed including lack of manufacturing permits and licences, poor processing technology, lack of proper facilities to monitor quality and safety of their product and lack of records keeping. The high contamination levels of aflatoxin found in these SMEs' peanut butter samples threat the safety of these products and raise a public health concern.

5.2 Recommendations

Based on the findings of this study, the following actions are proposed by the researcher;

i. It would be encouraging to get more information of various SME food products including peanut butter on reflection of quality and safety. Peanut butter SMEs need to improve their processing activities particularly advancement in processing equipment and facility construction (buildings) as recommended by regulatory requirements for the continuous production of quality and safe peanut butter products.

ii. SME peanut butter processors need to be continually enlightened on the proper ways of processing and solving the current experienced problems associated with them so as to avoid and/or reduce the risks that could be associated with poor quality of products.

iii. Inspection and monitoring should be made mandatory for the SME peanut butter processors with effective monitoring to ensure compliance and punitive measures should be appended to non-compliance.

iv. Tanzania Bureau of Standards should strengthen monitoring for compliance by amending and improving the peanut butter standard (TZS 844: 2014) which has been set so as to include other crucial requirements such as mineral contents, protein, peroxide and anisidine values which have been observed to be of paramount importance on assessing the quality status of peanut butter.

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APPENDICES

Appendix 1: Questionnaire for Peanut Butter SMEs

Scope:

My name is Zena Chijoriga, a student from Sokoine University of Agriculture. I am currently doing my research on assessment of quality and safety of peanut butter produced by SMEs. This research has to be completed for me to be able to graduate for MSc. Food Quality and Safety Assurance. This questionnaire applies to all selected peanut butter SMEs in Dar es Salaam region. It aims to get more information on production challenges from SMEs regarding quality and safety of peanut butter produced. The quality and safety will mainly evaluate the production means and the controls implemented in the factory/premise to prevent final products from main microbiological, chemical and physical risks. You are asked to respond to questions in this questionnaire which are strictly confidential and will be used for study purposes only to facilitate the intended learning at the Sokoine University of Agriculture.

1.0 General Information:

1.1 Processor/enterprise Name………………………………Code No………………

1.2 Date of Interview……………………………………………………………….

1.3 Name of Person interviewed…………………………….....................His/her position in a particular Processor……………………...

1.4 Processor's Address

P.O.Box…………………….Tel/Mob.………………Email……….………….

District……………………Street…………………..Region…………………

2.0 Enterprise's attributes

2.1 Do you have business (food) manufacturing permit/ license? .Yes/No (tick one)

If Yes, provide business licence number……………………

2.2 How many employees do you have (please fill out the current number of employees) (in general figure) …………… people

2.3 What is your education level (tick the appropriate)

i) Technical College/University…....

ii) VETA………..

iii) SIDO…………

iv) Others…………

2.4 Production capacity

i) Daily Average…......……….. …

ii) Monthly Average……….……..

iii) Annual Average………………..

2.5 Do you have TFDA permit? Yes/No (tick one)

If Yes, state the registration no……………………. and date…………………….

If No, give brief reasons……………………………………………………………

2.6 Do you have TBS license? Yes/No (tick one)

If Yes, state the license no…………………… and date…………………………

If No, give brief reasons………………………………………………………..

3.0 Quality and Safety aspects

3.1 Are you aware of quality and safety control measures? Yes/No (tick one)

3.2 Do you know the source of all raw materials used? Yes/No (tick one)

3.3 Do you know the safety and quality requirements for peanuts/groundnuts, packaging materials and other raw materials used? Yes/No (tick one)

If Yes give details……………………………………………………………

………………………………………………………………………………

3.4 Do you have suitable area for storage of peanuts/groundnuts, packaging materials and other raw materials intended for production of peanut butter? Yes/No (tick one)

If No how do you store your peanuts/groundnuts, packaging materials and other raw materials?………………………………………………………………………

………………………………………………………………………………………..

3.5 Is the size of your storage enough for your activities? Yes/No (tick one)

3.6 Is there a distinction between Quality and Safety issues in your factory/premise? Yes/No (tick one) If Yes, Could you explain the difference for your factory/premise?

…………………………………………………………………………………………

……………………………………………………………………………………

3.7 Which indicators do you use to monitor and adjust quality? (tick the appropriate)

i) Visual quality checks (i.e. colour, aroma, taste, oil separation, insect damage, spread ability etc.)

ii) Testing/inspecting peanut butter for microbiological/chemical parameters

iii) Others (indicate)…………………………………………………………...

………………………………………………………………

3.8 What positive effects do you expect (or have already been achieved) as a result of quality management**?** (tick the appropriate)

i) Good peanut butter quality performance

ii) Employee satisfaction/performance

iii) Customer satisfaction results

iv) Others (indicate)…………………………………………………………...

3.9 Has your premise/factory experienced any negative effects as a result of quality management? Yes/No (tick one). If Yes, explain…………………………………

3.10 Do you know that washing hands before work reduces the risk of food contamination? Yes/No/ Do not know (tick one).If Yes, where in particular do you wash your hands? (ticking all that apply)

v) the wash room……….

vi) in the toilet ………….

vii) washing sink/basin in processing area………..

3.11 Do you check the condition status of the environment (temperature) periodically to reduce the risk of peanut/peanut butter contamination? Yes/No (tick one).If Yes, explain………………………………………………………………………………………

…………………………………………………………………………………………………

3.12 Have do you set up a cleaning plan? Yes/No (tick one)

If YES, does it include; the roofs? Yes/No (tick one), the waste storing areas? Yes/No (tick one), the dustbins and waste containers? Yes/No (tick one), the equipment? Yes/No (tick one).

3.13 How often the cleaning for peanut butter processing is done? (tick the appropriate)

i) Cleaning before processing ……………..

ii) Cleaning after processing ………………

iii) Cleaning before and after processing……………

3.14 Do you use any aid in cleaning to remove soils and oil residues on different surfaces in your processing plant? (tick the appropriate)

i) Detergents…………………

ii) Liquid soap……...………..

iii) Hot water ………………….

iv) Combination of hot water and detergents/soap……………..

3.15 Do you keep a record for list of cleaning products/operations used? Yes/No (tick one)

3.16 What is the origin/source of the running water used?

i) Municipal source

ii) Well/bore water

iii) Reserve tank

iv) Other source (indicate)…………………………………

3.17 How do you dispose of wastes and by-products from the processing plant?

i) burning…………………

ii) landfilling……...………..

iii) as fertilizer/manure……………

iv) selling for animal feed ………………….

v) Others…………………………

3.18 Do you and the employees attend any training on quality and safety aspects of peanut butter processing? Yes/No (tick one).If yes specify;

i) Quality and management systems………….

ii) Cleaning and Sanitation……………………

iii) Hygiene and Good hygiene Practices and Good Manufacturing Practices…… (tick the appropriate)

3.19 Challenges/Problem(s) in peanut butter production (Select by ticking all that apply)

i) Insufficient production capacity due to lack of facilities/inferior technology (..…)

ii) Difficulty in quality/safety control (……)

iii) Other (indicate) (…………………………………………………………)

Many thanks for completing this questionnaire.

Observation Checklist

1.0 General Information

Processor/enterprise Name………………………Code No……………………………

Processors' Address: P.O. Box………………………Tel/Mob.…………………..

Email………..… District…………………Street……………………….

Region…………………..

Date of observing………………………

2.0 Facilities

2.1 Is premise protected from sun, dust, wind, etc.? Yes/No (tick one)

2.2 Is the premise maintained in a clean condition? Yes/No (tick one)

2.3 Is there access to potable water at the site or close to the site? Yes/No (tick one)

2.4 Are adequate hands washing facilities available? Yes/No (tick one)

2.5 Is the cleaning facilities maintained in a clean condition? Yes/No (tick one)

2.6 Are adequate waste (water or food) disposal facilities available? Yes/No (tick one)

3.0 Environment around the premise

3.1 Is environment around the premise clean: far from rubbish, waste water, toilet facilities, open drains and animals? Yes/No (tick one)

4.0 Personal hygiene

4.1 Do operators wash their hands in clean water each time before handling, preparation and packaging the peanut butter? Yes/No (tick one)

4.2 Do operators wash their hands each time after visiting the toilet? Yes/No (tick one)

4.3 Are the operators' clothes clean and presentable? Yes/No (tick one)

4.4 Do operators handle peanut/peanut butter with bare hands? Yes/No (tick one)

If answer is No, do they use disposable or reusable gloves?

4.5 Are the gloves cleaned properly i.e. in clean water (with or with soap) before the handling, preparation and packing of peanut butter?

Please note down any unhygienic behaviour you may notice by the operator

…………………………………………………………………………………………

5.0 Peanut butter storage

5.1 Is peanut butter stored/displayed? Openly in the premise……………….. In sealed (transparent or opaque) containers ………………………

6.0 Equipment / Utensils

6.1 Are equipment/utensils cleaned with? warm soapy water ……………., Cold soapy water ……………, Clean water with no soap……………

6.2 Are utensils covered when not in use? Yes/No (tick one)

6.3 Is there any pest control devices (including rodent traps and electrical fly killers)? Yes/No (tick one)

7.0 Records

7.1 Is there any written and signed policy document for hygiene commitment?

....

7.2 Is there any records for; training………………, detailed procedure for cleaning operation…………………., inspection and testing of raw materials, processes and finished peanut butter…………………

Appendix 2: Characteristics of SME Peanut Butter Processors in Dar Es Salaam Region

SME Processor Code No	No of Employee (S)	Hygienic Status	Ingredients Used	Roasting and Grinding Methods	Attended Training On Quality and Safety Aspects in Peanut Butter Processing
PB1	2	Satisfactory but most of the processing activities were done while sitting on the floor	Roasted groundnuts (peanuts) and salt	Charcoal stove and hand grinder	Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB2	5	Satisfactory	Roasted groundnuts (peanuts),salt and sugar	Charcoal oven and electric grinder	Hygiene and Good Hygiene Practices
PB3	3	Uncondusive processing area, not practice hand washing frequently and not wearing protective gears	Roasted groundnuts (peanuts) and salt	Charcoal woods and hand grinder	Hygiene and Good Hygiene Practices
PB4	1	Satisfactory	Roasted groundnuts (peanuts),salt and sugar	Electric oven and hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB5	3	Satisfactory but improper handling of processing equipment	Roasted groundnuts (peanuts),salt, sugar and vegetable oil	Electric oven and grinder (blender)	Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB6	2	Uncondusive processing area and not wearing protective garments	Roasted groundnuts (peanuts), salt, sugar and vegetable oil	Electric oven and grinder (blender)	Hygiene and Good Hygiene Practices
PB7	1	Satisfactory	Roasted groundnuts (peanuts) and salt	Charcoal stove and hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB8	5	Processing was at the uncondusive environment due to lack of sufficient space and not wearing protective garments	Roasted groundnuts (peanuts), salt, sugar and vegetable oil	Electric oven and grinder	Hygiene and Good Hygiene Practices
PB9	3	Processing was carried in uncondusive environment due to lack of sufficient space	Roasted groundnuts (peanuts), salt, sugar and vegetable oil	Charcoal stove and hand grinder	Hygiene and Good Hygiene Practices
PB10	4	Satisfactory but	Roasted	Charcoal stove	Not trained on Quality

		not wearing protective garments	groundnuts (peanuts) and salt	and electric grinder	management systems, Cleaning and sanitation and Good Hygiene Practices
PB11	8	Satisfactory but no control of entering to the processing area	Roasted groundnuts (peanuts) and salt	Electric oven and grinder	Hygiene and Good Hygiene Practices
PB12	5	Satisfactory	Roasted groundnuts (peanuts), salt, sugar and vegetable oil	Electric oven and grinder	Hygiene and Good Hygiene Practices
PB13	2	Satisfactory	Roasted groundnuts (peanuts), salt and vegetable oil	Electric cooker and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB14	5	Satisfactory	Roasted groundnuts(peanuts),salt and sugar		Cleaning and sanitation and Good Hygiene Practices
PB15	4	Satisfactory	Roasted groundnuts (peanuts) and salt	Charcoal stove and hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB16	3	Satisfactory	Roasted groundnuts (peanuts) and salt	Electric cooker and hand grinder	Hygiene and Good Hygiene Practices
PB17	10	Satisfactory	Roasted groundnuts (peanuts) and salt	Charcoal oven and electric grinder	Hygiene and Good Hygiene Practices
PB18	6	Satisfactory	Roasted groundnuts (peanuts) and salt	Electric oven and grinder	Hygiene and Good Hygiene Practices
PB19	2	Satisfactory	Roasted groundnuts (peanuts), salt and vegetable oil	Electric cooker and Hand grinder	Quality Management Systems
PB20	2	Satisfactory	Roasted groundnuts (peanut) and salt	Electric cooker and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB21	4	Satisfactory	Roasted groundnuts (peanuts) and salt	Electric oven and grinder	Hygiene and Good Hygiene Practices
PB22	3	Satisfactory but not wearing protective coats	Roasted groundnuts (peanuts), salt and vegetable oil	Charcoal stove and Hand grinder	Hygiene and Good Hygiene Practices
PB23	2	Satisfactory	Roasted groundnuts (peanuts) and	Electric oven and grinder	Quality Management Systems

			salt		
PB24	1	Satisfactory	Roasted groundnuts (peanuts) and salt	Charcoal stove and Hand grinder	Hygiene and Good Hygiene Practices
PB25	6	Satisfactory	Roasted groundnuts (peanuts), salt and vegetable oil	Electric oven and Hand grinder	Cleaning and Sanitation
PB26	3	Satisfactory	Roasted groundnuts (peanuts) and salt	Electric cooker and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB27	5	Satisfactory but no frequent hand washing habit	Roasted groundnuts (peanuts), salt and vegetable oil	Charcoal stove and Hand grinder	Hygiene and Good Hygiene Practices
PB28	2	Satisfactory	Roasted groundnuts (peanuts) and salt	Electric cooker and Hand grinder	Hygiene and Good Hygiene Practices
PB29	3	Satisfactory	Roasted groundnuts (peanuts) and salt	Electric oven and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB30	4	Satisfactory	Roasted groundnuts (peanuts), salt, sugar and vegetable oil	Charcoal stove and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB31	4	Satisfactory	Roasted groundnuts (peanuts), salt, sugar and vegetable oil	Charcoal stove and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB32	1	Satisfactory	Roasted groundnuts (peanuts), salt and vegetable oil	Charcoal stove and Hand grinder	Not trained on Quality management systems, Cleaning and sanitation and Good Hygiene Practices
PB33	5	Satisfactory but too much talking during processing without wearing the protective masks	Roasted groundnuts (peanuts), salt and sugar	Electric oven and Hand grinder	Hygiene and Good Hygiene Practices

Appendix 3: MPN indexes and confidence limits (95 %) when three test portions of 1g (ml), three of0, 1 g (ml) and three of 0, 01 g (ml) are used

Number of positive results			MPN index [a]	Category [b]	Confidence limits (95 %) [a, c]	
					Lower limit	Upper limit
0	0	0	< 0,30		0,00	0,94
0	0	1	0,30	3	0,01	0,95
0	1	0	0,30	2	0,01	1
0	1	1	0,61	0	0,12	1,7
0	2	0	0,62	3	0,12	1,7
0	3	0	0,94	0	0,35	3,5
1	0	0	0,36	1	0,02	1,7
1	0	1	0,72	2	0,12	1,7
1	0	2	1,1	0	0,4	3,5
1	1	0	0,74	1	0,13	2
1	1	1	1,1	3	0,4	3,5
1	2	0	1,1	2	0,4	3,5
1	2	1	1,5	3	0,5	3,8
1	3	0	1,6	3	0,5	3,8
2	0	0	0,92	1	0,15	3,5
2	0	1	1,4	2	0,4	3,5
2	0	2	2,0	0	0,5	3,8
2	1	0	1,5	1	0,4	3,8
2	1	1	2,0	2	0,5	3,8
2	1	2	2,7	0	0,9	9,4
2	2	0	2,1	1	0,5	4
2	2	1	2,8	3	0,9	9,4
2	2	2	3,5	0	0,9	9,4
2	3	0	2,9	3	0,9	9,4
2	3	1	3,6	0	0,9	9,4
3	0	0	2,3	1	0,5	9,4
3	0	1	3,8	1	0,9	10,4
3	0	2	6,4	3	1,6	18,1
3	1	0	4,3	1	0,9	18,1
3	1	1	7,5	1	1,7	19,9
3	1	2	12	3	3	36
3	1	3	16	0	3	38
3	2	0	9,3	1	1,8	36
3	2	1	15	1	3	38
3	2	2	21	2	3	40
3	2	3	29	3	9	99
3	3	0	24	1	4	99
3	3	1	46	1	9	198
3	3	2	110	1	20	400
3	3	3	> 110			

[a] Source: Reference [27]

[b] See Table B.6.

[c] The confidence limits given in this table are meant only to provide some idea of the influence of statistical variations on results. There will always also be other sources of variation, which may sometimes be even more important.

Appendix 4: Anova means separation

Dependent Variable: SALT (NaCl)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	11.97776364	0.37430511	278.83	<.0001
Error	66	0.08860000	0.00134242		
Corrected Total	98	12.06636364			

R-Square	Coeff Var	Root MSE	SALT Mean
0.992657	6.574718	0.036639	0.557273

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	11.97776364	0.37430511	278.83	<.0001

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The ANOVA Procedure

Dependent Variable: MAGNESIUM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	3406959.210	106467.475	7.30	<.0001
Error	66	962685.654	14586.146		
Corrected Total	98	4369644.864			

R-Square	Coeff Var	Root MSE	MAGNESIUM Mean
0.779688	5.605091	120.7731	2154.704

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	3406959.210	106467.475	7.30	<.0001

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The ANOVA Procedure

Dependent Variable: CALCIUM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	737768.9297	23055.2791	7.97	<.0001
Error	66	190985.8952	2893.7257		
Corrected Total	98	928754.8249			

R-Square	Coeff Var	Root MSE	CALCIUM Mean
0.794363	10.20762	53.79336	526.9921

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	737768.9297	23055.2791	7.97	<.0001

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The ANOVA Procedure

Dependent Variable: ACID VALUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	128.6791636	4.0212239	1053.18	<.0001
Error	66	0.2520000	0.0038182		
Corrected Total	98	128.9311636			

R-Square	Coeff Var	Root MSE	ACID VALUE Mean
0.998045	5.789658	0.061791	1.067273

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	128.6791636	4.0212239	1053.18	<.0001

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The ANOVA Procedure

Dependent Variable: PEROXIDE VALUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	11977.80147	374.30630	1240.17	<.0001
Error	66	19.92000	0.30182		
Corrected Total	98	11997.72147			

R-Square	Coeff Var	Root MSE	PEROXIDE VALUE Mean
0.998340	2.463029	0.549380	22.30505

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	11977.80147	374.30630	1240.17	<.0001

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The ANOVA Procedure

Dependent Variable: ANISIDINE VALUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	7337.669317	229.302166	3847.81	<.0001
Error	66	3.933133	0.059593		
Corrected Total	98	7341.602451			

R-Square	Coeff Var	Root MSE	ANI Mean
0.999464	2.973150	0.244117	8.210707

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	7337.669317	229.302166	3847.81	<.0001

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
pro	8	1 3 5 9 11 15 27 33

Number of Observations Read	24
Number of Observations Used	24

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The ANOVA Procedure

Dependent Variable: yeast/molds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	779.1666667	111.3095238	10.69	<.0001
Error	16	166.6666667	10.4166667		
Corrected Total	23	945.8333333			

R-Square	Coeff Var	Root MSE	yeast/molds Mean
0.823789	30.98387	3.227486	10.41667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	7	779.1666667	111.3095238	10.69	<.0001

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The ANOVA Procedure

Duncan's Multiple Range Test for yeas

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	10.41667

Number of Means	2	3	4	5	6	7	8
Critical Range	5.586	5.858	6.028	6.144	6.229	6.291	6.339

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	pro
A	21.667	3	11
A			
A	18.333	3	15
B	10.000	3	27
B			
B	6.667	3	9
B			
B	6.667	3	1
B			
B	6.667	3	3
B			
B	6.667	3	5
B			
B	6.667	3	33

Anova: AFG1

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
pro	9	1 2 19 24 25 26 28 31 33

Number of Observations Read	27
Number of Observations Used	27

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The ANOVA Procedure

Dependent Variable: AFG1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	412.2372296	51.5296537	40.51	<.0001
Error	18	22.8978000	1.2721000		
Corrected Total	26	435.1350296			

R-Square	Coeff Var	Root MSE	AFG1 Mean
0.947378	26.45292	1.127874	4.263704

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	8	412.2372296	51.5296537	40.51	<.0001

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The ANOVA Procedure

Duncan's Multiple Range Test for AFG1

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	18
Error Mean Square	1.2721

Number of Means	2	3	4	5	6	7	8	9
Critical Range	1.935	2.030	2.090	2.132	2.162	2.185	2.203	2.217

Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	pro
	A	12.2500	3	26
	B	9.5367	3	2
	C	6.1833	3	28
	D	2.9800	3	19
	D			
E	D	2.4333	3	31
E	D			
E	D	1.5733	3	25
E	D			
E	D	1.4733	3	33
E	D			
E	D	1.4433	3	24
E				
E		0.5000	3	1

Anova **AFB1**

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The ANOVA Procedure

Class Level Information

Class	Levels	Values

pro 23 2 3 4 5 6 7 8 9 10 11 14 16 18 19 20 24 25 26 27 29 30 31 33

Number of Observations Read	69
Number of Observations Used	69

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The ANOVA Procedure

Dependent Variable: AFB1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	828514.5614	37659.7528	30688.3	<.0001
Error	46	56.4499	1.2272		
Corrected Total	68	828571.0113			

R-Square	Coeff Var	Root MSE	AFB1 Mean
0.999932	2.020915	1.107778	54.81565

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	22	828514.5614	37659.7528	30688.3	<.0001

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The ANOVA Procedure

Duncan's Multiple Range Test for AFB1

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	46
Error Mean Square	1.227171

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	1.821	1.915	1.976	2.021	2.055	2.083	2.105	2.123	2.139	2.152	2.164

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	2.174	2.183	2.191	2.198	2.204	2.209	2.214	2.218	2.222	2.226	2.229

Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	pro
	A	380.8133	3	5
	B	329.5233	3	27
	C	282.2800	3	11
	D	73.8200	3	20
	D			
	D	72.1833	3	2
	E	17.9200	3	3
	E			
	E	16.9500	3	14
	E			
	E	16.2333	3	24
	F	10.1033	3	31
	F			
	F	9.9800	3	8
	G	7.0767	3	10
	G			
	G	6.8833	3	6
	G			
H	G	5.9633	3	26
H	G			
H	G	5.3467	3	19
H	G			
H	G	5.2933	3	25

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The ANOVA Procedure

Duncan's Multiple Range Test for AFB1

Means with the same letter are not significantly different.

Duncan Grouping			Mean	N	pro
H	G				
H	G	I	5.1967	3	30
H		I			
H	J	I	4.3767	3	7
	J	I			
K	J	I	3.2833	3	9
K	J				
K	J	L	2.9867	3	33
K		L			
K	M	L	1.5600	3	16
	M	L			
	M	L	1.1733	3	18
	M	L			
	M	L	1.1133	3	29
	M				
	M		0.7000	3	4

Anova AFG2

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The ANOVA Procedure
Class Level Information

Class	Levels	Values
pro	15	2 5 6 7 8 10 15 17 18 19 22 27 28 29 31

Number of Observations Read 45
Number of Observations Used 45

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The ANOVA Procedure

Dependent Variable: AFG2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	384.9264133	27.4947438	69.79	<.0001
Error	30	11.8188667	0.3939622		
Corrected Total	44	396.7452800			

R-Square	Coeff Var	Root MSE	AFG2 Mean
0.970210	14.73621	0.627664	4.259333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	14	384.9264133	27.4947438	69.79	<.0001

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The ANOVA Procedure

Duncan's Multiple Range Test for AFG2

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	30
Error Mean Square	0.393962

Number of Means	2	3	4	5	6	7	8
Critical Range	1.047	1.100	1.134	1.159	1.178	1.192	1.204

Number of Means	9	10	11	12	13	14	15
Critical Range	1.214	1.222	1.228	1.234	1.239	1.243	1.246

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	pro
A	11.3233	3	27
A			
A	11.0200	3	15
B	4.9767	3	5
B			
B	4.8700	3	10
B			
C B	4.3800	3	28
C B			
C B D	4.2133	3	2
C D			
C E D	3.5600	3	19
C E D			
C F E D	3.3067	3	17
C F E D			
C F E D	3.2500	3	8
F E D			
F E D	3.1067	3	18

```
F    E
F    E          2.9567     3    31
F
F    G          2.1700     3    6
F    G
F    G          2.1300     3    22
     G
     G          1.5367     3    29
     G
     G          1.0900     3    7
```

Anova **AFB2**

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
pro	23	1 2 3 5 6 7 8 9 11 14 15 16 18 20 22 24 25 27 28 29 30 31 33

Number of Observations Read	69
Number of Observations Used	69

The SAS System 13:38 Thursday, August 27, 2017 15

The ANOVA Procedure

Dependent Variable: AFB2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	12331.52003	560.52364	86.27	<.0001
Error	46	298.86280	6.49702		
Corrected Total	68	12630.38283			

R-Square	Coeff Var	Root MSE	AFB2 Mean
0.976338	24.27313	2.548925	10.50101

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	22	12331.52003	560.52364	86.27	<.0001

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The ANOVA Procedure

Duncan's Multiple Range Test for AFB2

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	46

Error Mean Square 6.497017

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	4.189	4.406	4.548	4.650	4.729	4.792	4.843	4.886	4.922	4.952	4.979

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	5.002	5.023	5.040	5.056	5.070	5.083	5.094	5.104	5.113	5.121	5.128

Means with the same letter are not significantly different.

Duncan Grouping			Mean	N	pro
	A		45.470	3	11
	A				
	A		44.950	3	27
	B		39.840	3	5
	C		15.460	3	2
	C				
	C		12.803	3	15
	C				
D	C		12.410	3	3
D	C				
D	C		11.637	3	30
D					
D	E		8.120	3	16
	E				
F	E		6.933	3	14
F	E				
F	E		6.473	3	24
F	E				
F	E	G	5.207	3	18
F	E	G			
F	E	G	5.043	3	22
F		G			
F		G	3.277	3	9
F		G			
F		G	3.160	3	28
F		G			
F		G	3.090	3	29

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The ANOVA Procedure

Duncan's Multiple Range Test for AFB2

Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	pro
F	G			
F	G	3.023	3	25
F	G			
F	G	2.443	3	20
F	G			
F	G	2.307	3	33
F	G			
F	G	2.270	3	8
F	G			
F	G	2.213	3	7
F	G			
F	G	2.000	3	6
F	G			
F	G	1.993	3	1
	G			
	G	1.400	3	31

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
processor	33	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

Number of Observations Read	99
Number of Observations Used	99

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The ANOVA Procedure

Dependent Variable: moisture

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	173.3594182	5.4174818	1168.48	<.0001
Error	66	0.3060000	0.0046364		
Corrected Total	98	173.6654182			

R-Square	Coeff Var	Root MSE	moisture Mean
0.998238	4.572645	0.068091	1.489091

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	173.3594182	5.4174818	1168.48	<.0001

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The ANOVA Procedure

Dependent Variable: ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	160.0468505	5.0014641	219.28	<.0001
Error	66	1.5053333	0.0228081		
Corrected Total	98	161.5521838			

R-Square	Coeff Var	Root MSE	ash Mean
0.990682	6.204640	0.151023	2.434040

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	160.0468505	5.0014641	219.28	<.0001

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The ANOVA Procedure

Dependent Variable: fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	4038.757329	126.211167	1145.40	<.0001
Error	66	7.272533	0.110190		
Corrected Total	98	4046.029863			

R-Square	Coeff Var	Root MSE	fat Mean
0.998203	0.622484	0.331949	53.32646

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	4038.757329	126.211167	1145.40	<.0001

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The ANOVA Procedure

Dependent Variable: protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	1212.757018	37.898657	317.85	<.0001
Error	66	7.869400	0.119233		
Corrected Total	98	1220.626418			

R-Square	Coeff Var	Root MSE	prot Mean
0.993553	2.850379	0.345302	12.11424

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	1212.757018	37.898657	317.85	<.0001

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The ANOVA Procedure

Dependent Variable: carbohydrate

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	32	6540.706752	204.397086	723.37	<.0001
Error	66	18.649067	0.282562		
Corrected Total	98	6559.355818			

R-Square	Coeff Var	Root MSE	carbohydrate Mean
0.997157	1.735114	0.531565	30.63576

Source	DF	Anova SS	Mean Square	F Value	Pr > F
pro	32	6540.706752	204.397086	723.37	<.0001

The SAS System 23:00 Thursday, September 2, 2017 7

The ANOVA Procedure

Duncan's Multiple Range Test for moisture

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	66
Error Mean Square	0.004636

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	.1110	.1168	.1206	.1234	.1255	.1272	.1287	.1299	.1309	.1318	.1325

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	.1332	.1338	.1343	.1348	.1352	.1356	.1360	.1363	.1366	.1369	.1371

Number of Means	24	25	26	27	28	29	30	31	32	33
Critical Range	.1373	.1375	.1377	.1379	.1380	.1382	.1383	.1384	.1385	.1387

Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	protein
	A	6.71333	3	20
	B	4.12333	3	30
	C	3.30667	3	15
	D	2.63333	3	18
	D			
E	D	2.58333	3	28
E				
E	F	2.50000	3	25
	F			
	F	2.43333	3	19
	G	2.11000	3	6
	H	1.95667	3	1
	I	1.80000	3	24
	J	1.67667	3	14
	K	1.53000	3	26
	K			
	K	1.51000	3	5

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The ANOVA Procedure

Duncan's Multiple Range Test for moisture

Means with the same letter are not significantly different.

```
Duncan Grouping          Mean      N    processor

                L     1.34333      3    31
                L
          M     L     1.30000      3    27
          M
          M     N     1.21333      3    22
          M     N
          M     N     1.18333      3    16
                N
                N     1.17667      3    29

                O     1.01000      3    33
                O
                O     1.00667      3    9

                P     0.84333      3    2
                P
          Q     P     0.73000      3    8
          Q     P
          Q     P     0.72667      3    10
          Q
          Q     R     0.63667      3    3
                R
          S     R     0.56667      3    4
          S     R
          S     R     0.53333      3    23
          S
          S     T     0.45000      3    32
                T
          U     T     0.41333      3    12
          U
          U     V     0.32000      3    11
                V
                V     0.28667      3    17
                V
          W     V     0.21333      3    21
          W     V
          W     V     0.20000      3    7
          W
          W           0.11000      3    13
```

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The ANOVA Procedure

Duncan's Multiple Range Test for ash

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	66
Error Mean Square	0.022808

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	.2462	.2590	.2675	.2737	.2784	.2822	.2854	.2880	.2903	.2922	.2939

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	.2954	.2968	.2980	.2990	.3000	.3008	.3016	.3023	.3030	.3036	.3041

Number of Means	24	25	26	27	28	29	30	31	32	33
Critical Range	.3046	.3050	.3055	.3058	.3062	.3065	.3068	.3071	.3073	.3075

Means with the same letter are not significantly different.

```
Duncan Grouping          Mean      N    processor

          A            6.9967      3    11

          B            5.2700      3    33

          C            4.0767      3    31

          D            3.2867      3    5
          D
          D            3.2400      3    15
          D
          D            3.1367      3    2
          D
          D            3.1133      3    3

          E            2.8333      3    21
          E
F         E            2.7533      3    27
F         E
F         E    G       2.7167      3    17
F         E    G
F    H    E    G       2.6767      3    10
F    H    E    G
F    H    E    G       2.6600      3    14
F    H    E    G
F    H    E    G       2.6500      3    4
F    H         G
```

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The ANOVA Procedure

Duncan's Multiple Range Test for ash

Means with the same letter are not significantly different.

Duncan Grouping				Mean	N	processor
F	H		G	2.5500	3	1
F	H		G			
F	H		G	2.5100	3	7
F	H		G			
F	H		G	2.5033	3	19
F	H		G			
F	H		G	2.4933	3	6
F	H		G			
F	H		G	2.4900	3	8
	H		G			
	H		G	2.4433	3	22
	H					
	H			2.3967	3	29
		I		2.0733	3	9
		J		1.8200	3	23
		J				
		J		1.8133	3	32
		J				
		J		1.7867	3	30
		J				
K		J		1.6733	3	28
K						
K		L		1.4900	3	12
		L				
		L		1.4100	3	13
		L				
		L		1.2900	3	18
		L				
		L		1.2867	3	24
		L				
		L		1.2800	3	26
		M		0.9900	3	25
		N		0.3567	3	20
		N				
		N		0.2567	3	16

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The ANOVA Procedure

Duncan's Multiple Range Test for fat

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	66
Error Mean Square	0.11019

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	.5412	.5693	.5879	.6015	.6120	.6204	.6273	.6331	.6380	.6423	.6461

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	.6494	.6523	.6549	.6572	.6593	.6612	.6630	.6645	.6659	.6672	.6684

Number of Means	24	25	26	27	28	29	30	31	32	33
Critical Range	.6695	.6705	.6714	.6722	.6730	.6737	.6743	.6749	.6754	.6759

Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	processor
	A	66.4333	3	17
	B	64.1000	3	27
	B			
	B	63.9600	3	11
	C	63.1167	3	25
	D	60.1833	3	20
	E	57.5933	3	12
	E			
F	E	57.3733	3	16
F	E			
F	E	57.1600	3	29
F				
F		56.8333	3	18
	G	56.1600	3	26
	G			
H	G	55.8300	3	13
H				
H		55.5433	3	6
	I	54.8067	3	28
	I			

The SAS System 23:00 Thursday, September 2, 2017 12

The ANOVA Procedure

Duncan's Multiple Range Test for fat

Means with the same letter are not significantly different.

```
Duncan Grouping          Mean       N    processor

          J    I       54.2967      3    21
          J
          J            54.1667      3    22

               K       53.0633      3    23
               K
          L    K       52.6767      3    3
          L    K
          L    K       52.6600      3    14
          L    K
          L    K       52.5367      3    24
          L
          L            52.3433      3    32
          L
          L            52.3000      3    5

               M       51.0100      3    9
               M
          N    M       50.4700      3    19
          N
          N    O       50.3467      3    31
               O
          P    O       49.8733      3    33
          P
          P    Q       49.6900      3    1
          P    Q
          P    Q       49.6033      3    8
               Q
               Q       49.2500      3    4

               R       46.8733      3    7

               S       46.2300      3    10
               S
               S       45.8067      3    2

               T       44.3200      3    30

               U       33.1633      3    15
```

The SAS System 23:00 Thursday, September 2, 2017 13

The ANOVA Procedure

Duncan's Multiple Range Test for protein

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	66
Error Mean Square	0.119233

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	.5629	.5922	.6116	.6257	.6366	.6453	.6525	.6585	.6637	.6682	.6721

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	.6755	.6785	.6813	.6837	.6859	.6878	.6896	.6912	.6927	.6941	.6953

Number of Means	24	25	26	27	28	29	30	31	32	33
Critical Range	.6964	.6975	.6984	.6993	.7001	.7008	.7014	.7021	.7026	.7031

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	processor
A	21.2800	3	26
B	19.2033	3	29
C	17.3933	3	28
C			
C	16.9100	3	17
D	16.0367	3	22
E	15.3300	3	31
F	14.5467	3	25
G	13.6500	3	3
G			
G	13.4000	3	5
G			
G	13.3267	3	27
G			
G	13.3000	3	4
G			
G	13.2133	3	13
G			
G	13.1767	3	19
G			

The SAS System 23:00 Thursday, September 2, 2017 14

The ANOVA Procedure

Duncan's Multiple Range Test for prot

```
Means with the same letter are not significantly different.

   Duncan Grouping          Mean      N    processor

          G              13.1733      3    8

          H              12.2100      3    21
          H
     I    H              11.7400      3    9
     I    H
     I    H              11.6600      3    2
     I    H
     I    H              11.6200      3    14
     I
     I    J              11.4867      3    16
     I    J
     I    J              11.3867      3    7
     I    J
     I    J    K         11.2267      3    1
          J    K
          J    K         10.9200      3    11
               K
               K         10.6967      3    32
               K
               K         10.6667      3    20

          L               9.3567      3    18
          L
     M    L               9.0867      3    33
     M    L
     M    L               8.9467      3    30
     M    L
     M    L               8.8967      3    15
     M
     M                    8.7267      3    23
     M
     M                    8.5500      3    12

          N               7.2233      3    24
          N
          N               6.7467      3    6

          O               4.6833      3    10
```

The SAS System 23:00 Thursday, September 2, 2017 15

The ANOVA Procedure

Duncan's Multiple Range Test for carbohydrate

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	66
Error Mean Square	0.282562

Number of Means	2	3	4	5	6	7	8	9	10	11	12
Critical Range	0.867	0.912	0.941	0.963	0.980	0.993	1.004	1.014	1.022	1.029	1.035

Number of Means	13	14	15	16	17	18	19	20	21	22	23
Critical Range	1.040	1.045	1.049	1.052	1.056	1.059	1.062	1.064	1.066	1.068	1.070

Number of Means	24	25	26	27	28	29	30	31	32	33
Critical Range	1.072	1.074	1.075	1.076	1.078	1.079	1.080	1.081	1.082	1.082

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	processor
A	51.3967	3	15
B	45.6900	3	10
C	40.8300	3	30
D	39.0267	3	7
D			
D	38.5533	3	2
E	37.1533	3	24
F	35.8600	3	23
G	34.7633	3	33
G			
G	34.7000	3	32
G			
G	34.5800	3	1
G			
G	34.2367	3	4
G			
G	34.1700	3	9
G			
G	33.9967	3	8

The ANOVA Procedure

Duncan's Multiple Range Test for carb

Means with the same letter are not significantly different.

```
Duncan Grouping          Mean       N    processor

          H           33.1033      3    6

          I           31.9467      3    12
          I
          I           31.4167      3    19
          I
          I           31.3800      3    14

          J           30.4467      3    21
          J
     K    J           29.9233      3    3
     K    J
     K    J           29.8833      3    18
     K    J
     K    J    L      29.6967      3    16
     K    J    L
     K    J    L      29.5067      3    5
     K         L
     K         L      29.4367      3    13
               L
               L      28.9000      3    31

          M           26.1400      3    22

          N           23.5400      3    28

          O           22.0767      3    20

          P           20.0633      3    29
          P
          P           19.7467      3    26

          Q           18.8467      3    25
          Q
     R    Q           18.5233      3    27
     R
     R                17.8000      3    11

          S           13.6467      3    17
```