EFFECTIVENESS OF TOMATO POSTHARVEST PROCESSING TECHNOLOGIES BY BOILING AND SOLAR DRYING FOR SMALL SCALE PROCESSING IN MOROGORO REGION

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT 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

This study determine effectiveness of tomato postharvest processing technologies by boiling and solar drying for small scale processing based on nutritional and sensory quality. Tomato sample varieties *Asira*, *Imara* and *Reogrande* were collected from small scale farmers in Morogoro region for tomato paste and powder development. Nutritional quality was determined based on moisture, lycopene, ß-carotene and ascorbic acid contents, titratable acidity and pH. Sensory properties were determined using Quantitative Descriptive and Affective Analysis by assessing the level of consumer profile and acceptability of juices and soups prepared from fresh tomato, paste and powder using 9-point hedonic scale. Data were analysed using R-software significantly at $p < 0.05$. The initial moisture content (MC) in fresh weight basis (FW) for three varieties ranged from 92.97±0.31 to 95.12±0.12% in fresh tomato, 68.97±0.32 to 71.73±0.48% in tomato paste and 11.02±0.09 to 11.74±0.41% in tomato powder samples. The lycopene contents varied from 6.11±0.26 to 7.34±0.02 mg/100g, 8.12±0.25 to 8.81 mg/100g and 10.57±0.01 to 11.30 mg/100gFW in fresh tomato, paste and powder, respectively. The β-carotene content ranged from 1.46±0.18 to 2.33±0.04 mg/100gFW in fresh tomato, 2.57±0.17 to 2.91 mg/100gFW in paste and 3.19±0.01 to 3.26±0.03 mg/100gFW in powder. The ascorbic acid content ranged from 10.64 to 12.67±1.76

mg/100g in fresh tomato, 2.03±0.88 to 5.83±0.44 mg/100g in paste and 48.13±2.32 to 51.93±4.19 mg/100g in powder. The titratable acidity (%citric acid) ranged from 0.30± 0.07 to 0.38% in fresh tomato, 0.64 to 2.23±0.07% in paste and 6.23±0.30 to 6.48± 0.15% in powders. The pH ranged from 4.50 to 4.66 in fresh tomato, 4.56 to 4.68 in paste and 4.76 to 4.95 in powder. The results indicate significant difference between tomato products in terms of nutritional content as an effect of processing and individual variety. Therefore, tunnel solar drying of fresh tomato into powder concentrates nutrients contents in comparison to boiling into tomato paste. Boiling fresh tomato into paste retains better nutrients but due to physical removal of skin and seed some of the nutrients were lost along the process. The Quantitative Descriptive Analysis (QDA) showed that, juice from fresh samples had significantly higher colour intensity scores 8.50±0.80 (like very much), paste was aromatic rated 8.10±1.00 (like very much) and powder liked very much due to acidity, consistency, sweetness, viscosity and clarity rated with 3.20±1.27, 8.30±0.49, 8.10±1.38, 7.70±0.89 and 8.30±0.49, respectively. Overall acceptability of juice sample from Paste_*Asira* and Powder_*Asira* were the most acceptable by consumers with hedonic scores of 7.00±1.97 and 7.00±2.02 (like moderately). Furthermore, soup from Fresh_*Imara* had significantly colour and reddishness intensity score 8.30±0.65 and 8.20±0.58, respectively. Samples from Paste_*Asira* had aroma rated 7.60±1.17 while those from Powder_*Imara* was liked with acidity and consistency score 6.30±0.89 and 8.30±0.62, Powder_*Reogrande* with saltiness score 5.90±0.67 and Powder_*Asira* with viscosity score of 8.50±0.52. Overall acceptability of soup samples from Paste_*Imara*, Powder_*Imara* and Paste_*Asira* were the most acceptable by consumers with hedonic scores of 7.40±1.30**,** 7.40±1.21 and 7.00±1.50, respectively. Conclusively, juice and soup samples from powder and paste were moderately liked.

Keywords: Postharvest-losses, Tomatoes, Powder, Paste, Acceptability

DECLARATION

I, **Remigius Muganyizi Christian** do 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 concurrently being submitted in any other institution.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
AVRDC	Asia/Africa Vegetable Research Development Centre
COSTECH	Commission for Science and Technology
DM	Dry Matter
DW	Dry Weight
FAOSTAT	Food and Agriculture Organisation Statistical data base
FW	Fresh Weight
HSD	Honest Significant Difference
ISO	International Organisation for Standards
MC	Moisture Content
MUVI	Muunganisho wa Ujasiriamali Vijijini
NaOH	Sodium Hydroxide
NBS	National Bureau of Statistics
NPHMS	National Post-Harvest Management Strategy
PCA	Principal Component Analysis
PE	Petroleum ether
PLSR	Partial Least Squares Regression
PREFMAP	Preference Mapping
QDA	Quantitative Descriptive Analysis
RDI	Recommended Daily Intake
SAGCOT	The Southern Agricultural Growth Corridor of Tanzania
SD	Standard Deviation
SIDO	Small Industries Development Organization
SUA	Sokoine University of Agriculture
SUGECO	Sokoine University Graduate Entrepreneurs Cooperative
TA	Titratable Acidity
TARI	Tanzania Agricultural Research Institute
TCA	Trichloroacetic Acid
URT	United Republic of Tanzania
WB	Wet basis

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

The tomato (*Solanum lycopersicum*) is short-lived perennial plants belong to Solanaceae or nightshade family, with a weakly woody stem that usually crawls over other plants (Workie, 2016; Shah *et al*., 2019). The fruit is an edible, brightly coloured berry, commonly red when mature, but can be varieties of colour, including yellow, orange, green, and purple. The tomato is native to South America (Mexico) but growing in temperate climates worldwide (Dari *et al*., 2016; Saavedra *et al*., 2017). It is nutritionally characterized as vegetable and the most popular eaten vegetable worldwide (Aliyu *et al*., 2018). For small scale farmers, the production of tomatoes can assist them as a basis of income generation especially those from rural and semi-urban areas in most developing countries like Tanzania (Arah e*t al*., 2015).

1.2 Tomato production

Global production of tomatoes is estimated to be around 182.3 million metric tons per year with China (61.52 million metric tons), India (19.38 million metric tons), United States of America (12.61 million metric tons) and Turkey (12.15 million metric tons) as the leading producers in the world (FAOSTAT, 2020). According to the Food and Agriculture Organization of the United Nations, in 2018 Tanzania ranked forty-fifth position in the World (FOASTAT, 2020) and twelfth and the third in Africa and East Africa, respectively (FAOSTAT, 2020).

1.2.1 Overview of tomatoes production in Tanzania

Tanzania is among the tropical countries in Africa with good favourable climatic supporting a multiple vegetables production such as tomatoes, eggplant, African eggplant, amaranths and cabbages. However, vegetable production processing and exportation levels are very low compared to other countries. Tomatoes are foremost vegetable crop and the greatest bulks are produced by small scale farmers in Tanzania (Mutayoba and Ngaruko, 2018). Production of tomato in Tanzania differs significantly from one region to another. Total production for the year 2016/17 was 0.247 million metric tons of which 0.237 million metric tons were from Tanzania Mainland and 9 600 tons from Zanzibar (URT, 2017). Morogoro region is the biggest producer in the country with 0.155 million metric tons, followed by Kilimanjaro region with 18 600 tons (URT, 2017).

However, numerous traits in postharvest tomato may arise because of quantitative, qualitative and economic loss (Arah *et al*., 2015; URT, 2019). The postharvest losses of tomato ranged from 30% to 100% mainly due to genetic, environmental conditions and on-farm treatment methods (MUVI-SIDO, 2009). Other causes include spoilage, inadequate transportation, improper sorting and grading, improper packaging and handling, lack of cold storage facilities, inadequate processing technologies and lack of reliable markets (URT, 2019; MUVI-SIDO, 2009). These factors affect marketing effectiveness due to increased marketing costs resulting into upper retail prices which are finally incurred by consumers (Mutayoba and Ngaruko, 2018; Salau and Salman, 2017).

Due to seasonality nature of tomato crops, bulkiness and perishability more technologies on handling, packaging, transportation, processing are needed to remove postharvest losses and increase income of the smallholder farmers. In developing countries including Tanzania, there is a limited value-addition of tomatoes which hinders large purchase by retailers and buyers thereby decreasing productivity of tomato. For instance, improper handling technology during post-harvest decreases the quality and safety of tomatoes thereby lowering its shelf-life and causing losses. This wastage discourages tomato's growers to engage in large scale farming that would generate income through exportation and internal market resulting into poverty eradication from their community.

1.3 Quality characteristics and processing effects of tomatoes

Quality is generally defined as a degree of fineness or value in conformity that exceeds consumer expectations, determined by sensory characteristics, chemical and physical properties, microbial load and toxicological contaminants in additional to shelf-life, packaging and labelling (Barrett *et al*., 2010). The quality of tomato and tomato products depend on pre-harvest features including geographical location, climatic condition, agricultural practices (supplementary nutrients, water and pest control); postharvest handling practices (harvesting, packing, transport and storage) and processing methods (James and Zikankuba, 2017). According to these authors, tomato growers consider quality of their produce based on visual appearance (shine) at maturity and ripening stage, extended harvesting time with high yield, diseases resistance, easy to handle at harvest, transport and packaging with minimal defect criteria. On the other hand, traders and wholesalers regard quality as good visual appearance (shine), stability to bruising during transport, loading and offloading, firmness and stay fresh for long time after harvest under room temperature (James and Zikankuba, 2017). Generally, the food quality aspects rely on precise parameters such as sensory properties based on colour, flavour (aroma and taste), texture and quantitative properties namely; amount or percentage of moisture content, carbohydrate/sugar, fibre, protein, fat, vitamins, minerals, pH, acidity, microbial load, free from pests, insects and other contaminants as well as unseen parameters such as free fatty acids and enzyme (Edith and Ochubiojo, 2012). Therefore food qualities attributes can be categorized into physical, chemical, microbial, nutritional and sensory qualities.

1.3.1 Physical, chemical and microbial quality of tomato

The quality of tomato and tomato products can be influenced by physical changes including structure, case hardening, bruising, decay, pore formation, rehydration, caking and stickiness (Sagar and Suresh, 2010). For instance, texture of dried tomato powder is influenced by their moisture content, configuration, pH, genetic, ripening and maturity of produce (Sagar and Suresh, 2010). The quality of fresh tomato relies on firmness of tissue as one of the greatest significant characteristics governed by the stages of fruit maturity, variety, and environmental factors. Presence of numerous spots on the peel and softening of tomato are signs of decay or rotting which is one of the physical changes determined by visual observation.

The chemical changes associated with textural changes in tomato and tomato products are browning, colour, lipid oxidation, off-flavour, crystallisation of cellulose, degradation of pectin, and starch gelatinization (Sagar and Suresh, 2010). Most of chemical changes in tomato products happen through processing and storage. Dried tomato powder are well-thought-out safe in respect with infectious microbes due to low moisture content that limit/ minimize the microbial growth (Sagar and Suresh, 2010). The type and load of microbe presents in processed tomato products rely on the attributes such as total acidity, pH, configuration, processing method used, pre-harvest treatments and extent of postharvest contamination with micro-flora.

1.3.2 Nutritional and sensory quality properties of tomatoes

Tomato and tomato products are good source of both "macro" nutrients such as carbohydrates, and "micro" nutrients such as vitamins and minerals including vitamin C, E, K, B complex (thiamin, riboflavin, B6, niacin, folate), potassium, copper, manganese, iron, zinc and calcium; β-carotene (vitamin A), chlorogenic acid, lycopene, phenolic, glucosinolates and α-tocopherol compounds (Bjarnadottir, 2019; Hariyadi *et al.,* 2018; James and Zikankuba, 2017; Joseph *et al*., 2017; Workie, 2016). Raw tomato have high percentage moisture content but still it remains a brilliant source of minerals and vitamins that meet the recommended daily allowance (RDA) of 40% vitamins C and around 15% vitamin A (Bjarnadottir, 2019; Adejo *et al*., 2015). Nevertheless, the antioxidant contents of tomato and tomato products can be governed by environmental factors including temperature, water and nutrient accessibility, genetic factors such as variety, farming methods and post-harvest processing and storage environments (Kamiloglu *et al*., 2013). Some nutritive components have health-promoting benefits including antioxidant such as lycopene (Domínguez *et al*., 2020). Though, through value addition process some of nutritional quality content changes may occur during dehydration. For instance, vitamins C and thiamine are heat labile and sensitive to oxidative degradation (Sagar and Suresh, 2010). Also during storage slight changes may happens in dietary fibre and mineral content, but the vitamins are utmost lost (Barrett *et al*., 2010). Therefore, the main factor for optimal nutritional retention in tomato in the course of processing is the quality of raw material used (Shatta *et al*., 2017).

Sensory quality reveals insights into the way in which sensory characteristics drive consumer and customer acceptability or preference of the given product. It shows significant role in quality control and marketing acceptability of the respective products (Sailaja and Parameshwari, 2018). It is a science of judging and evaluating the quality of a food product by the use of the senses of sight, smell, taste, touch and hearing for various attributes of quality like colour/appearance, flavour (aroma and taste) and texture (Sharif *et al*., 2017).

Sensory characteristics of dried foods are most essential in discriminating the quality such as colour, flavour and texture. For example, Sagar and Suresh (2010) reported quality deterioration for dried products due to changes of aroma and flavour caused by loss of volatile organic compounds. Food including tomato and tomato products must have attractive sensory properties such as appearance, satisfactory flavour, suitable texture, and optimistic nutritional image to be accepted by consumers. Therefore, quality of food product can be observed from both a food product and consumer profile and acceptability. The sensory characteristic of any food product is what drives the consumer at the points of purchase and consumption (Jang and Lee, 2019). This is the importance of assessing sensory properties of tomato products that will be developed.

1.4 Health benefits of tomato

Many researchers found that bioactive compounds derived from tomato, tomato products and by-products have anti-cancer, anti-oxidative, anti-microbial, anti-inflammatory, antiallergenic, colorant properties, vasodilatory, antithrombotic and immune modulating effects and reduces incidence of cardiovascular diseases, cancer, and type-two diabetes in human (Domínguez *et al*., 2020; Bjarnadottir, 2019; Hariyadi *et al*., 2018; James and Zikankuba, 2017; Joseph *et al*., 2017). Moreover, intake of tomato could reduce serum lipid levels and low-density lipoprotein oxidation (Kamiloglu *et al*., 2013). The health benefits of tomato are associated with the presence of antioxidants compound such as carotenoids for instance β-carotene (vitamin A) and lycopene, vitamins C, tocopherols, and phenolic compounds. These compounds play a vital role in preventing reactive oxygen species accountable for numerous significant diseases, through free-radical scavenging, metal chelation, hang-up cellular proliferation, and modulation of enzymatic activity and signal transduction pathways (Kamiloglu *et al*., 2013). The overall benefits of tomatoes rely on lycopene content which is the most efficient single oxygen quencher twice than β-carotene with antioxidant and anti-inflammatory properties (Domínguez *et al*., 2020; Eletr *et al*., 2017). Present of Potassium in tomato is essential for blood pressure regulation and other cardiovascular diseases prevention (Bjarnadottir, 2019). Tomato and tomatoes-based products are great in fibre which facilitate digestion and may be linked with aiding in weight loss. Also, the consumption of tomato has a substantial association with the decline of mortality rate by 48% and with abridged threat of death connected with diarrhoea between children elderly 6–60 months (Kamiloglu *et al*., 2013). Therefore, tomato had pharmaceutical values and being intended for blood purification, clean up urinary tract toxicities and healing gastrointestinal disorders (Arah *et al*., 2015; Workie, 2016). For such reasons of having plentiful health benefits to human body, tomato and tomatoes products may perhaps be interconnected to its high global production (Arah *et al*., 2015).

1.5 Socio – economic importance of tomatoes in Tanzania

Tomatoes are essential and versatile vegetable crop in the day-to-day meal preparation of Tanzanian, serving as a low-cost source of nutrients comprising vitamins, minerals and fibres to consumer. Despite, foreign exchange earnings for farmers as well as country wise, consumption as fresh fruits or cooked, and processed into pastes, puree, sauces, ketchup, chutney, jam, juices, salsa or powder (Shatta *et al*., 2017; Workie, 2016; Dari *et al*., 2016) provides numerous economic advantages. Furthermore, tomato reject and by-product are used as animal feed and composite manure. Tomatoes production is conquered by small-scale farmers, in which the possibility of poverty reduction and income generation is huge, although the level to which tomato farming is profitable is determined by the degree to which farmers can invest (Mutayoba and Ngaruko, 2018). The seeds from pulp and residues comprise oil which is good for salad dressing and in the manufacturing of margarine and soap.

Tomato crops are preferred by many small-scale farmers due to multiple harvests which offers superior economic returns per unit area (Mutayoba and Ngaruko, 2018; Workie, 2016). Several researches have demonstrated that postharvest technologies reduce postharvest losses by increasing the shelf life and may possible be a brilliant strategic path to decrease poverty and hunger (Affognon *et al*., 2015). The availability and accessibility of reliable postharvest technology can fasten horticultural businesses thereby fulfilling the demand of consumer for nutrition and food security (James and Zikankuba, 2017).

1.6 Postharvest processing technologies

Tomato being a perishable crop with very high nutrition contents, it needs to be preserved. Even after being harvested, tomatoes remain metabolically active experiencing ripening and senescence variations hence affecting its quality and shorten shelf life. Possessing the fresh produces is the superlative technique to preserve its nutritive worth, similarly processing such as drying increase their shelf life stability (Hariyadi *et al*., 2018; Baradey *et al*., 2016). Therefore, postharvest technologies influence the level of post-harvest losses, quality and shelf-life of produce thereby controlling ripening and senescence changes as well as reducing crop spoilage and microbial attraction (James and Zikankuba, 2017). Extended shelf life of tomatoes can be affected through a number of interventions including technologies. Some of the technologies are sorting, cleaning, grading, packaging, pre-cooling, storage, processing and transportation. Others include temperature control such as heat treatment and low temperature treatment (refrigeration and freezing); acceleration and delay of ripening and senescence such as use of ethylene gas and chemicals treatment (1-methylcyclopropene and Calcium Chloride), controlled atmosphere packaging, modified atmosphere packaging (MAP), irradiation, ultra-sound, edible coating (use of starch, chitosan, cellulose, polysaccharides, bees wax, mineral oils and other proteins based material), ozone, and combined methods (James and Zikankuba, 2017). Although, tomatoes are commonly consumed as fresh, over 80% comes from processed products such as tomato juice, paste, puree, ketchup, and sauce (Kamiloglu *et al*., 2013). The present study evaluates solar tunnel drying into powder in comparison to boiling treatment into paste.

Tomatoes can be processed into different dried end products by mechanical or thermal treatment, freeze drying, vacuum drying, chemical drying and addition of ingredients such as oil or salt (Baradey *et al*., 2016). In solar drying, the product is habitually in a more secure environment whereby the energy for dehydration process which depends on outward factors such as temperature, and humidity of air is generated from the sun (Kessy *et al*., 2018; Baradey *et al*., 2016; Mongi, 2013). The benefit of solar drying is the less energy input than other techniques such as freeze or canning (Ahmed *et al*., 2013). Some studies reported that, the solar tunnel dryer has shorter drying time with the superior quality of final products when compared with other types of drying (Mohsen *et al*., 2019; Mongi, 2013). However, the drying time for solar stove and solar dryer indicated a decrease of more than 40% while in the drying tunnel is more than 60% when compared with traditional open-air sun drying (Ahmed *et al*., 2013).

1.7 Problem statement and study justification

As perishable crop, postharvest losses of tomatoes is very high contributed by many factors such as seasonality, bulkiness, spoilage, poor harvesting techniques, incorrect packaging and handling, inadequate storage facilities and unskilled processing technologies (URT, 2019; Salau and Salman, 2017; MUVI-SIDO, 2009). In Tanzania the postharvest losses of tomatoes estimated to be around 30% to 50% (URT, 2019; Mtui, 2017; MUVI-SIDO, 2009). According to Mtui, (2017) about 1.8 tons of tomatoes were lost per acre per season per farmer equivalent to TZS 918 500 as well as 0.4 and 0.5 tons are lost by wholesalers and retailers per capita per season corresponding to TZS 237 000 and TZS 468 000, respectively. Nevertheless, the global progress agenda is to minimize postharvest losses of fruits and vegetables including tomato to around 12.3% by 2030 (James and Zikankuba, 2017; URT, 2019).

Many small-scale farmers and traders have insufficient postharvest controlling skills and technologies including value addition and packaging triggering some produce being rejected, in so doing shortened marketing values and income which bring economic and food security impediments for various small-scale farmers in developing countries like Tanzania (James and Zikankuba, 2017). Tomatoes have limited shelf life of approximately 48 hours in tropical conditions (Arah *et al*., 2016), thus are prone to postharvest losses. In Tanzania, postharvest management, handling and processing technologies are very limited. The small number of tomato growers, traders and consumers in Tanzania, face such losses that hinder large purchase by retailers and buyers thereby dwindling productivity. Therefore, focused postharvest handling techniques and processing approaches are needed to make it available with suitable quality and quantity after harvest (Arah *et al*., 2016).

One of the best technique to reduce postharvest losses of tomato is through processing, such as drying of tomatoes by using tunnel solar dryer (Kessy *et al*., 2018; Mohsen *et al*., 2019; Mongi, 2013) because have diverse substantial effects on some quality attributes but maintains considerable quantities and has prospective to prolong its shelf life (Prasath *et al*., 2018). Several studies conducted in Tanzania for postharvest losses of tomato have focused on quantitative and economic losses with limited research on qualitative losses occurred during value-addition. In Tanzania studies conducted on tomato solar drying into powder were limited which presented a gap (MUVI-SIDO, 2009). In addition, tomato powder products were not common in Tanzanian markets. Currently, tomato paste was used as a starting material to many tomato-based products. Tomato powder is durable, lighter, and small in volume that simplifies handling. Being in powder increase its applicability thus can be efficiently recycled into several products such as juice, jam, soup and combination supplements mineral food. Therefore, tunnel solar drying and conversion of the products into powder form are alternatives processing technologies for reducing post-harvest losses but these technologies are not well adapted for Tanzanian.

1.8 Objectives of the study

1.8.1 General objective

The main objective of this study was to determine effectiveness of tomato postharvest processing technologies by boiling and solar drying for small scale processing in Morogoro region, Tanzania.

1.8.2 Specific objectives

(i) To develop tomato powder product dried by using tunnel solar dryer.

(ii) To determine the nutrition contents of the developed products

(iii) To determine consumer profile and acceptability of the developed products.

The findings of this work were represented in two manuscripts as chapter two and three.

1.8.3 List of manuscripts

(i) Nutritional quality of tunnel solar dried tomato powder compared with paste of selected varieties cultivated in Morogoro region-Tanzania

(ii) Acceptability of juice and soup prepared from fresh tomato, paste and tunnel solar dried tomato powder

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CHAPTER TWO

2.0 NUTRITIONAL QUALITY OF TUNNEL SOLAR DRIED TOMATO POWDER COMPARED WITH PASTE OF SELECTED VARIETIES CULTIVATED IN MOROGORO REGION-TANZANIA.

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Abstract

Tomatoes are important in the daily meal preparation, serving as a low-cost source of vitamins, minerals and dietary fibres to consumer. It is susceptible to postharvest losses that force farmers to sell produce at a low price to avoid economic losses. Value-addition including canned paste and drying into powder can minimize these losses. However, technology such as solar drying into powder has not been well adapted by majority of processors in Tanzania. The study aimed to reduce postharvest losses of tomatoes through drying into powder by using tunnel solar drier. The nutritional quality of dried product was evaluated and compared with that of paste based on moisture, lycopene, ß-carotene, ascorbic acid, titratable acidity and pH. The results show that the lycopene varied from 6.11±0.26 to 7.34±0.02 mg/100g, 8.12±0.25 to 8.81 mg/100g and 10.57±0.01 to 11.30 mg/100gFW in fresh tomato, paste and powder, respectively. The β-carotene ranged from 1.46±0.18 to 2.33±0.04 mg/100gFW in fresh tomato, 2.57±0.17 to 2.91 mg/100gFW in paste and 3.19±0.01 to 3.26±0.03 mg/100gFW in powder. The ascorbic acid ranged from 10.64 to 12.67±1.76 mg/100g in fresh tomato, 2.03±0.88 to 5.83±0.44 mg/100g in paste and 48.13±2.32 to 51.93±4.19 mg/100g in powder. The titratable acidity (%citric acid) ranged from 0.3±0.07 to 0.38% in fresh tomato, 0.64 to 2.23±0.07% in paste and 6.23±0.30 to 6.48±0.15% in powders. The pH ranged from 4.50 to 4.66 in fresh tomato, 4.56 to 4.68 in paste and 4.76 to 4.95 in powder. The results indicated significant difference

between tomato paste and dried powder in terms of nutritional content. There was also a significant difference based on individual variety.

Keywords: Postharvest-loss, Tomato, Powder, Paste, Tanzania.

2.1 Introduction

Tomato (*Solanum lycopersicum*) is widely produced crop throughout Tanzania regions. Tomato and tomato products are rich source of “macro” nutrients and “micro” nutrients such as vitamins (vitamin A and ascorbic acid), minerals, carotenoids (lycopene and β-carotene); glycoalkaloids and polyphenol compounds (Domíngue *et al*., 2020; Hariyadi *et al.*, 2018; Mwende *et al*., 2018; Obadina *et al*., 2018; Workie, 2016; Adejo *et al*., 2015). It has been used as an ideal addition to different types of processed foods. Tomatoes are frequently eaten as fresh while above 80% originates from processed products (Kamiloglu *et al.*, 2013).

In Tanzania, the postharvest losses of tomatoes are estimated to be around 30 to 50% (URT, 2019; Mtui, 2017) which deny communities to access nutrients present. Unfortunately, in Tanzania postharvest management, handling and processing technologies are inadequate. In order to alleviate the situation, focused postharvest handling techniques and processing approaches are needed to make it available with suitable nutrition quality and quantity (Hariyadi *et al*., 2018; Arah *et al*., 2016). Adoption of postharvest technologies has resulted in reduced produce losses, income generation, minimize household expenditure and increase productivity, possibly will be an ideal mitigation for malnutrition and poverty in Tanzania (James and Zikankuba, 2017; Affogno *et al*., 2015). Similarly, they have boosted horticultural industries to encounter internal and external market demand for nutrition and food security (James and Zikankuba, 2017).

Usually, tomatoes are processed into different final products and affected by several factors such as the kind of product, accessibility and availability of equipment type, affordability and quality of end product (Sagar and Suresh, 2010). The best appropriate technique is by drying (Abdulmalik *et al*., 2014). Several studies show that, tomatoes dried using tunnel solar dryer are delicious, concentrated nutrients, reduced bulk, easy-to convey and stock (Ahmed *et al*., 2013). Therefore, solar drying of tomato is an alternatives processing technology for reducing post-harvest losses of tomato. However, these technologies are not well adapted in Tanzania.

Disadvantages related to thermal processing is the loss of some of the nutrients such as vitamin C. On the other hand, this process affects the structure, quality in terms of chemical, nutritional content, and sensory attributes of the final product. Nevertheless, the quality factor of processed product is governed by the quality of initial raw materials and handling environments (Sobowale *et al*., 2012; Barrett *et al*., 2010). As soon as more intrusive processing stages are employed, several antioxidant capabilities deviate in final manufactured produce (Ilahy *et al*., 2019). In the present study, the effect of boiling and tunnel solar drying technologies where compared on the product quality based on six parameters; moisture, lycopene, ß-carotene, ascorbic acid contents, pH and titratable acidity.

2.2 Material and Methods

2.2.1 Study Area

The study was conducted at Sokoine University Graduate Entrepreneurs Cooperative (SUGECO) and Department of Food Technology, Nutrition and Consumer Sciences (DFTNCS) laboratory, Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Solar drying was conducted at SUGECO while processing into powder and paste, sensory and chemical analyses were conducted at DFTNCS laboratory.

2.2.2 Materials

2.2.2.1 Sample collection (Raw materials)

Three varieties of tomatoes widely cultivated from Dakawa, Dumila and Mvumi in Morogoro region were collected from small scale farmer's fields at maturity and red ripen stage at 8.30 am on November, 2019. The samples were collected from farmers in order to ensure freshness of tomato and for proper post-harvest handling. These varieties were known by their local names as *Asira* and *Imara* are hybrid varieties and *Riogrande* is a local variety. The maturing point for all samples was chosen according to local consumers' standards. A total of 180kg of matured ripened tomatoes were collected from 60 purposively and snowballing selected small-scale farmers. They were put in cool boxes and stored at 4ºC prior to preparation, solar drying into powder, boiling into tomato paste and laboratory analysis.

Table 2.1: Number of samples collected from each location

SN	Sample site (Field)	*Asira*	*Imara*	*Riogrande*	Total
1	Dumila	30	50	10	90
2	Mvumi	20	10	20	50
3	Dakawa	10	-	30	40
	Total	**60**	**60**	**60**	**180**

2.2.2.2 Processing equipment used

Tunnel solar dryer installed at SUGECO (Fig. 2.1) were used which consist of small fans to facilitate the required air flow over the drying products. The drying units were covered with UV stabilized visible-queen sheets. The samples to be dried were placed in trays with a single layer of mesh.

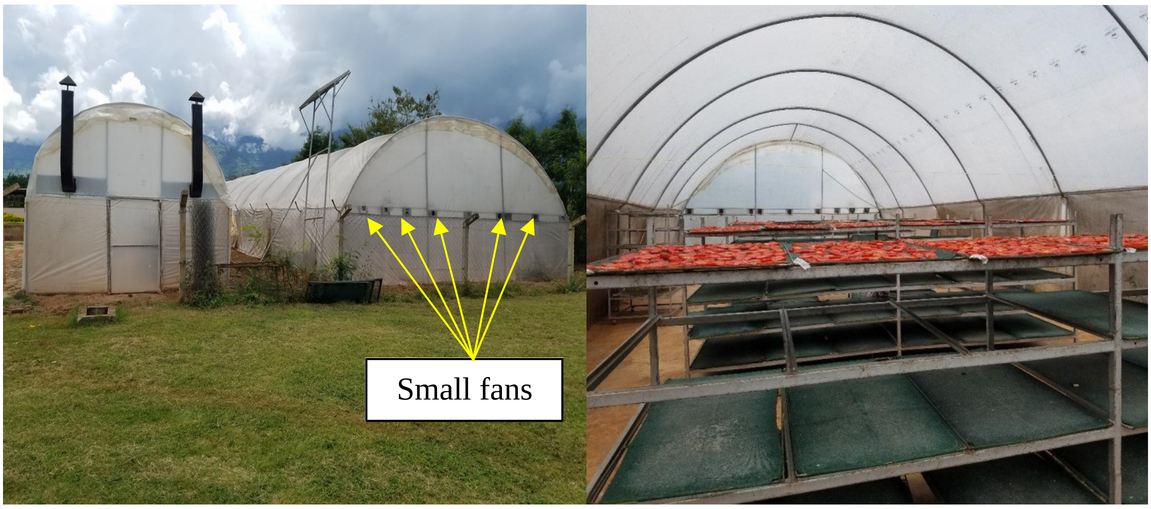

Figure 2.1: The solar dryer used for tomato drying (Photo by: Christian, 2019)

2.2.2.3 Chemicals

Petroleum ether (PE), Sodium Hydroxide (NaOH) pellets were supplied by Loba Chemie Pvt. Ltd 107 (United States), Anhydrous Sodium Sulfate (Na2SO4) was bought from by Yakuri pure Chemicals Co. LTD (Kyoto, Japan), Trichloroacetic acid (TCA) was obtained from Sanand, Ahmedabad 382110 (Gujarat, India) and 2,6-dichloroindophenol solution was supplied by American Custom Chemicals Corporation (United States).

2.2.2.4 Product Development

Prior to experimental analysis, trial was conducted three times for estimation of fresh tomatoes of each variety required to produce 1 kg of tomato powder and paste. The results were shown in Table 2.2 and 2.3. Also, Fig. 2.2 represents flow chart of tomatoes paste and powder development.

Table 2.2: Mean value for fresh tomato required for 1kg tomato Powder

Tomato Variety	%Moisture Content (WB)	Fresh tomatoes (kg)
Asira	92.97±0.13	18.89±0.44
Imara	94.21±0.19	20.31±0.79
Riogrande	95.11±0.11	21.08±0.48

Values are expressed as mean ±SD (n=3) (SD = Standard deviation, WB = wet basis)

Table 2.3: Mean value for fresh tomatoes required to make 1kg tomato paste

Tomato Variety	% Moisture Content (WB)	Fresh tomato (kg)
Asira	92.97±0.13	3.70±0.14
Imara	94.21±0.19	5.71±0.07
Riogrande	95.11±0.11	6.04±0.05

Values are expressed as mean ±SD (n=3) (SD = Standard deviation, WB = wet basis)

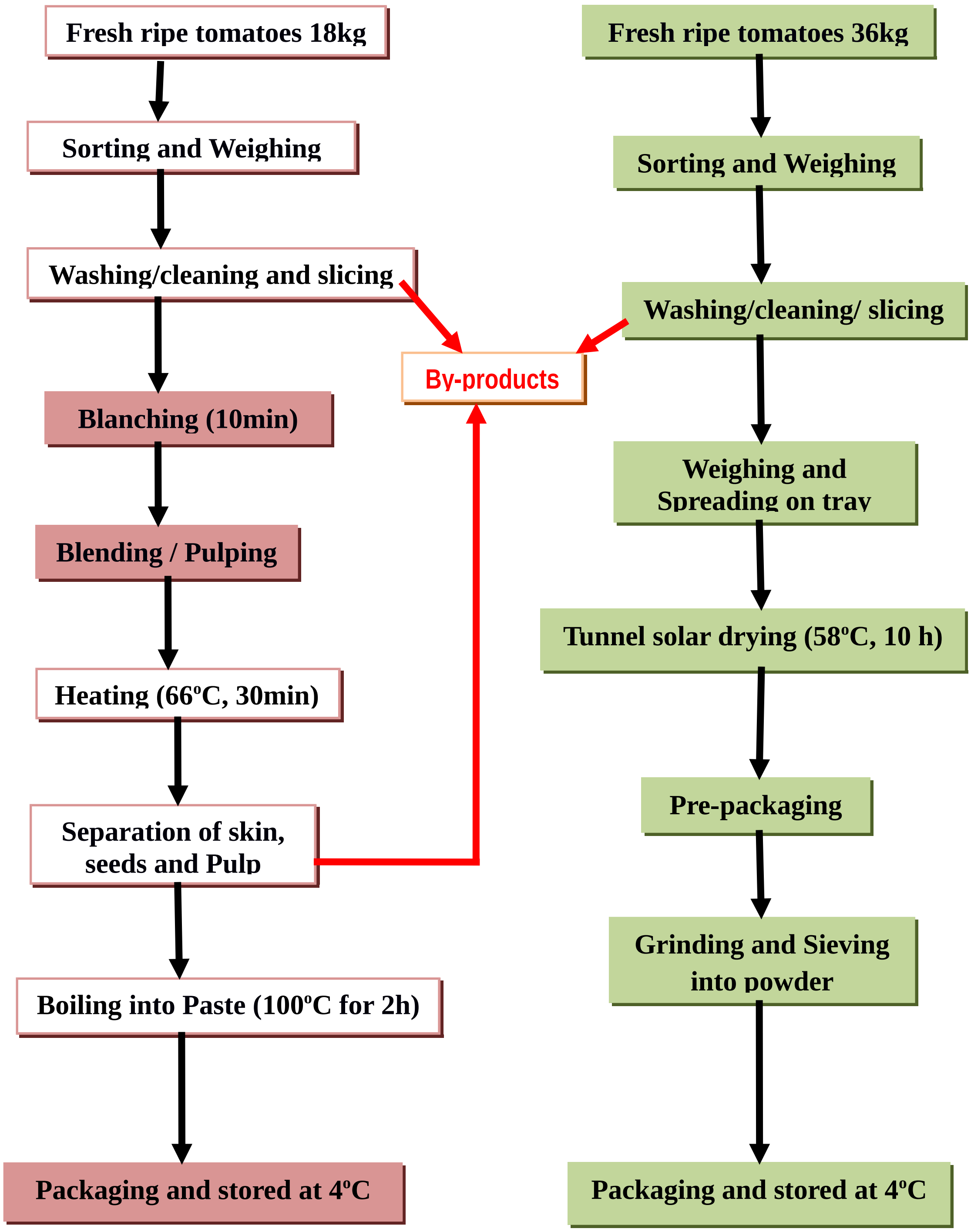

Figure 2.2: General flow chart for tomato Paste production (left) and tomato Powder production (right) modified from (Abdulmalik *et al.*, 2014; Mongi, 2013; Koh *et al.*, 2012; MUVI-SIDO, 2009)

(a) Tomato powder development

Samples collected were sorted to remove the damaged ones and a total of 36 kg were weighed from each variety for solar drying. Washing and cleaning was followed using portable water. Then sliced into 5 mm round and reweighed prior spread on drying tray. Trays with samples were introduced into solar drying chamber for 10 h at a temperature 58°C. Dried tomato slices were prepacked into sealable plastic bags to prevent water absorption from the surrounds. The samples in bags were then stored at cool and dry place at room temperature in a desiccator prior grind into powder. Heavy duty blender was used for grinding and sieving with 1 mm mesh size (Test sieve ISO 3310-1 Body S-Steel/RF Mesh S-Steel/RF S/N 11046004 P/N: 30.3200.03, Germany) into fine particles. Tomato powder sample was packed into 500 g sealable bags and stored at 4°C prior to analysis. Figure 2.3 represent the preparation of samples of tomato powder and more explanatory photo were shown in Appendix 7.

Figure 2.3: Tomato Powder preparation (Photo by: Christian, 2019)

(b) Tomato Paste development

Tomato samples of 18 kg were weighed per each variety for tomato paste production. Then washed and cleaned prior to slicing and blanching. Blanching was done for 10 min to inactivate microbes and enzymes as well as facilitate blending process. Blending was effected by using heavy duty blender. The blended tomato pulps were then heated at temperature 66ºC for 30 min to ensure plentiful separation of a soften tomato tissue from the peel and inactivate microbes and enzymes. Then filtering to separate skin and seed from pulp juice was done using sieve (Test sieve ISO 3310-1 Body S- Steel / RF Mesh S-Steel/RF S/N 11046004 P/N: 30.3200.03, Germany) with 1 mm mesh size. The pulp juice was boiled with frequent stirring using wooden bar at a temperature 100ºC for 2 h to get concentrate paste as illustrated in figure 2.4. The concentrate paste was immediately packaged while hot into sterilized clean containers with covers and cooled at room temperature for 30 min the cooled tomato paste was then stored at 4ºC prior to analysis.

Figure 2.4: Tomato paste preparation (Photo by: Christian, 2019)

2.2.3 Data collection

The data were collected using quantitative methods. Nutritional content analyses were done on fresh tomato, paste and powder samples for easy comparison.

2.2.3.1 Moisture content determination

The moisture content was determined according to AOAC method of 931.04 of AOAC 2005 using oven (Wagtech International Limited, Britain) drying method at 105^{0}C. The empty dish and lid in triplicate were dried in the oven at 130°C for 3h and then cooled to room temperature in a desiccator. The dried empty dishes and lids were weighed. 5g of sample was weighed to the dishes. Then dishes with samples were placed in the oven and dried for 24 h at 105°C while the lids are open to get uniform weight. After drying, the lids were closed and cooled to room temperature in a desiccator. Then the dishes and its dried sample were reweighed. Moisture content was calculated by using the formula below:

Moisture content (%) = $(W_1-W_2) \times 100/W_1$ -- (i)

Where: W_1 = weight (g) of sample before drying

W_2 = Weight (g) of sample after drying

2.2.3.2 Determination of β-carotene contents

β-carotene contents was determined according to Rodriguez-Amaya and Kimura (2004). A sample of 2 g was weighed; 50 ml of petroleum ether (PE) was introduced in each bottle. The mixture was shaken vigorously by using orbital shaker (KS501 digital IKALABORTECHNIK, Japan) at 150 r.p.m for 1 hour and then filtered through filter papers (125 mm Dia x 100 Circles 4 Whatman). Ten (10) g of anhydrous Sodium Sulphate was added in the filtrate in order to absorb water. The wave length of extract was read at 450 nm ultraviolet visible Spectrophotometer (Model X-ma 3000 series, Human Corporation, South Korea). The total β-carotene content was calculated using the formula below and expressed in mg/100g of fresh weight (FW).

Total β-carotene content (μg/g) = A X V (ml) X 10^4 / $A_{1cm}^{1\%}$ X Sample weight (g) ------- (ii)

Where A = absorbance at 450 nm; V = total volume of tomato extract (50 ml);

$A_{1cm}^{1\%}$= absorption coefficient of β-carotene in PE (2592).

The results were multiplied by 0.1 to get the total β-carotene content in (mg/100g) of fresh weight (FW).

2.2.3.3 Determination of Lycopene content

Lycopene content was determined according to Eletr *et al*., (2017); Owureku-Asare *et al*. (2014); and Rodriguez-Amaya and Kimura, (2004). A sample of 2 g was weighed; 50 ml of petroleum ether extract was introduced in each bottle. The mixture was shaken vigorously by using orbital shaker (KS501 digital IKALABORTECHNIK, Japan) at 150 r.p.m for 1 hour and 10 g of anhydrous Sodium Sulphate was added then filtered through filter papers (125 mm Dia x 100 Circles 4 Whatman). The wave length of extract was read at 470 nm ultraviolet visible spectrophotometer (Model X-ma 3000 series, Human Corporation, South Korea). The total lycopene content was calculated using the formula below and expressed in mg/100g of fresh weight (FW).

Total lycopene content (μg/g) = A X V (ml) X 10^4 / $A_{1cm}^{1\%}$ X sample weight (g) -------- (iii)

Where A = absorbance at 470 nm; V = total volume of tomato extract (50 ml);

$A_{1cm}^{1\%}$= absorption coefficient of lycopene in PE (3450).

The result was multiplied by 0.1 to get the total lycopene content in (mg/100g) of fresh weight (FW).

2.2.3.4 Determination of ascorbic acid content

The ascorbic acid content was determined according to Hussein *et al*. (2016) using 2, 6-dichloroindophenol titration method. Samples of 5 g were taken into a 100ml volumetric flask and distilled water was added up to mark. The mixture was shaken vigorously by using orbital shaker (KS501 digital, IKALABORTECHNIK, Japan) at 150 r.p.m for 30 min and then filtered through filter papers (125 mm Dia x 100 Circles 4 Whatman). Two blanks composed of 5 ml of water and 20 ml Trichloroacetic acid (TCA) reagent was titrated until a light but distinct rose-pink colour persisted for at least 15 seconds. Similarly, a test sample of 5 ml of filtrate tomato in a conical flask and 20 ml of TCA (10%) reagent was added to get 25 ml. The mixture was then titrated rapidly with the Indophenol solution until a light but distinct rose-pink colour persisted for at least 15 seconds. Then the volume of indophenol solution (0.0760 mg/ml) used was recorded in triplicate. The ascorbic acid content in the sample was calculated and expressed in mg/100g of fresh tomato weight (FW) by using the following equation:

Ascorbic acid content (mg/100g) = (T – Vb) X DF X V_1 / (W X V_2) --------------------- (iv)

Where: T= Volume in ml of the indophenol solution used for sample titration (Titre)

Vb= Volume in ml of the indophenol solution used for sample blank titration

DF= Dye factor or Mass in mg of ascorbic acid equivalent to 1.0ml of indophenol standard solution (0.0760 mg/ml)

V_1= Volume made up to 100 ml

W= aliquot of extract taken for estimation (5 g)

V_2= Volume of sample taken for estimation (5 ml).

2.2.3.5 Calculation of percentage retention of β-carotene, lycopene and ascorbic acid

The percentage retention of β-carotene, lycopene and ascorbic acid was calculated according to Soares (2013); and Rodriguez-Amaya and Kimura (2004), using the equation below:

% Retention = Cp X Pp X 100 / Cc X Pc -- (v)

Where: Cp = the nutrient content per gram of prepared food (tomato powder or paste)

Pp = food weight (in grams) after preparation (tomato powder or paste);

Cc = nutrient content per gram of raw food before cooking (fresh tomato); and

Pc = raw food weight before cooking (fresh tomato) (g).

2.2.3.6 pH

A sample of 5 g was taken and 95 ml of distilled water was added to get 100 ml. The mixture was shaken vigorously by using orbital shaker for 30 min and then filtered through filter papers (125 mm Dia x 100 Cicles 4 Whatman). After calibration with standard buffers of pH 4.00 and 7.00, the pH of sample extract tomato extract in conical flask was determined using pH-meter (Model 3305, JENWAY Cole-Parmer Ltd, United Kingdom) and readings were recorded in triplicate (Obadina *et al*., 2018).

2.2.3.7 Determination of titratable acidity

Titratable acidity was determined by potentiometric titration, by titrating 10 ml of tomato extract with 0.1N Sodium hydroxide (NaOH) up to pH 8.1 and the volume used was recorded in triplicate. The titratable acidity in the samples was calculated by using the equation below and was expressed in g of citric acid per 100 g of fresh tomato weight (FW) (Owureku-Asare *et al*., 2018; Zhu *et al*., 2018; Majidi *et al*., 2011).

TA (%citric acid) = (Titre X Normality X M.eq.wt of acid X 100 / V) X 100 ---------- (vi)

Where: M.eq.wt of acid = Milli-equivalent weight of citric acid (predominant acid in tomato) is 0.06404

V = Volume of sample (ml)

2.2.4 Statistical data analysis

The collected data were coded on Microsoft-excel then analyses using R-statistical software (Ri386 3.5.3). All quantitative data was expressed as mean value ± SD (standard deviation). Differences among nutritional quality parameters were determined by using the one-way analysis of variance (ANOVA) test at 95% confidence interval. The significance of the difference between the means were determined using *post hoc* Tukey's Honest Significant Difference (HSD) test at $p<0.05$.

2.3 Results and Discussion

The results compared effect of boiling and solar drying techniques (tomato paste and tunnel solar dried tomato powder) for moisture, β-carotene, lycopene and ascorbic acid contents, pH and titratable acidity. Biochemical parameters of tomato samples were compared with that of the fresh tomato for three tomato varieties (*Asira*, *Imara* and *Reogrande*) collected from small scale farmers' fields.

2.3.1 Moisture content of fresh tomato, paste and powder

As indicated in figure 2.5, the initial moisture content (MC) in fresh weight basis (FW) for three varieties were significantly different at ($p<0.05$) and ranged from 92.97±0.31 to 95.12±0.12% in fresh tomato, 68.97±0.32 to 71.73±0.48% in tomato paste and 11.02±0.09 to 11.74±0.41% in tomato powder samples.

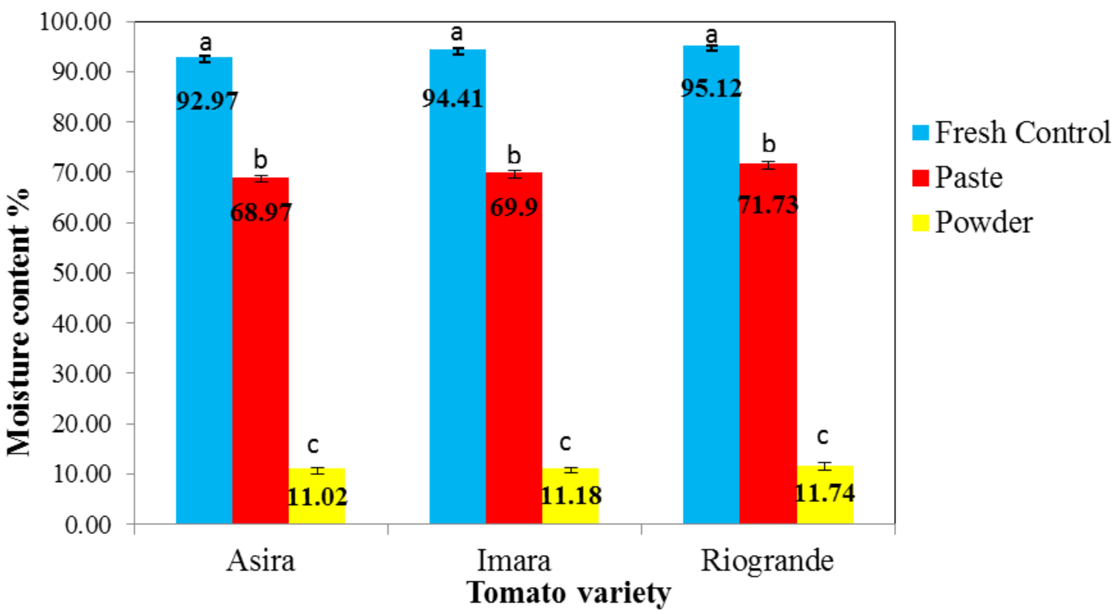

Figure 2.5: Moisture content (%) of fresh tomato, paste and powder of different variety (means ± SD, n = 3). Bar means with different letter are significantly different at p<0.05

The results of moisture content for fresh tomato was comparable to those obtained by other researchers 88.19 to 95.91% (Mwende *et al*., 2018; Owureku-Asare *et al*., 2018; Hussein *et al*., 2016; Owureku-Asare *et al.*, 2014; D'Evoli *et al*., 2013; Mongi, 2013; Mozumder *et al*., 2012; Koh *et al*., 2012; Adubofuor *et al*., 2010). The high moisture content found makes tomatoes to be more vulnerable to deterioration due to spoilage and supporting microbial growth. That result in increased postharvest losses in both quantity and quality. Therefore, specific postharvest processing technologies are prerequisite to extend its storability, availability and accessibility.

For tomato paste, Eke-Ejiofor (2015) observed 69.00 to 84.85% moisture content in six unlike products of tomato paste collected from a grocer's shop and one locally processed and Koh *et al*. (2012) found 73.11% slightly higher than that results (68.97 to 71.73%) obtained in this study. According to Sobowale *et al*. (2012), the moisture content of tomato paste was determined by the total solid which might be of high content important for quality determination among other criteria. So, tomato paste was termed as tomato concentrate that contains more than 24% of natural total solids which was equivalent to minimum 76% MC (Codex, 2017). Tomato pastes were categorised into three main forms: heavy with not less than 33% natural tomato solids, medium concentration range from 29 to 33% natural solids and light containing 25 to 29% of salt free tomatoes (Sobowale *et al*., 2012; Kumari and Singh, 2018). Moreover, the developed tomato paste was between medium and light tomato paste whereby *Imara* and *Riogrande* with similar moisture content as that obtained by Eke-Ejiofor (2015). Similarly, the moisture content in the developed tomato paste was higher than those presented by Sobowale *et al*. (2012)

with total solid content ranging from 54.9-68.90% which corresponded with 31.1 to 45.1% moisture content.

The results for moisture content in tunnel solar dried tomato powder were in similar to those reported by Obadina *et al.* (2018) with 11.25 to 13.75% MC; Mongi (2013) reported moisture content of 11.1 to 11.7%. The results obtained from this study were lower compared to that obtained by Owureku-Asare *et al*. (2018) which ranged from 13.94 to 14.57% and Dauda *et al*. (2019), ranged from 16.85 to 18.15% of dried tomato at different temperatures. On the other hand, the results of moisture content of powder in this study were higher than those presented by Sarker *et al*. 2014 (8.12%), Sahin *et al*. 2011 (10%), Mozumder *et al*. 2012 (6.9%), Surendar *et al*. 2018 (5.42 to 5.80%), Srivastava and Kulshreshtha 2013 (5.60%) and Prasath *et al*. 2018 (8.67 to 10.05%). Dried tomato powder comprises sugars and cellulose which had hygroscopic characteristics and great affinity to water which facilitates the absorption of moisture apprehended from the surrounding environment air (Owureku-Asare *et al*., 2018). According to Baradey *et al*. (2016) high level moisture content was regarded as the key cause for microbial growth linked with decomposition of food products.

2.3.2 β-carotene content of fresh tomato, paste and powder

From figure 2.6 the results showed a significant variation at $p < 0.05$ among the tomato product samples with average β-carotene content ranging from 1.46 ± 0.18 to 2.33 ± 0.04 mg/100g FW in fresh tomato and 2.57 ± 0.17 to 2.91 mg/100g FW in paste. The retention for paste ranged from 21.53% to 40.57%. For tomato powder, it had 3.19 ± 0.01 to 3.26 ± 0.03 mg/100g FW with retention of 7.58% to 17.46%. The result shows that, value addition processing technologies have significantly effect on β –carotene present. This effect was much observed in dried tomatoes powder due to low moisture content and concentration of the nutrients, β-carotene.

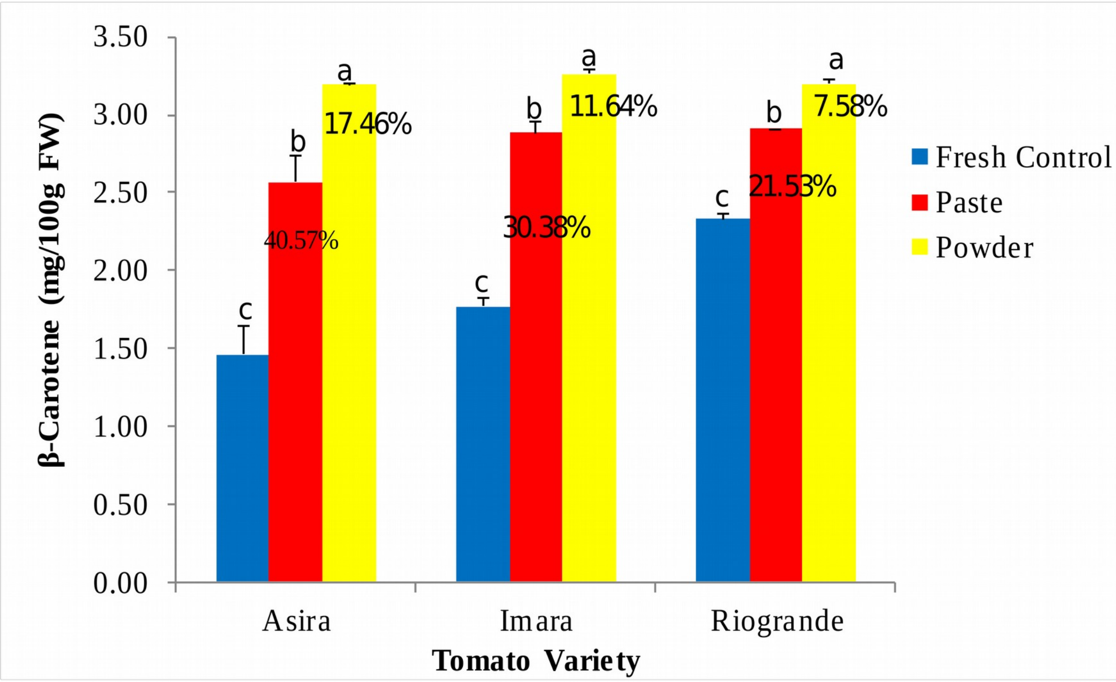

Figure 2.6: β-carotene content (mg/100g) of fresh tomato, paste and powder of different variety (means ± SD, n = 3). Bar means with different letter are significantly different at $p<0.05$ and values in percentage are retention rate.

The finding of this study concurs with the results reported by other researchers with 0.88 to 4.15 mg/100g FW (Mwende *et al*., 2018; Shatta *et al*., 2017; Hussein *et al*., 2016; D′Evoli *et al*., 2013; Georgé *et al*., 2011; Vogel *et al*., 2010) in fresh tomato. Besides, the results of β-carotene in tomato paste (2.57 to 2.91 mg/100g FW) were comparable to that reported by Shatta *et al*. (2017) with 3.291 to 3.389 mg/100g FW and higher compared to Koh *et al*. (2012) observed 1.0 mg/100g FW for processed tomato paste developed from mixed tomatoes cultivars collected from local fields.

Furthermore, the results (3.19 to 3.26 mg/100g FW) obtained for tomato powder from this study were slightly lower to those reported by Sarker *et al*. (2014) with 4.567 mg/100g FW and Hussein *et al*. (2016) who obtained the value ranged from 4.25 to 4.98 mg/100g FW for solar dried tomato. Also, the results obtained were slightly higher than that obtained by Buren *et al*. (2019) with 2.1 mg/100g FW in dried tomato powder.

The result shows that the β-carotene content decreased as the processing time increases and when moisture contents decreased. This was evidenced on percentage retention in which processed tomato powder with 11.64 to 17.46% retention compared with tomato paste with 21.53 to 40.57% retention. This because during solar drying much time (10 h) were used to get dried tomato powder with moisture content around 11.02 to 11.74% compared to duration of 2 h used to get tomato paste with 68.97 to 71.73% MC. Also, these variations might be ascribed to the dissimilarities in processes method used such as in solar drying; enzymatic reaction on carotenoids could be greatly troublesome compared to boiling into paste due to high temperature (up to 100ºC) used (Rodriguez-Amaya and Kimura, 2004). Therefore, tunnel solar drying concentrates β-carotene content due to an upsurge in the extractability which is extremely initiated by temperature and time length of heating or drying. The final quantity and quality of β-carotene in tomato processed products depend greatly on initial content in raw materials, genotype, geographical location, season, stage of maturity and harvesting time and processing method used (Rodriguez-Amaya and Kimura, 2004; Hussein e*t al*., 2016). Therefore, the result shows total β-carotene content was low in tomato paste compared to tomato powder. This was attributed with skin and seed separation from tomato pulp during paste processing although, β-carotene was better retained in paste compared with tomato powder.

2.3.3 Lycopene content of fresh tomato, paste and powder

The average lycopene contents in figure 2.7 showed a significant difference at $p < 0.05$ with variation from 6.11 ± 0.26 to 7.34 ± 0.02 mg/100g FW in tomato fresh, 8.12 ± 0.25 to 8.81 mg/100g FW in tomato paste with the percentage retention of 20.73 to 30.28, and in tomato powder the content of lycopene ranged from 10.57 ± 0.01 to 11.30 mg/100g FW with the percentage retention of 7.96 to 14.66. The findings indicate that value-addition technique considerably affected the lycopene content in paste and solar dried tomato samples.

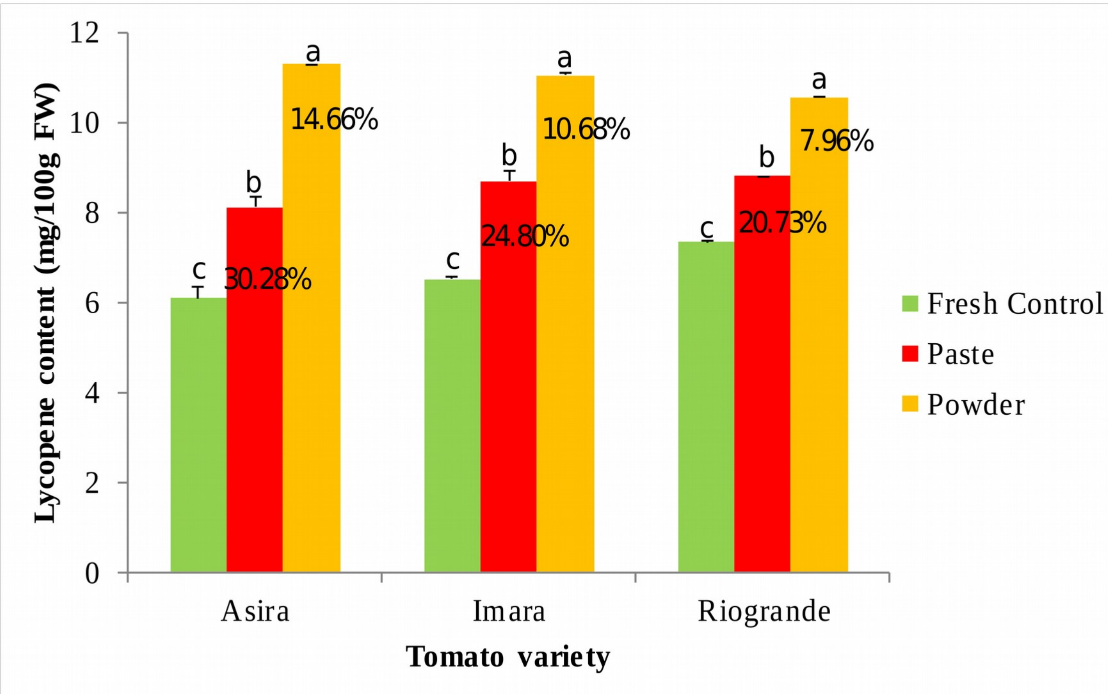

Figure 2.7: Lycopene content (mg/100g) of fresh tomato, paste and powder of different variety (means ± SD, n = 3). Bar means with different letter are

significantly different at $p<0.05$ and values in percentage are retention rate.

Boiling and drying process can interrupt lycopene content in terms of concentration, isomerization and bio-accessibility (Owureku-Asare *et al*., 2018) based on the phenomena of isomerisation and oxidation (Hussein *et al*., 2016). The lycopene was much higher concentrated in solar dried tomatoes powder in comparison to paste due to reduced moisture content when expressed in wet basis. This indicates that during processing lycopene was better concentrated in powder form.

In addition, the results of lycopene in fresh tomato obtained were higher than previous reported studies with 1.49 to 3.18 mg/100g FW (Dauda *et al*., 2019; Owureku-Asare *et al*., 2018; Shatta *et al*., 2017; Verma *et al*., 2016) in fresh tomato. According to Owureku-Asare *et al*. (2018), standard lycopene content in fresh tomato should range from 0.72 to 20.0 mg/100g FW, which comprises for nearly 30% of the total carotenoids in the cell plasma. These indicate that the results obtained from this study for fresh tomato samples were within the recommended limit of 0.72 to 20.0 mg/100g FW.

Moreover, the results of lycopene in tomato paste in this study were comparable to that reported by other researcher with 3.59 to 92.34 mg/100g FW (Shatta *et al*., 2017; Eke-Ejofor, 2015; Koh *et al*., 2012) in tomato paste collected from the commercial markets. The difference may be due to raw tomato used in processing influenced by seasonality, variety and processing method employed. The results of lycopene in tomato powder were in agreement to those obtained by other researcher ranged 2.69 to 25.12 mg/100g FW (Buren *et al*., 2019; Dauda *et al*., 2019; Obadina *et al*., 2018; Owureku-

Asare *et al*., 2018; Hussein *et al*., 2016; Adejo *et al*., 2015; Owureku-Asare *et al*., 2014; Sarker *et al*., 2014) in dried powder.

The lycopene content in tomato and tomato products is governed by variety, season geographical location, ripening stage of maturity, environmental condition, agricultural practices and processing technologies used (Rodriguez-Amaya and Kimura, 2004; Hussein *et al*., 2016). Also, the initial content in the raw tomatoes as well as method used for processing may affect final lycopene content. The results obtained were in agreement with other studies that, the concentration of lycopene content in tomato products rises with increased process temperature in which mechanical action and heating influence the tomato matrix to release the lycopene compound (Hussein *at al*., 2016; Obadina *et al*., 2018). Several researches demonstrated that processing operations, like heat treatment disintegrate the cell walls, supporting the discharge of lycopene from tomato chromoplasts and thereafter improving its bioavailability (Kamiloglu *et al*., 2013). In spite of, drying environments, together with high temperature, light, and oxygen exposure, may facilitate lycopene degradation and in that way affect the colour and nutritive value of the end products (Sahin *et al*., 2011).

Although, the results shows lycopene content was high in solar dried powder than in paste because during processing of fresh tomato to dried powder, peels which contain high percentage of lycopene were included compared to paste whereby the pomace (peel and seeds) are discarded during processing to paste (Eletr *et al*., 2017). Since tomato and tomato products are used in wet basis, daily preparation of diet by using tomato powder shortens the way of attaining the Recommended Daily Intake (RDI). Thus, it was possible for the lycopene to rise during meal preparation by thermal treatment when the tomato powder used compared to paste. The same study also has reported by Urbonaviciene *et al*.

(2012) who found the lycopene content as 10 times extra in the tomato peel than in the tomato flesh of the ripe fruit of the 'Admiro' F_1 variety with average lycopene around 62.92 mg/100g in the non- blanched tomato skins and 6.37 mg/100g in the non-blanched tomato skin. Since, the lycopene are not synthesized by human body, therefore, adequate consumption in the meal is crucial in order for the body to benefit from external source (Kamiloglu *et al*., 2013).

2.3.4 Ascorbic acid (vitamin C) content of fresh tomato, paste and powder

The results of ascorbic acid content were shown in figure 2.8 with a significant difference at $p < 0.05$ variation from 10.24 to 12.67 $\pm$ 1.76 mg/100g FW in fresh tomato. For tomato paste were 2.03 $\pm$ 0.88 to 5.83 $\pm$ 0.44 mg/100g FW while tomato powder ranged from 48.13 $\pm$ 2.32 to 51.93 $\pm$ 4.19 mg/100g FW. The retention of ascorbic acid was 22.85 to 30.31 for tomato powder and 3.58 to 9.68% for tomato paste.

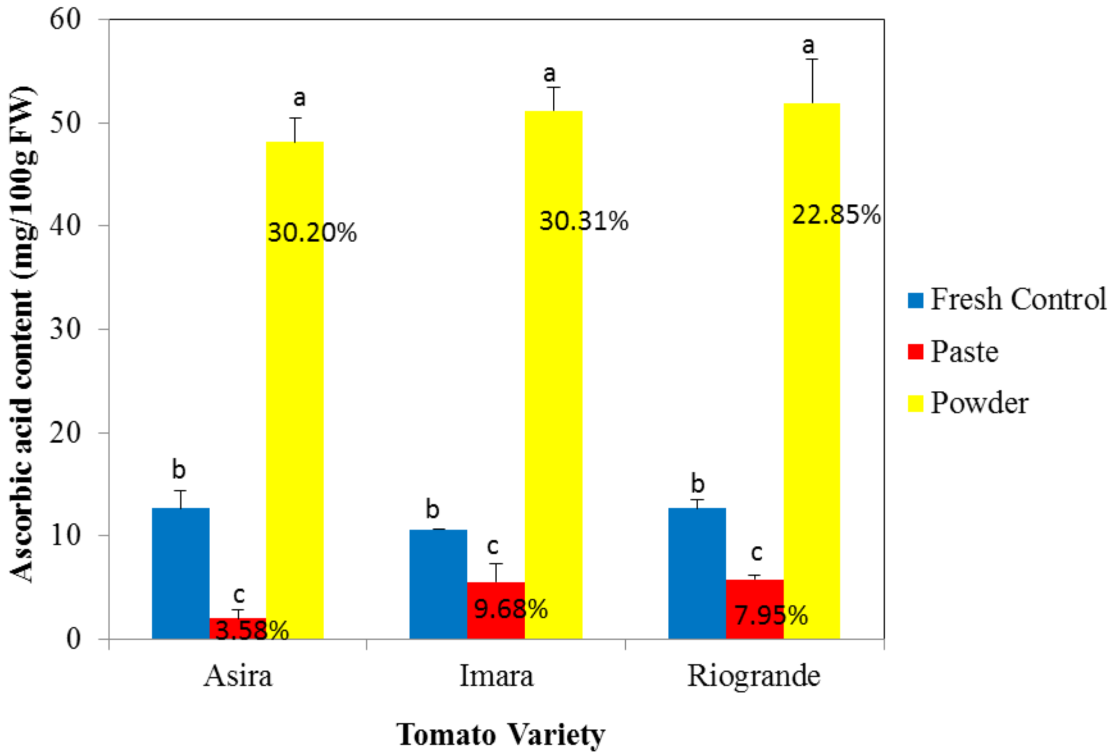

Figure 2.8: Ascorbic acid (mg/100g) of fresh tomato, paste and powder of different variety (means ± SD, n = 3). Bar means with different letter are significantly different at p<0.05 and values in percentage are retention rate.

The results in fresh tomatoes were comparable with those reported by other researcher showing ascorbic acid content ranged from 10.86 to 40.15 mg/100g FW (Dauda *et al*., 2019; Hussein *et al*., 2016; Kamiloglu *et al*., 2013, Adenike, 2012; Pinela *et al*., 2012; Georgé *et al*., 2011; Koh *et al*., 2012; Adubofuor *et al*., 2010) in fresh tomato samples. According to Koh *et al*. (2012), the value for ascorbic acid in fresh tomato is around 12.70 mg/100g FW.

For tomato paste, the results (2.03 to 5.83 mg/100g FW) were lower with those obtained by Sobowale *et al*. (2012) obtained values of ascorbic acid ranged from 12.60 to 17.20

mg/100g FW. Nevertheless, the results reported by Koh *et al*. (2012) of 66.32 mg/100g FW in processing samples of tomato paste was higher than the results from this study. According to Koh *et al*. (2012), substantial decrease of ascorbic acid content occurred by 66% when tomato paste was processed from fresh tomatoes due to rise in temperature at hot break (95ºC) as the critical point for indicating ascorbic acid in the final product. The current study shows the ascorbic acid level in tomato paste was affected by processing procedure of prolonged boiling (100ºC for 2 h) and separation of skin and seed from pulp compared to tomato powder.

Moreover, the results (48.13 to 51.93 mg/100g FW) for tomato powder ascorbic acid content in this study were comparable with results reported by other researcher ranged from 13.37 to 49.00 mg/100g FW (Buren *et al*., 2019; Hussein *et al*., 2016; Sarker *et al*., 2014; Adenike, 2012) in tomato powder. Similarly to those reported by Mongi, (2013) reported the value of ascorbic acid of tunnel dried tomato ranged from 35 to 37.30 mg/100g FW which correspond to retention of 28.90 to 31.10%. Furthermore, the results obtained from dried tomato powder were lower than that reported by Srivastava and Kulshreshtha (2013) showing around 125 mg/100g FW.

This was supported by the temperature (58°C) inside the tunnel solar dryer and shorter drying time (10 h) length used which inactivated the ascorbic acid oxidase enzyme and safeguard vitamin from enzymatic oxidation (Mongi, 2013). The decreases in ascorbic acid content was also reported by Kadam *et al*. (2012); and Srivastava and Kulshreshtha (2013). Fresh tomato fruit is a good source of ascorbic acid which necessitates the assessment of its percentage retained in processed tomato products. In addition to that, since ascorbic acid can be damaged utmost quickly therefore, can be used as an indicator of freshness (Barrett *et al*., 2010). During processing, losses of ascorbic acid content were enhanced by water loss which was influence with processing temperature and genotype of produce (Srivastava and Kulshreshtha, 2013). The decreases of ascorbic acid at low moisture content were due to increase in concentration and rate of oxidation reaction. Consequently, the major elements triggering loss of ascorbic acid during tomato processing are heat and oxygen (Obadina *et al*., 2018). In addition, oxidation reaction occurs during processing in the presence of oxygen, react with ascorbic acid to form dehydroascorbic acid, followed by hydrolysis into 2,3-diketogulonic acid and additional oxidation and polymerization to several sedentary nutritional products especially under high temperature conditions (Obadina *et al*., 2018; Santos and Silva, 2008). Figure 2.9 show the degradation of ascorbic acid during processing.

$$C_6H_8O_6 \longleftrightarrow C_6H_6O_6 \longleftrightarrow \text{Products}$$

L-Ascorbic Acid L-Dehydroascorbic Acid

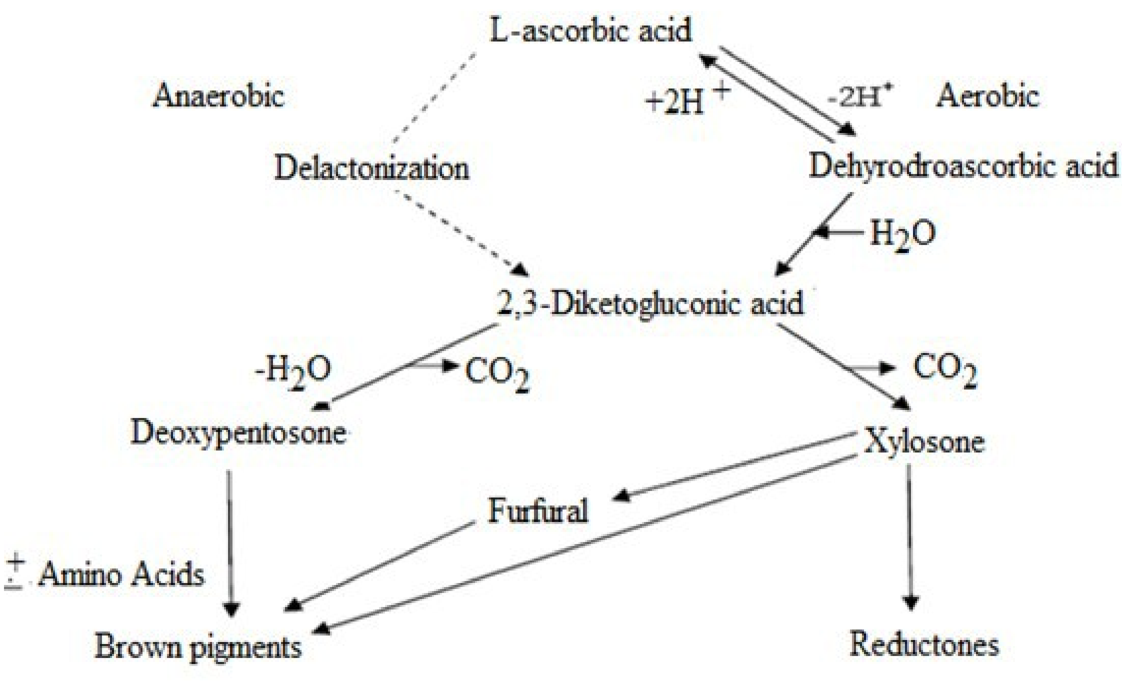

Figure 2.9: Degradation of ascorbic acid (source: Mongi, 2013)

2.3.5 pH

From Table 2.4, the pH shows a significance difference between varieties of tomato product samples at $p < 0.05$ ranged from 4.50 to 4.66 in tomato fresh, 4.56 to 4.68 in tomato paste and 4.76 to 4.95 in tomato powder.

The results of pH in fresh tomato were similar to those reported by Mongi (2013), found pH ranging from 4.58 to 4.6 in fresh tomato but slightly higher from those obtained by Owureku-Asare *et al*. (2014) that ranged from 4.18 to 4.45 in fresh tomato.

Table 2.4: Mean values for pH and Titratable Acidity of tomato (Fresh, Paste and Powder)

Tomato Variety	SAMPLE	pH	Titratable Acidity (%Citric acid)
Asira	Fresh (control)	4.66^{c}	0.30 ± 0.07^{c}
	Paste	4.68^{b}	0.64 ± 0.00^{b}
	Powder	4.95^{a}	6.41 ± 0.23^{a}
Imara	Fresh (control)	4.50^{c}	0.34 ± 0.15^{c}
	Paste	4.60^{b}	1.32 ± 0.07^{b}
	Powder	4.90^{a}	6.48 ± 0.15^{a}
Riogrande	Fresh (control)	4.50^{c}	0.38 ± 0.00^{c}
	Paste	4.56^{b}	2.23 ± 0.07^{b}
	Powder	4.76^{a}	6.23 ± 0.30^{a}

Values are expressed as mean ±SD (n=3). Mean values with different superscript letters (a, b and c) along the columns are significantly different at $p < 0.05$

On the other hands, the pH values for tomato paste were lower than those reported from previous studies, such as Sobowale *et al*. (2012) ranged from 4.87 to 5.30, Eke-Ejiofor (2015) reported 3.99 to 4.38, and Shatta *et al*. (2017) observed 4.22 to 4.26 for developed paste. According to Codex, (2017), the pH of tomato paste must be below 4.6 as well as Sobowale *et al*. (2012) reported that standard pH of tomato paste ranged from 3.80 to 4.30. During processing of paste might need addition of citric acid in order to attain level of pH required. For that reasons pH of tomatoes is a vital feature during thermally value addition in tomato manufacturing industry. However, pH is a factor that signifies hygienic quality of tomato paste (Eke-Ejiofor, 2015). Furthermore, low pH was an essential aspect for microbial stability, as tomato pastes were pasteurized and not sterilized thereby inhibiting spoilage of microbial growth that necessitates assessment of pH along processing (Sobowale *et al*., 2012).

Moreover, tomato powder results were lower than those observed by Joseph *et al*. (2017) as reported pH of 5.90 for dried tomato products. Also, Owureku-Asare *et al*. (2018) and Sarker (2014) observed pH ranging from 4.07 to 4.3 for solar-dried tomato powder. Tomatoes are considered as high-acid foods (pH <4.6) (Codex, 2017, Obadina *et al*., 2018), thus the lower the pH the better for value addition.

2.3.6 Titratable acidity

The average titratable acidity (TA) are shown in figure 2.10, the results show significant difference between varieties at $p < 0.05$ which ranged from 0.30 ± 0.07 to 0.38% (as citric acid) in tomato fresh, 0.64 to 2.26±0.07% (as citric acid) in tomato paste and 6.23±0.30 to 6.48±0.15% (as citric acid) in tomato powder.

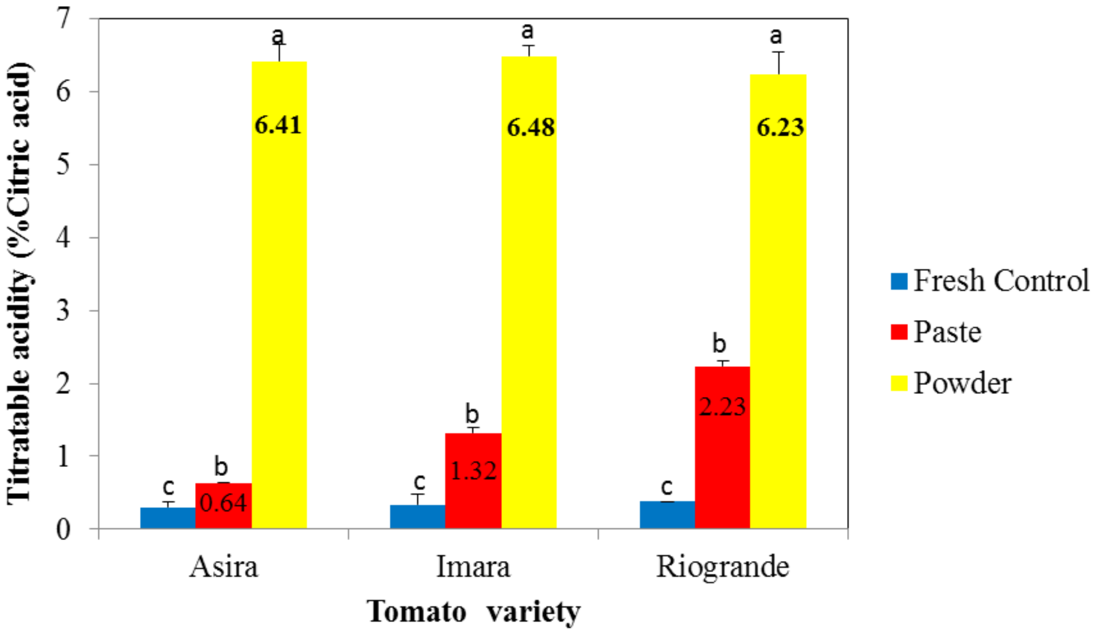

Figure 2.10: Titratable acidity (as % citric acid) of fresh tomato, paste and powder of different variety (means ± SD, n = 3). Bar means with different letter are significantly different at $p<0.05$

The titratable acidity of tomato and tomato product is associated with the presence of citric and malic acids which predominantly bring the sour taste (Majidi *et al*., 2011). However, the supreme care has to be taken to reduce the unfavourable properties of the technique used and following the environmental storage along the process.

These results were in comparable with TA value reported by Surendar *et al*. (2018) and Iijama *et al*. (2016) showed values varying from 0.38 to 0.49% in fresh tomato. However, the result of this study was slightly higher from 0.15 to 0.17% (as citric acid) reported for fresh tomato by Mongi, (2013). On the other hands, it was lower than that reported previously, such as 0.44% citric acid (Shatta *et al*., 2017), 3.53 to 4.32% citric acid (Adubofuor *et al*., 2010) and 3.10 to 5.70% citric acid (Vogel *et al*., 2010) for raw tomato. Also, for tomato paste the average results of titratable acidity (TA) obtained were comparable with those observed by Shatta *et al*., (2017) with 0.52 to 3.07 % (as citric acid). Titratable acidity of tomato powder results from this study were comparable to that determined by Sarker (2014) with 6% citric acid, Mazumder *et al*. (2012), reported TA value with 6.12% citric acid in solar dried tomato.

2.4 Conclusion

The study has shown that, comparatively tomato powder possesses high nutritional content than fresh tomato and paste. Therefore, technology of drying fresh tomato using tunnel solar dyer into powder could be helpful to reduce vast postharvest losses that occur due to seasonal, bulkiness and spoilage. Moreover, tunnel solar drying has diverse substantial effects on some nutritional quality attributes (Ascorbic acid, β-carotene and lycopene) compared to boiling into paste. Loss of β-carotene and lycopene during processing fresh tomato into paste is due to physical removal (separation of skin and seed from pulp). Boiling fresh tomato into paste has shown better percentage retention of β-carotene and lycopene compared to solar drying. Also, tunnel solar drying of fresh tomato into powder has shown high percentage retention of ascorbic acid compared to boiling into tomato paste.

Nutritionally, the consumption of tomato and tomato products was associated with the accomplishment of great portion of Recommended Daily Intake (RDI) of micronutrients such as vitamins and minerals. One strategy to increase food availability to feed the ever-increasing population was to ensure proper and better utilization of the food that was already produced. However, processed tomatoes were regularly deliberated as not as much of appreciated than the fresh ones owing to the damage of nutritious parameters. The study results conducted showed processed tomato powder and paste has concentrated β-carotene and lycopene in comparison to fresh tomato. In contrast, daily preparation of diet and drinks by using tomato powder shortens the way of attaining the Recommended Daily Intake (RDI) of vitamin C, β-carotene, lycopene and minerals.

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CHAPTER THREE

3.0 ACCEPTABILITY OF JUICE AND SOUP PREPARED FROM FRESH TOMATO, PASTE AND TUNNEL SOLAR DRIED TOMATO POWDER

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Abstract

The study aimed to assess acceptability based on sensory characterisation of juice and soup made from fresh tomato, paste and powder. Sensory analysis is a vital part of food quality in product development. Results showed that, juice from fresh samples had significantly higher colour intensity scores 8.50±0.80 (like very much), paste was aromatic rated 8.10±1.00 (like very much) and the powder liked very much due to acidity, consistency, sweetness, viscosity and clarity rated with 3.20±1.27, 8.30±0.49, 8.10±1.38, 7.7±0.89 and 8.30±0.49, respectively. Overall, juices from Powder_*Asira* and Paste_*Asira* were the most acceptable by consumers with hedonic scores of 7.00±1.97 and 7.00±2.02 (like moderately), respectively. Soup from Fresh_*Imara* had significantly more coloured and reddishness with intensity score 8.30±0.65 and 8.20±0.58, respectively. Soup samples from Paste_*Asira* had aroma rated 7.60±1.17 while those from Powder_*Imara* was liked with acidity and consistency score 6.30±0.89 and 8.30±0.62, Powder_*Reogrand* with saltiness score 5.90±0.67 and Powder_*Asira* with viscosity score of 8.50±0.52. Overall acceptability of samples showed that, soup from Paste_*Imara*, Powder_*Imara* and Paste_*Asira* were the most acceptable by consumers with hedonic scores of 7.40±1.30**,** 7.40±1.21 and 7.00±1.50, respectively. Therefore, juice and soup samples from fresh tomato, paste and powder were liked by consumer at moderate level.

Keywords: Tomato-Powder, Paste, Juice, Soup, Acceptability.

3.1 Introduction

Tomato (*Solanum lycopersicum*) is one of the greatest essential edible vegetable crops nutritionally. It is used daily in meal preparation and income generation (Aliyu *et al*., 2018; Chidege *et al*., 2016). It serves as a low-cost crop providing adequate supply of vitamins, minerals and fibres to public community. Due to tomato's seasonality, bulkiness and perishability necessitates more technologies on handling, packaging, processing and sales. The sensory information in product development in an economical way lowers the risks in judgments about product development. Therefore, in order to measure the actual impact of value-added processed product such as solar dried tomato, sensory evaluation should be employed to assess quality profile and the level of consumer acceptability. Tomato juice and soups can be reformulated from tomato products and they are the main sources of vitamins, minerals and fibres eaten with the staple foods (Babayeju *et al*., 2017) as an essential component of the Tanzanian diet.

The sensory quality attributes affected by tomato processing are colour, flavour and texture depending on processes employed and the sources of raw materials used. Tomato juice and soup are widespread dietary vegetable products with great nutritional content and a distinguishing flavour although, is very limited for Tanzanians. Marketable juice from tomato fruits normally comprises the process of homogenizing and thermal actions such as heating or blanching, pasteurization, and sometimes sterilization. All these employed processing techniques in one way or another affect the sensory characteristics of final product in terms of flavour, colour and texture. According to Iijima *et al*. (2016), enzymatic activity along the process of homogenization influences the production of several aromatic complex compounds.

Tomato juice is the un-concentrated tomato product with a least of 5% (w/w) total soluble solids of salt free that involving of the watery fluid with a considerable percentage of the pulp, uttered from ripe tomatoes with or without the use of heat (either hot pulped or cold pulped) (Kumari and Singh, 2018). Normally, tomato juice does not contain peels and seeds and can be reconstituted into other diverse tomato products.

Tomato soup is a boiled concentrate prepared either from fresh tomato pulp or tomato juice or other tomato products such as paste, sauce and powder to desired consistency. There are various methods which give tomato soup a good quality alongside with addition of butter or cream, starch and spices in significant quantities for flavour improvement (Kumari and Singh, 2018). Consequently, emerging innovative fruit and vegetable improved foodstuffs for instance tomatoes, that encounter consumer prospects, minimise postharvest losses and upsurge its productivity and consumptions is considered to be significance (Hobbs *et al*., 2014). The objective of this study was to evaluate sensory characteristics and overall consumer acceptability of tomato juice and soup based on fresh tomato, paste and solar dried tomato powder by using Quantitative Descriptive Analysis (QDA) and Affective (hedonic) test methods.

3.2 Materials and Methods

3.2.1 Study area

Sensory evaluation study was carried out at the Department of Food Technology, Nutrition and Consumer Science laboratory, Sokoine University of Agriculture (SUA), Tanzania.

3.2.2 Materials

Sensory evaluation was used to assess the level of acceptability of tomato juice and soups made from fresh tomato, paste and powder by using 9-point hedonic scale. A quantitative descriptive sensory profiling was conducted by trained sensory panel of 12 panellists (Hough, 2010; Lawless and Heymann, 2010), comprising of 7 males and 5 female aged ranged from 20 to 24 years. The hedonic test was carried out by 31 untrained consumers comprising of 14 males and 17 female aged ranging from 20 years and 40. A group of twelve (12) panellists were selected, trained according to ISO 6658 (2017) and ISO 8586 (2012).

3.2.3 Methods

In a pre-testing session, the panellists were trained in developing sensory descriptors and the definition of the sensory attributes according to ISO 5492 (2008). The panellists developed a test vocabulary describing differences between samples and they agreed upon to a total number of attributes on colour, aroma, taste, viscosity, consistence and acidity. An unstructured 9-point hedonic scale (9-like extremely and 1 dislike extremely) was used for rating the intensity of each attribute during Quantitative Descriptive Analysis and Consumer Test following the instruction given. Panellists evaluated attribute intensities of tomato juice and soup samples made from processed fresh tomato, paste and powder according to ISO 13299 (2016).

3.2.3.1 Study design

Incomplete block design (IBD) was used in the sensory analysis of juice and soup from fresh tomato, paste and dried tomato powder (Singh and Bhatia, 2017). In this design, blocks are grouped such that each group of block constitutes one complete replication of treatments. Principal factors were processing methods of raw materials used (fresh tomato, paste and powder) as factor 1 and panellists as factor 2. The effects of these factors on sensory attributes during processing were determined. The mathematical expression is presented in equation (i).

$$Y_{ij} = \mu + X_i + \beta_j + \varepsilon_{ij} \qquad \text{(i)}$$

Where: Yij = the phenotype (Response) of i^{th} treatment in j^{th} replication;

$i = 1, 2, \ldots t$;

$j = 1, 2, \ldots r_i$;

μ = the overall mean (general effect);

X_i = the i^{th} treatment effect;

β_j = the j^{th} block effect;

ε_{ij} = random error effect due to ij^{th} replication receiving i^{th} treatment.

3.2.3.2 Sample collection and preparation

A standard juice (fig.3.1) and soup (fig. 3.2) were formulated for sensory evaluation from fresh tomato, paste and solar dried tomato powder and then were saved cold (for juice) and warm (for soup) to panellist for sensory analysis.

(a) Standardisation of juice samples

Standardisation of cold pulped single tomato juice was done by blending of sugar (10%) with fresh tomato, paste and powder mixed with portable water into juice (Table 3.1). The fresh tomato was blended using heavy duty blender. In each formulation, 100 g of sugar and 1 litre of water were added. Then the mixture was homogenized by stirring with wooden bar and filtered through stainless steel juice filter (300 µm pore size). The sample juice developed was store at 4°C prior sensory analysis. The flow chart steps for processing tomato juice were shown in figure 3.1.

Table 3.1: Formulation summary of standard juice

Sample code	Quantity (g)	Pulp : Water (w/v)
FTJ1	1000	1:1
FTJ2	1000	1:1
FTJ3	1000	1:1
PTJ1	200	1:5
PTJ2	200	1:5
PTJ3	200	1:5
WTJ1	50	1:20
WTJ2	50	1:20
WTJ3	50	1:20

FTJ = Fresh Tomato juice Sample, PTJ = Juice from Tomato Paste Sample; WTJ = Juice from Tomato Powder Sample. 1= *asira and* 2= *Imara* hybrid varieties and 3= *Riogrande* local variety.

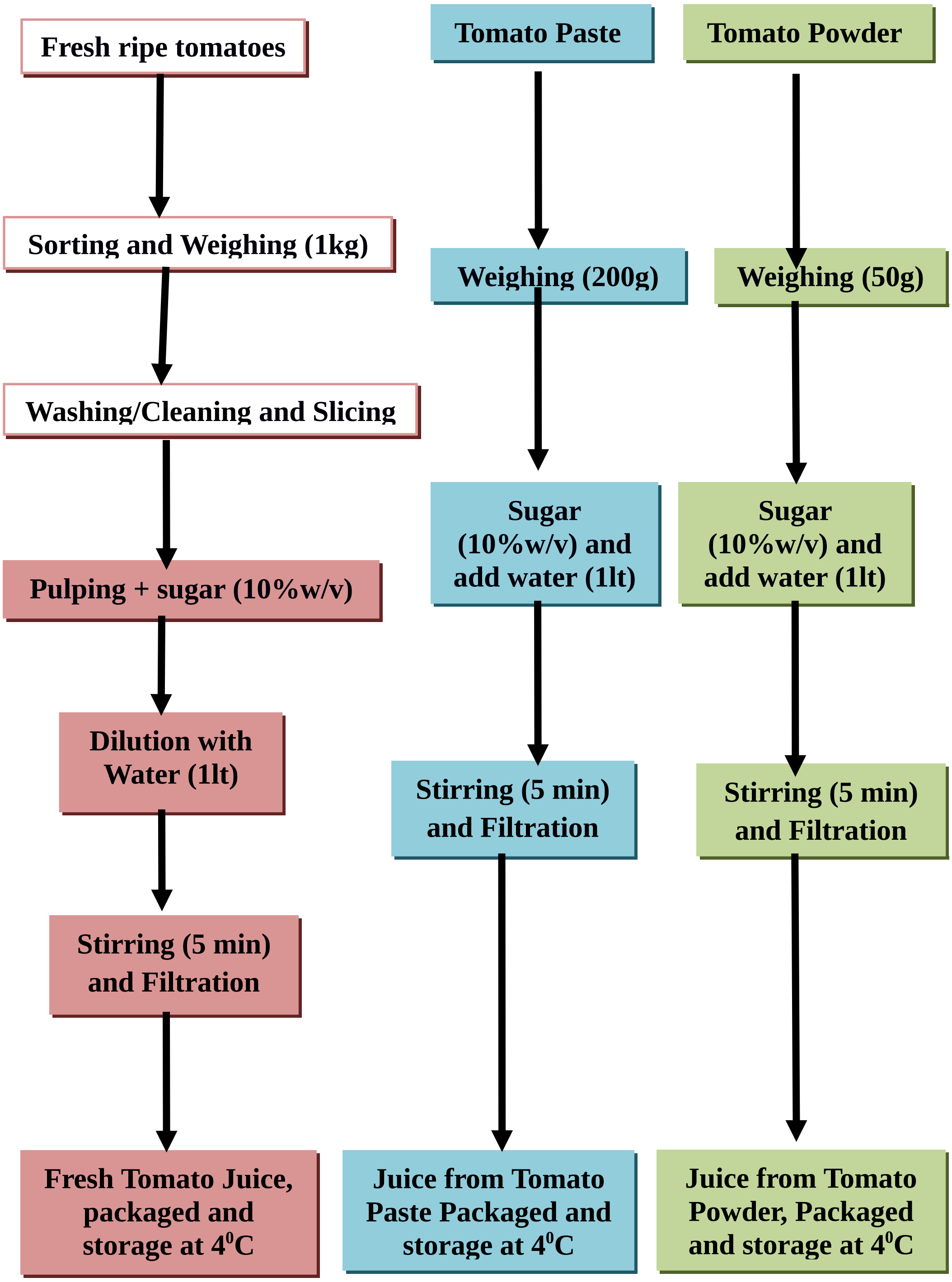


Figure 3.1: Flow chart for preparation of cold pulped Tomato juice by using tomato fresh, paste and powder.

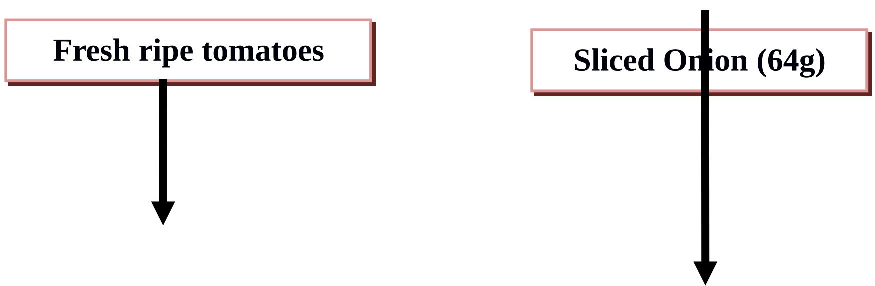
(b) Standardisation of soup samples

Standardisation of tomato soup was done by blending salt (1%), sliced onion and purely refined sunflower cooking oil with grams of fresh tomato, paste and powder (Table 3.2). The mixture was boiled in a stainless steel utensil into condensed tomato soup. Then the developed tomato soup was stored in hotpot utensils (temperature above 60°C) prior to sensory analysis. The flow chart steps for processing soup were shown in Figure 3.2.

Table 3.2**: Formulation summary of standard soup**

Samples code	**Quantity (g)**	**Vegetable Oil (ml)**	**Salt (1%, g)**	**Onion (g)**	**Water (ml)**
FTS1	1000	25	10	64	1000
FTS2	1000	25	10	64	1000
FTS3	1000	25	10	64	1000
PTS1	200	25	10	64	1000
PTS2	200	25	10	64	1000
PTS3	200	25	10	64	1000
WTS1	50	25	10	64	1000
WTS2	50	25	10	64	1000
WTS3	50	25	10	64	1000

FTS = Fresh Tomato soup Sample, PTS = Soup from Tomato Paste Sample; WTS = Soup from Tomato Powder Sample. 1= *asira* and 2 = *Imara* hybrid varieties and 3= *Riogrand* local variety.



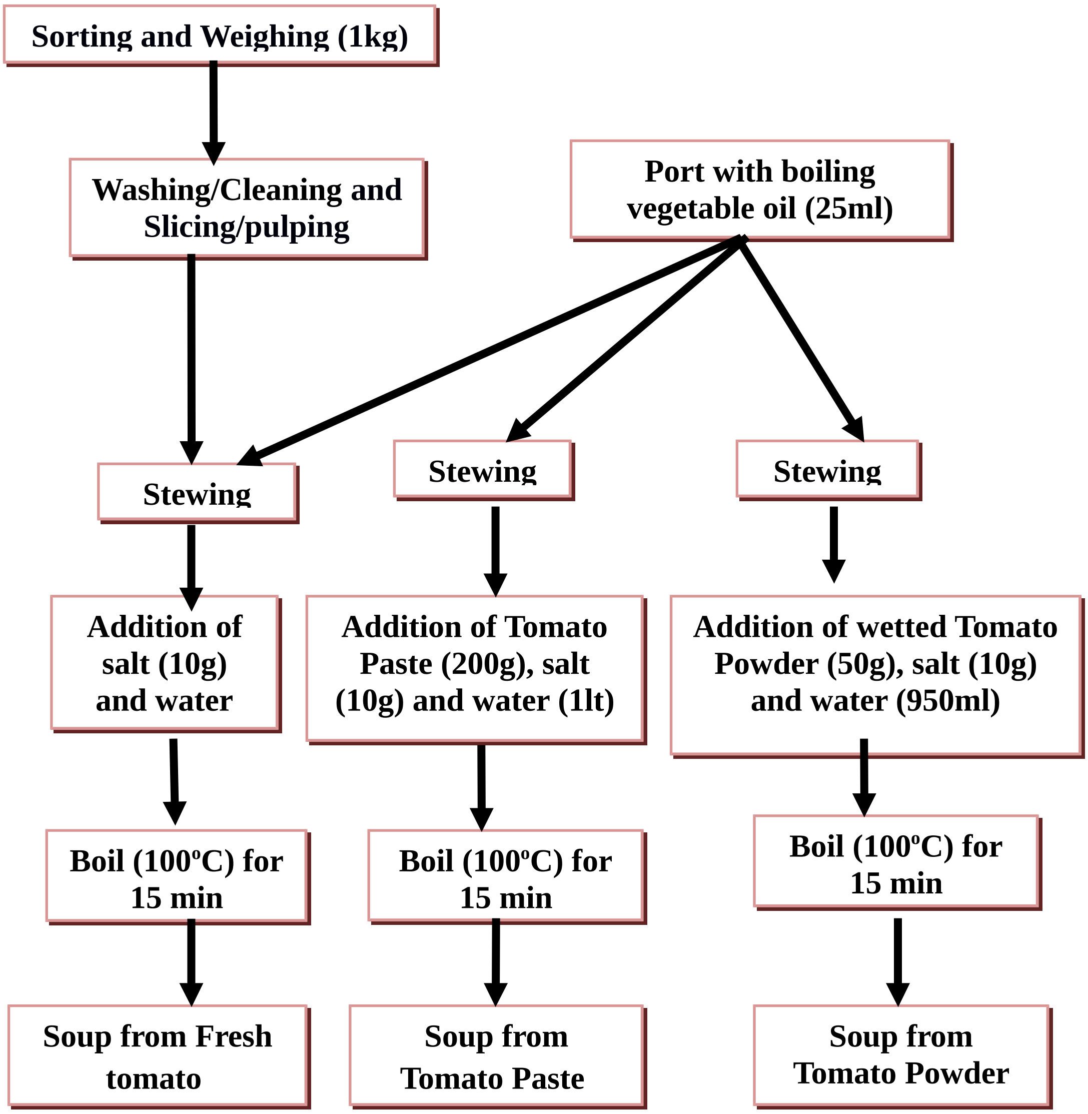


Figure 3.2: Flow chart for preparation of Tomato Soup by using fresh tomato, paste and powder.

3.2.4 Data collection

3.2.4.1 Quantitative Descriptive Analysis (QDA)

A descriptive sensory profiling was conducted by trained sensory panel of 12 panellists. The panellist were purposively selected from third year undergraduate students of BSc. Food Science and Technology and trained according to ISO Standard (2005). In a pre-testing sitting, the panellists were trained in developing sensory descriptors and the interpretation of the sensory attributes according to ISO 13299 (2016). The panellists developed a test terminology describing differences between samples (Table 3.3).

An unstructured 9-point hedonic scale (Where 9 – Like extremely and 1- Dislike extremely) as described by Hough (2010); Lawless and Heyman (2010), was used for rating the intensity of each attribute following the instruction given. Descriptive analyses of 9 juice and soup samples prepared from fresh tomato, developed tomato paste and solar dried tomato powder were carried out in single sessions of different product and each panellist evaluate nine samples per product per session. Random numbers (3-digit) were used for sample coding. Sample were served cold (for juice) and warm (for soup) to each panellist in a randomized order and instructed to rate the colour and appearance (consistency and clarity), aroma, taste (saltiness and sweetness), texture (viscosity and mouth feel) and acidity attributes. Water was served together with samples for mouth rinse before assessing each sample during the test. The average response was recorded to be used in the univariate and multivariate statistical analyses.

Table 3.3: Definitions of sensory attributes used in descriptive sensory analysis

Parameter	Attribute	Definition
Colour	Colour hue (type)	Reddish
	Colour intensity	Faint, strong colour
Appearance	Consistency	Uniformity of particles (no sedimentation)
	Clarity (Transparency)	Clearness or dull
Aroma	Fruity	Aromatics associated with fresh tomato fruit or pasteurised fruit juice
Taste	Acidity	The taste associated with citric acid (sour)
	Sweetness	The taste associated with sugar

	Saltiness	The taste associated with salt
Texture	Mouth feel	Slimy (slippery)
	Viscosity	Smoothness and thickness

Source: QDA Trained panellists in the study (01st January, 2020)

3.2.4.2 Consumer Test (Affective Test)

The test was carried out at the Department of Food Technology, Nutrition and Consumer Science (SUA) laboratory. According to Cliff *et al.* (2016) for new product development the size of the consumer panel should be small for consistency with the size recommended for in-house laboratory panel to provide early-stage or initial trend. Twenty to hundred panellists were practical to be involved in hedonic tests (Margeta *et al*., 2019). For current study 31 untrained panellists aged 20 and 40 years were used to rate the product using a 9-point hedonic scale as described by (Hough, 2010; Lawless and Heyman, 2010).

The samples were standardized into juice and soup made from fresh tomato, tomato paste and solar dried tomato powder, coded with 3-digit and was served cold (for juice) and warm (for soup) in a random order. The panellists were required to rate their preference for aroma, taste, colour, mouth feel, texture and overall acceptability of each sample on an unstructured 9-point hedonic scale. A single session was enough to complete a test of one product in which each panellist evaluated all 9 samples (3 samples per each three tomato variety) of juice and soup per session. The response was recorded and used in the univariate and multivariate statistical analyses.

3.2.5 Statistical Data Analysis

The collected data were coded on Microsoft-excel then analysed using Panel Check-statistical software (V1.4.2), Consumer Check-statistical software (Version 2.2.0), R-statistical software (Ri386 3.5.3) and IBM-SPSS statistical package (version 20). All quantitative analysis was expressed as mean value ± SD (standard deviation). Differences among mean scores were determined using Two-way analysis of variance (ANOVA) test at 95% confidence interval. The significant of the difference between the means were determined using *post hoc* Tukey's Honest Significant Difference (HSD) test at $p < 0.05$ for both tests. Principle Component Analysis (PCA) using a bi-plot was employed to the descriptive data to foresee how samples were discriminated and/or grouped across the sensory descriptors. Furthermore, correlation loadings from a partial least square regression (Plsr) were performed to the descriptive and consumer test data to determine the drivers of liking of products samples.

3.3 Results and Discussion

(a) Tomato juice

3.4.1 Quantitative Descriptive Analysis (QDA) of tomato juice samples

The sensory mean intensity ratings of descriptive attributes between tomato juice samples are shown in Table 3.4. There were significant differences ($p<0.05$) in mean intensity scores of attributes within tomato juice samples. The colour attribute, juice sample from Fresh_*Imara* have highest mean score of 8.50±0.80 while the statistically lowest mean score was for Fresh_*Asira* with 8.00±0.95. Also, juice from Fresh_*Reogrande* was aromatic, sweetness and cleanness with score intensity 7.0±0.95, 6.8±0.83 and 7.3±0.89, respectively. The difference in attribute intensity was signified by genotypic nature. From the results the colour of tomato and tomato products (juice) was contributed by the change of carotenoid pigmentation through maturation and ripening of tomato (Ilahy *et al*., 2019).

There were significant differences in mean intensity scores of attributes within juice samples from tomato paste. Paste_*Asira* sample had the highest mean score for aroma (8.10±1.00) but was not statistically different from the rest of the paste samples. Furthermore, colour intensity score of 7.1±1.24 in Paste_*Imara* was higher than that from Paste_ *Reogrande* with 6.4±1.08. Moreover, significance difference was observed within juice samples from tomato powder. Samples of juice from Powder_*Imara* had the highest acidity and consistency mean intensity score of 3.20±1.27 and 8.3±0.49, respectively compared to other. Also, Powder_*Asira* had the highest sweetness, viscosity and cleanness intensity score of 8.1±1.38, 7.7±0.89 and 8.3±0.49, respectively than other samples.

Furthermore, the results showed a significant differences ($p<0.05$) in mean intensity scores of all attributes between tomato juice samples. Colour attribute, juice sample from Fresh_*Imara* had statistically highest mean score of 8.50±0.80 while the statistically lowest score was for Powder_*Reogrande* with 5.50±1.00. The colour attribute intensity of juice from tomato powder resembled the colour of raw materials used. In powder form the carotenoid contributed to colour was affected with oxidation process taking place during drying. Also, juice from Paste_*Asira* sample had the highest mean score for aroma (8.10±1.00) but was not statistically different from the rest of the samples except for Fresh_*Asira*, Fresh_*Imara* and Fresh_*Reogrande* sample that had the lowest score of 6.10±1.44, 6.8±1.01 and 7.0±0.95, respectively. These results showed a clear discrimination of aromatic attribute between juice samples from fresh tomato and processed tomato products.

Moreover, samples from Powder_*Imara* had the highest acidity mean intensity score of 3.20±1.27 while Fresh_*Asira* and Fresh_*Imara* had the lowest acidity attribute score of

2.00±0.95 and 2.00±0.90, respectively. This indicates that tomato powder have concentrated the acid present instigating the sour taste in juice samples. Samples from Powder_*Imara* had the highest statistical intensity score for consistency attribute (8.30±0.49) while those from Fresh_*Imara* and Fresh_*Riogrande* exhibited lowest intensity score of 5.30±1.54 and 5.30±1.15, respectively. Powder_*Asira* samples had the highest mean score for sweetness, viscosity and clarity attributes of 8.10±1.38, 7.70±0.89 and 8.30±0.49, respectively. The statistically lowest intensity scores was observed for Fresh_*Asira* with sweetness (5.90±1.08), Fresh_*Imara* with viscosity (5.00±1.28) and also Fresh_*Asira* and Paste_*Reogrande* with clarity score of 5.70±1.07 and 5.70±1.61, respectively, (Table 3.2). According to Patana-anake (2014), addition of sugar in tomato juice may affect the partition coefficient of aroma volatiles by increasing activity coefficient of the volatiles in the solution. The results indicate that tomato powder has concentrated the acid and sugar present instigating the sour and sweetness taste attribute in the final juice samples. Similarly, the consistency of a tomato was predominantly organised by the extent of pectin, size spreading of insoluble constitute and total soluble solids present (Sobowale *et al.*, 2012). Tomato powder is hygroscopic in nature (Baradey *et al.*, 2016) that tend to absorb water during processing into juice and become enlarged not easy to pass through the filtrate thereby ending up with a clear juice in comparison with other from paste and fresh tomato. For that reasons, juices from tomato powder have been described with high level intensity score of consistency and clarity in relation to other samples.

Table 3.4: Mean intensity scores for QDA of tomato juice samples

Sample	Colour	Aroma	Acidity	Consistency	Sweetness	Viscosity	Clarity
Fresh_*Asira*	8.0±0.95[ab]	6.1±1.44[b]	2.0±0.95[c]	5.8±1.03[cd]	5.9±1.08[d]	5.7±0.89[c]	5.7±1.07[c]
Fresh_*Imara*	8.5±0.80[a]	6.8±1.01[ab]	2.0±0.90[c]	5.3±1.54[d]	6.3±0.65[cd]	5.0±1.28[c]	6.0±1.28[bc]
Fresh_*Reogrande*	8.3±0.65[a]	7.0±0.95[ab]	2.2±0.83[bc]	5.3±1.15[d]	6.8±0.83[bcd]	5.3±1.54[c]	7.3±0.89[ab]
Paste_*Asira*	7.0±0.74[bc]	8.1±1.00[a]	2.3±1.07[abc]	7.0±1.35[bc]	7.0±0.60[abcd]	6.3±1.29[bc]	7.0±1.13[abc]
Paste_*Imara*	7.1±1.24[bc]	8.0±1.13[a]	2.7±1.37[abc]	6.8±1.19[bc]	7.1±1.00[abc]	6.2±1.07[abc]	6.9±0.99[abc]
Paste_*Reogrande*	6.4±1.08[cd]	8.0±0.85[a]	2.1±1.13[bc]	6.9±1.00[bc]	7.4±0.79[abc]	6.1±1.31[bc]	5.7±1.61[c]
Powder_*Asira*	6.3±1.42[cd]	7.3±0.98[a]	3.0±1.21[ab]	7.9±0.67[ab]	8.1±1.38[a]	7.7±0.89[a]	8.3±0.49[a]
Powder_*Imara*	6.2±0.19[cd]	7.7±0.49[a]	3.2±1.27[a]	8.3±0.49[a]	7.6±0.79[ab]	7.3±0.75[ab]	8.0±0.85[a]
Powder_*Reogrande*	5.5±1.00[d]	7.8±0.87[a]	2.7±0.98[abc]	7.7±0.49[ab]	7.8±0.72[ab]	7.1±0.67[ab]	6.2±1.70[bc]

The results in the Table are expressed as mean ±SD (n=12). Mean values with different superscript letters (a, b c and d) along the columns were significantly different at $p < 0.05$

3.4.2 Consumer Test of tomato juice samples

3.4.2.1 Characteristics of consumer panel for tomato juice samples

The results Table 3.5 shows the general characteristics of consumer panel that comprised of 31 panellists in which 17 panellists equivalent to 54.8% were female and 14 panellist corresponding to 45.2 were male. All panellists were students at Sokoine University of Agriculture (SUA) whereby 25 (80.6%) panellists were undergraduates and 6 (19.4%) panellists were postgraduate students pursuing different course programs. Among of the panellists 71.0% were aged 19-23, 19.4% were aged 24-28, 6.4% were aged 29-33 and 3.5% were aged 39-43.

Table 3.5: General characteristics of the consumer panel (n=31)

Characteristics	Category	Frequency (N)	Percent (%)
Sex group	Female	17	54.8
	Male	14	45.2
	Total	**31**	**100**
Age group	19-23	22	71.0
	24-28	6	19.4
	29-33	2	6.4
	39-43	1	3.2
	Total	**31**	**100**
Education level	Undergraduate	25	80.6
	Postgraduate	6	19.4
	Total	**31**	**100**

Source: Consumer panel in the hedonic test (04th January, 2020)

Characteristics of the consumer panel in the hedonic test against tomato juice samples are shown in Table 3.6. Regarding awareness about tomato juice, 58.1% of panellists among the consumer panel had heard about it while 41.9% had not. The result shows that majority of the panellists were not consumed with 71% had never taste tomato juice before. Likewise, 93.6% of the panellists were either rarely or not frequent user of the tomato juice. This indicated that they were not familiar with the attributes of the products, thus decreased the reliability of the sample scores. Apart from, juices prepared either using fresh tomato or any other tomato products samples saved were not common in Tanzanian markets. Subsequently, 74.2% of panellists had highest preference on juice sample from Paste_*Reogrande* while Fresh_*Reogrande* was the least with 58.1% of panellists showed on Table 3.6.

Table 3.6: Characteristics of the consumers in the hedonic test of juice samples

Characteristics	Category	Frequency (N)	Percent (%)
Awareness	Yes	18	58.1
	No	13	41.9
	Total	**31**	**100**
Consumption	Yes	9	29
	No	22	71
	Total	**31**	**100**
Frequency of Consumption	Once in a month	2	6.5
	Rarely/Not applicable	29	93.6
	Total	**31**	**100**
Sample Preference	Fresh_*Asira*	22	71.0
	Fresh_*Imara*	20	64.5
	Fresh_*Reogrande*	18	58.1
	Paste_*Asira*	20	64.5
	Paste_*Imara*	21	67.7
	Paste_*Reogrande*	23	74.2
	Powder_*Asira*	21	67.7
	Powder_*Imara*	22	71.0
	Powder_*Reogrande*	20	64.5

3.4.2.2 Hedonic results of tomato juice samples

Acceptability of different tomato juice samples according to hedonic ratings are shown in Table 3.7. There was significant ($p<0.05$) difference in consumer hedonic scores attributes within juice samples. Fresh_*Reogrande* sample had highest liking by consumers for colour attribute with scores of 7.30±1.29 compared to other. There were no significant difference to degree of liking within the juice samples from fresh tomato on aroma and taste attributes. Similarly, juice samples from Fresh_*Reogrande* showed least hedonic rating attribute of consistency and viscosity with score 6.0±1.63 and 5.5±1.31, respectively. The difference existed due to individual variety. The overall liking of juice samples from Fresh tomato within the product was non significance. For paste product, the colour attribute of juice samples from Paste_*Imara* was most liked with hedonic score 7.3±1.1 while juice sample from Paste_*Asira* (6.4±1.80) was least liked. All juice samples made from paste showed non significance difference on aroma and consistence attributes. Likewise, juice samples from Paste_*Imara* and Paste_*Reogrande* were non significance on taste and viscosity attribute. Paste_*Asira* was having highest hedonic score of 6.8±1.77 and 7.0±2.11 for taste and viscosity attribute, respectively. The overall liking of juice samples within the paste was significance with Paste_*Asira* hedonic score 7.0±1.97. Powder_*Reogrande* was having least score (6.2±2.05, 6.0±2.14 and 5.9±2.40). for colour, aroma and taste attributes. Powder_*Asira* was more liked due to consistency attribute while Powder_*Imara* was liked because of viscosity attribute. The overall acceptability of juice sample from tomato powder indicates that, juices from Powder_*Asira* were more liked.

Also, the results indicated significant ($p<0.05$) difference between juice samples in consumer hedonic scores attributes. Fresh_*Reogrande* and Paste_*Imara* sample had highest liking by consumers for colour attribute with scores of 7.30±1.29 and 7.30±1.16, respectively while Powder_*Reogrand*e had the lowest liking for the same attributes with scores of 6.20±2.05. This difference was attributed due to processing method employed in initial raw materials used. During drying of fresh tomato into powder the carotenoids contributing to colour was affected as the moisture content was decreasing. The higher the moisture contents in the initial raw material the higher the colour intensity in the final product. Paste_*Imara* sample had the highest aroma liking of 6.40±2.29 but was statistically similar to the rest of the samples except for Powder_*Reogrande* which had the lowest liking of 6.00±2.14. For taste attribute, Paste_*Asira* sample had the highest liking score of 6.80±1.77 while the lowest liking score was observed for Powder_*Reogrande*

(5.90±2.40). According to Iijima *et al*. (2016) the flavour characteristics of tomato juices were influenced by tomato variety, season production and processing method employed. However, Powder_*Asira* was observed with highest consistency liking of 7.00±1.66 and Fresh_*Reogrande* with liking score of 6.0±1.63. Paste_*Asira* and Powder_*Imara* were liked with highest viscosity attribute score rating of 7.00±2.11 and 7.00±1.28, respectively while Fresh_*Reogrande* was liked least with score (5.50±1.31). As for overall acceptability, Powder_*Asira* were the most acceptable by consumers with hedonic scores of 7.00±2.02 followed by Paste_*Asira* with a score of 7.00±1.97. Fresh_*Asira* sample was least acceptable with score of 6.10±1.65 (Table 3.5). This may be related to the freshness of the raw materials used for juice blends. Similar results were reported by Vogel *et al*. (2010), that the consumer acceptability of fresh commercial tomatoes flavour was poorly accepted.

Table 3.7: Mean hedonic scores of tomato Juice samples

Sample	Colour	Aroma	Taste	Consistency	Viscosity	Acceptability
Fresh_*Asira*	7.1 ± 1.86^{ab}	6.3 ± 1.28^{a}	6.5 ± 1.43^{ab}	6.5 ± 1.50^{ab}	6.9 ± 1.30^{ab}	6.1 ± 1.65^{b}
Fresh_*Imara*	7.0 ± 2.07^{ab}	6.1 ± 1.65^{a}	6.0 ± 1.97^{ab}	6.3 ± 1.64^{ab}	6.5 ± 1.78^{ab}	6.2 ± 1.96^{b}
Fresh_*Reogrande*	7.3 ± 1.29^{a}	6.1 ± 1.63^{a}	6.2 ± 1.86^{ab}	6.0 ± 1.63^{b}	5.5 ± 1.31^{b}	6.2 ± 1.80^{b}
Paste_*Asira*	6.4 ± 1.80^{bc}	6.3 ± 1.83^{a}	6.8 ± 1.77^{a}	6.1 ± 2.02^{ab}	7.0 ± 2.11^{a}	7.0 ± 1.97^{a}
Paste_*Imara*	7.3 ± 1.16^{a}	6.4 ± 2.29^{a}	6.4 ± 2.04^{ab}	6.5 ± 1.61^{ab}	6.9 ± 1.47^{ab}	6.5 ± 2.11^{ab}
Paste_*Reogrande*	7.1 ± 1.22^{ab}	6.3 ± 1.90^{a}	6.6 ± 2.09^{ab}	6.6 ± 1.46^{ab}	6.4 ± 1.45^{ab}	6.5 ± 1.96^{ab}
Powder_*Asira*	6.5 ± 1.95^{bc}	6.1 ± 2.15^{a}	6.0 ± 2.20^{ab}	7.0 ± 1.66^{a}	6.5 ± 1.65^{ab}	7.0 ± 2.02^{a}
Powder_*Imara*	6.4 ± 1.76^{bc}	6.1 ± 2.08^{a}	6.2 ± 2.48^{ab}	6.4 ± 1.22^{ab}	7.0 ± 1.28^{a}	6.6 ± 2.22^{ab}
Powder_*Reogrande*	6.2 ± 2.05^{c}	6.0 ± 2.14^{b}	5.9 ± 2.40^{b}	6.5 ± 1.52^{ab}	6.5 ± 1.77^{ab}	6.5 ± 2.11^{ab}

The results in the Table are expressed as mean $\pm$SD (n=31). Mean values with different superscript letters (a, b and c) along the columns were significantly different at $p < 0.05$

3.4.3 Preference Mapping of juice samples

In preference mapping, the relationship of panellists rating, processing methods of juice samples and the attributes were analysed. Therefore, the correlation variations between juice samples and associated attributes, and the influence that drives the panellist preferences were explained by mapping (Figure. 3.3 and 3.4).

3.4.3.1 Principal component for QDA data of tomato juice

Figure 3.3 shows PCA bi-plot with the two first significant principal components from Principal Component Analysis (PCA) on average sensory attributes of tomato juice samples. The obtained results showed Principal Component 1 (PC 1) accounted for 76.35% of the systematic total variation in the data while Principal Component 2 (PC 2) accounted for 15.41% of the total variations. The juice samples from fresh tomato, paste and powder samples were well separated. PC 1 accounts for most of the variations and was a clear contrast between Fresh_*Asira*, Fresh_*Imara* and Fresh_*Reogrande* samples correlated with colour attribute on one side. Powder_*Asira*, Powder_*Imara*, Powder_*Reogrand*e, Paste_*Asira*, Paste_*Imara* and Paste_*Reogrande* juice samples correlated with descriptive attributes of aroma, consistency, sweetness, viscosity, acidity and clarity on other side. The findings indicate that, the variation between samples were explained by attributes colour on negative side and attributes acidity, consistency, viscosity, sweetness, aroma and clarity on the positive side along PC 1. However, PC 2 was a contrast between Fresh_*Reogrande*, Fresh_*Imara*, Powder_*Imara* and Powder_*Asira* described by variation in colour, acidity, viscous, and clarity in the negative side while Fresh_*Asira*, Paste_*Reogrande* and Powder_*Reogrande* correlated with attributes aroma and consistency in positive side. Additionally, Paste_*Asira* and Paste_*Imara* correlated with sweetness attribute which had no effect on the contribution of total variability along PC2.

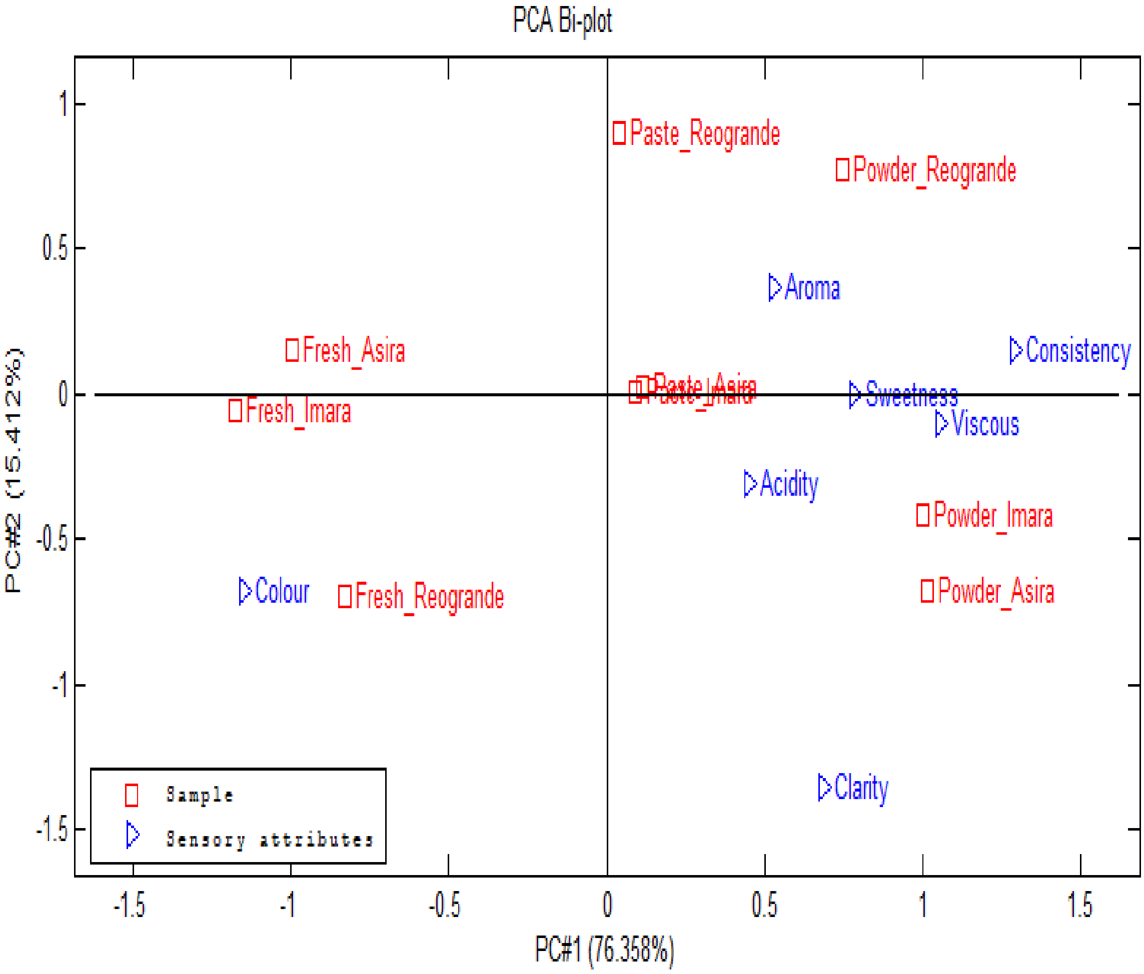


Figure 3.3: PCA Bi-plot showing relationship between tomato juice samples and descriptive attributes

3.4.3.2 Relationship between descriptive data and consumer liking of tomato juice by Plsr (PREFMAP)

Figure 3.4 shows the contribution of each attribute on acceptability of tomato juice samples through correlation loading. Whereby component 1 was explained by X (39%), Y (31%) of the variation and component 2 was explained by X (11%), Y (17%) of the variation. This means that only one PCA can explain 39% quantitative descriptive analysis (QDA) and 31% consumer acceptability. The drivers for liking of juice samples was closely associated with aroma, sweetness consistency, viscosity, acidity and clarity attributes related to Paste_*Asira*, Paste_*Imara*, Paste_*Reogrande*, Powder_*Asira*, Powder_*Imara* and Powder_*Reogrande* juice samples. The findings show that, most consumers fall to the right of the vertical Y-axis which means that consumer had highest preference for all processed samples associated with aroma, acidity, clarity, sweetness, viscosity and consistency attributes. Thus, these attributes contributed strongly and positively towards juice sample preference and acceptability. Contrarily, colour attribute contributed weakly to the acceptance of juice samples with very few consumers preferred Fresh_*Asira*, Fresh_*Imara* and Fresh_*Reogrande*.

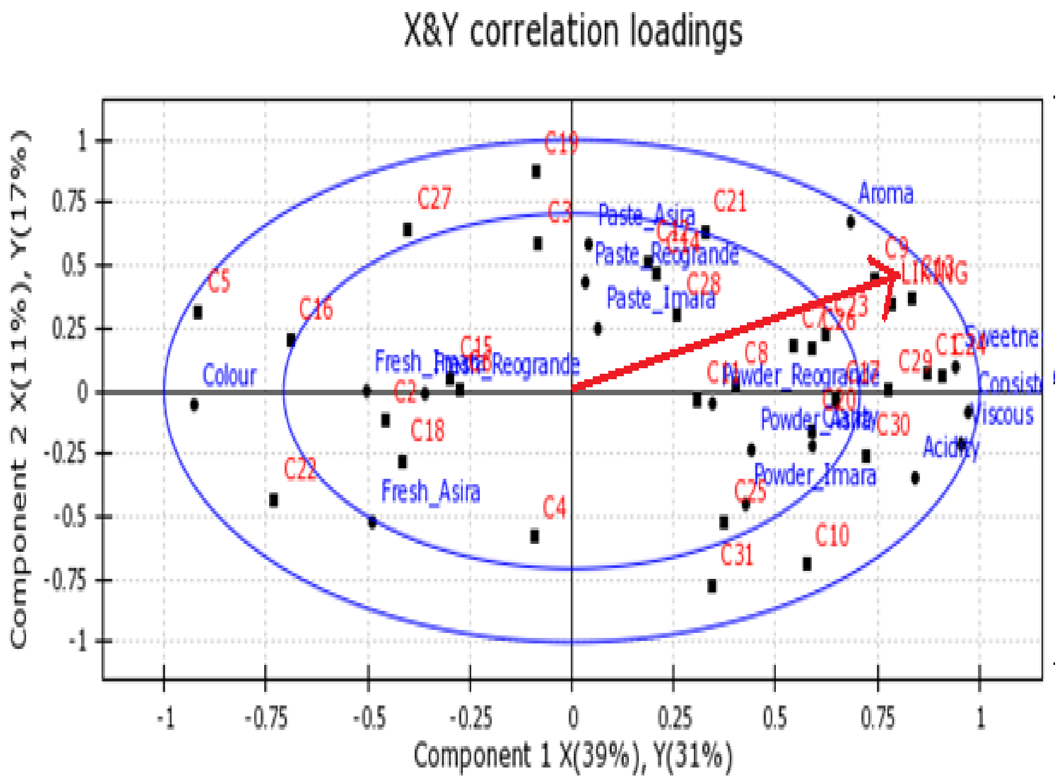


Figure 3.4: Correlation loadings from a partial least squares regression of tomato juice samples with descriptive data as X variables and consumer acceptability as Y variables

(b) Tomato soup

3.4.4 Quantitative Descriptive Analysis (QDA) of tomato soup samples

Mean intensity ratings of descriptive attributes between tomato soups samples are shown in Table 3.8. The results showed that there were significance difference at $p<0.05$ in mean intensity score within different soup samples. For colour attribute, soup sample from Fresh_*Imara* had statistically highest mean score of 8.30±0.65 while the statistically lowest score was for Fresh_*Asira* with 7.8±0.87. The soup sample from Fresh_*Reogrande* and Fresh_*Imara* were not significance in aroma and consistency attributes mean intensity. Also samples from Fresh_*Asira* and Fresh_*Imara* were not significant on acidity attribute intensity. Similarly, all samples showed non significance mean intensity on reddishness attribute. This signifies that the maturity index for raw tomato used were ideal at maturity red ripe stage. The least mean intensity for saltiness and viscosity were observed on soup sample from Fresh_*Reogrande*. Soup sample from Paste_*Imara* was having higher colour attribute mean intensity score 7.3±0.65 compared to other paste. Although, the mean intensity for all soup samples was not significant on aroma, acidity, consistency and reddishness attributes. Samples from Paste_*Asira* was having least mean intensity on saltiness and viscosity attributes with score 5.0±0.74 and 6.4±0.79. Soup samples from Powder_*Asira* and Powder_*Imara* were not significant on colour and viscosity mean attributes intensity score whereby Powder_*Reogrande* and Powder_*Imara* were not significant on aroma mean attribute intensity score. Powder_*Imara* was having higher mean intensity score of 6.3±0.89 and 8.3±0.62 in attribute acidity and consistency, respectively. The mean intensity for reddishness attribute was not significant within soup samples from tomato powder products.

Moreover, the results showed significant differences ($p<0.05$) in mean intensity scores of attributes between different soup samples. For colour attribute, Fresh_*Imara* soup sample had statistically highest mean score of 8.30±0.65 while the statistically lowest score was for Powder_*Reogrande* with 6.50±0.80. This implies that the carotenoid contributed to colour was more affected in processed initial raw materials. Paste_*Asira* sample had the highest mean score for aroma (7.60±1.17) but was not statistically different from the rest of the samples except for Powder_*Asira* sample that had the lowest score of 5.10±1.93. According to Patana-anake (2014), oil added to tomato products has been reported to have an effect on flavour by decreasing the volatility of some aroma compounds caused by its hydrophobic characteristics. Similarly, oil affects the water activity and viscosity present in tomato soup thereby inducing the chemical interaction between compounds.

Also, for saltiness attribute Powder_*Reogrande* sample had statistically highest mean intensity score (5.90±0.67) while the statistically lowest score was for Fresh_*Reogrande* with 4.50±0.52. Fresh_*Imara* sample had the highest mean score for reddish attribute (8.20±0.58) but was not statistically different from the rest of the samples except for Powder_ *Reogrande*, Powder_*Imara* and Powder_*Asira* samples that had the statistically lowest scores of 6.30±0.49, 6.40±1.10, 6.50±0.80, respectively. This indicates that the red colour hue was more affected in the soup sample from tomato powder. Powder_*Imara* samples had the highest mean intensity score for acidity and consistency of 6.30±0.68 and 8.30±0.62, respectively while Fresh_*Asira* had the lowest acidity score of 4.80±1.54 and Fresh_*Reogrande* had the lowest consistency score of 6.00±1.21. Furthermore, the highest mean intensity score for viscosity was observed for Powder_*Asira* sample (8.5±0.52) and Fresh_*Reogrande* with the lowest score of 5.0±1.71. Dried tomato powder had hygroscopic characteristics nature and absorbs water from the surrounding environment due to great affinity (Owureku-Asare *et al*., 2018; Joseph *et al*., 2017; Baradey *et al*., 2016; Abdulmalik *et al*., 2014). Because of this phenomenon, soup samples from tomato powder products were observed to have highest mean intensity on acidity, consistency and viscosity attributes compared to other samples. This makes the water present to be better concentrated with sour taste. The powder particles absorb water and became enlarged and heavier thereof increasing the viscosity and become more consistency.

Table 3.8: Mean intensity scores for QDA of tomato soup samples

Sample	Colour	Aroma	Acidity	Consistency	Reddish	Saltiness	Viscosity
Fresh_*Asira*	7.8±0.87[abc]	6.5± 1.24[ab]	4.6±1.54[b]	6.2±1.53[bc]	7.8±0.97[a]	5.4±0.51[ab]	5.5±1.62[de]
Fresh_*Imara*	8.3±0.65[a]	6.9±1.16[a]	4.8±0.90[b]	6.1±0.99[c]	8.2±0.58[a]	5.2±0.94[abc]	6.0±1.60[cde]
Fresh_*Reogrande*	8.0±0.60[ab]	7.5± 0.51[a]	5.0±1.76[ab]	6.0±1.21[c]	8.1±0.90[a]	4.5±0.52[c]	5.0±1.71[e]
Paste_*Asira*	7.2±0.94[bcd]	7.6 ±1.17[a]	5.4±1.73[ab]	6.3±1.29[bc]	7.6±0.67[a]	5.0±0.74[bc]	6.4±0.79[bcde]
Paste_*Imara*	7.3±0.65[abcd]	7.5 ±1.09[a]	5.4±0.90[ab]	6.6±0.51[bc]	7.8±0.87[a]	5.7±0.78[b]	7.1±0.67[abc]
Paste_*Reogrande*	7.2±0.97[bcd]	7.5 ±0.67[a]	5.8±2.00[ab]	6.5±1.89[bc]	7.7±0.78[a]	5.8±0.39[b]	7.0±1.28[abcd]
Powder_*Asira*	6.8±1.22[cd]	5.1± 1.93[b]	5.9±1.68[ab]	7.7±0.78[ab]	6.5±0.80[b]	5.1±0.79[abc]	8.5±0.52[a]
Powder_*Imara*	6.8±0.58[cd]	6.4± 0.90[ab]	6.3±0.89[a]	8.3±0.62[a]	6.4±1.10[b]	5.8±0.58[b]	8.3±0.89[a]
Powder_*Reogrande*	6.5±0.80[d]	6.3± 1.54[ab]	5.8±1.70[ab]	7.7±1.72[ab]	6.3±0.49[b]	5.9±0.67[a]	7.9±1.51[ab]

The results in the Table are expressed as mean ±SD (n=12). Mean values with different superscript letters along the columns were significantly different at $p < 0.05$

3.4.5 Consumer test for tomato soup samples

3.4.5.1 Characteristics of consumer panel for tomato soup samples

The results in Table 3.9, it was observed that majority of the panellists (74.2%) were aware about tomato soup and 64.5% had already consumed the product. This indicates that most of consumer panel members were familiar with the attributes of the products, thus increased the consistency of the sample scores. However, majority of panellist had rarely or no tendency of consuming the product. Soup samples saved from Paste_*Imara* were highly liked by 83.9% while soup samples from Fresh_*Reogrande* and Powder_*Asira* were least liked by 64.5% (Table 3.9).

Table 3.9: Characteristics of the consumers in the hedonic test of soup samples

Characteristics	Category	Frequency (N)	Percent (%)
Awareness	Yes	23	74.2
	No	8	25.8
	Total	**31**	**100**
Consumption	Yes	20	64.5
	No	11	35.5
	Total	**31**	**100**
Frequency of Consumption	Daily	7	22.6
	Once in a week	4	12.9
	Once in a month	3	9.7
	Rarely/ Not applicable	17	54.8
	Total	**31**	**100**
Sample Preference	Fresh_*Asira*	24	77.4
	Fresh_*Imara*	21	67.7
	Fresh_*Reogrande*	20	64.5
	Paste_*Asira*	23	74.2
	Paste_*Imara*	26	83.9
	Paste_*Reogrande*	24	77.4
	Powder_*Asira*	20	64.5
	Powder_*Imara*	24	77.4
	Powder_*Reogrande*	23	74.2

3.4.5.2 Hedonic results of tomato soup samples

Acceptability of different tomato soup samples is shown in Table 3.10. The results show that there was a significance difference at $p < 0.05$ within soup samples in hedonic scores. Soup samples from Fresh_*Reogrande* was liked with hedonic score 7.4±1.36 on colour attribute. The aroma, taste and consistency attributes of soup from Fresh_*Imara* was least liked with 6.2±1.76, 6.0±1.64 and 5.9±1.77, respectively. The hedonic score for mouth feels attribute was shows no significant within all soup samples from fresh tomato. Fresh_*Reogrande* was most liked with hedonic score of 6.8±1.40 in viscosity attribute. The overall acceptability of soup sample was on Fresh_*Reogrande* with hedonic score 6.6±1.46 but not significant from other soup samples prepared from fresh tomato. Also, within tomato paste products, Paste_*Imara* was liked with higher hedonic score of 6.9±2.01, 7.1±1.50, 7.3±1.44 and 7.2±1.78 in attribute colour, aroma, taste and consistency, respectively. Paste_*Reogrande* was having higher hedonic score with 6.5±1.90 and 6.7±1.76 in mouth feel and viscosity attributes, respectively. The results indicated that overall acceptability of soup samples from tomato paste was soup from Paste_*Imara* with hedonic score of 7.4±1.30. Moreover, within tomato powder, soup samples from Powder_*Imara* were having high hedonic score on colour attribute (7.3±1.32). Soup samples from Powder_*Reogrande* (6.5±1.63) were liked in aroma attribute. The results show no significance in consumer liking within soup samples from tomato powder in taste and consistency attributes. Although, soup samples from Powder_*Asira* has least hedonic score in mouth feel and viscosity with 6.2±2.02 and 6.1±2.15, respectively. The overall acceptability within soup samples from tomato powder, the soup from Powder_*Imara* was most liked with hedonic score of 7.4±1.21 compared to other samples.

Furthermore, consumer tests for sensory evaluation of soup from fresh tomato, paste and powder shows a significant variation at $p < 0.05$ between consumer hedonic scores in attributes. Paste_*Imara* sample had highest liking by consumers for aroma, taste and consistency attributes with scores of 7.1±1.50, 7.3±1.44 and 7.2±1.78, respectively while Fresh_*Imara* had the lowest liking for the same attributes with scores of 6.3± 1.76, 6.0±1.64 and 5.9±1.77. Fresh_*Reogrande* sample had the highest colour liking of 7.4±1.36 but was statistically similar to the rest of the samples except for Paste_*Reogrande* which had the lowest liking of 6.3±1.60. For mouth feel and viscosity attribute, Powder_*Asira* sample had the lowest liking scores of 6.2±2.02 and 6.1±2.15, respectively while Powder_*Imara* had the highest mouth feel liking of 6.8±1.89 and Fresh_*Reogrande* had the highest viscosity liking of 6.8±1.40. As for overall acceptability, Powder_*Imara* and Paste_*Imara* were the most acceptable by consumers with hedonic scores of 7.4±1.21 and 7.4±1.30 followed by Paste_*Asira* with a score of 7.0±1.50. Fresh_*Imara* sample was least acceptable with score of 6.4±1.50. The flavour characteristics of tomato soup in this study were probably influenced by tomato variety nature of initial raw materials and season of production (Iijima *et al*., 2016).

Table 3.10: Mean hedonic scores of tomato soup samples

Sample	Colour	Aroma	Taste	Consistency	Mouth Feel	Viscosity	Acceptability
Fresh_*Asira*	$7.3±1.64^{ab}$	$6.4±1.52^{bc}$	$6.5±1.46^{ab}$	$6.5±1.50^{ab}$	$6.7±1.35^{a}$	$6.2±1.28^{ab}$	$6.6±1.40^{c}$
Fresh_*Imara*	$7.3±1.40^{ab}$	$6.2±1.76^{c}$	$6.0±1.64^{b}$	$5.9±1.77^{b}$	$6.6±1.48^{a}$	$6.6±1.41^{ab}$	$6.4±1.50^{c}$
Fresh_*Reogrande*	$7.4±1.36^{a}$	$6.4±1.54^{bc}$	$6.1±1.71^{ab}$	$6.3±1.47^{ab}$	$6.7±1.56^{a}$	$6.8±1.40^{a}$	$6.6±1.46^{c}$
Paste_*Asira*	$6.4±1.78^{bc}$	$6.7±1.56^{abc}$	$7.0±1.80^{ab}$	$6.9±1.68^{ab}$	$6.3±1.92^{ab}$	$6.5±1.75^{ab}$	$7.0±1.50^{abc}$
Paste_*Imara*	$6.9±2.01^{abc}$	$7.1±1.50^{a}$	$7.3±1.44^{a}$	$7.2±1.78^{a}$	$6.4±1.90^{ab}$	$6.7±1.81^{ab}$	$7.4±1.30^{a}$
Paste_*Reogrande*	$6.3±1.60^{c}$	$7.0 ±1.40^{ab}$	$6.9±1.03^{ab}$	$6.9±1.62^{ab}$	$6.5±1.90^{a}$	$6.7±1.76^{a}$	$6.7±1.64^{bc}$
Powder_*Asira*	$7.0±1.33^{abc}$	$6.4±1.80^{bc}$	$6.5±2.00^{ab}$	$6.0±2.40^{ab}$	$6.2±2.02^{b}$	$6.1±2.15^{b}$	$6.7±1.75^{bc}$
Powder_*Imara*	$7.3±1.32^{ab}$	$6.3±1.62^{bc}$	$6.4±1.77^{ab}$	$6.2±2.06^{ab}$	$6.8±1.89^{a}$	$6.3±1.75^{ab}$	$7.4±1.21^{a}$
Powder_*Reogrande*	$7.2±1.25^{abc}$	$6.5±1.63^{abc}$	$6.7±1.61^{ab}$	$6.4±1.80^{ab}$	$6.7±1.49^{a}$	$6.5±1.52^{ab}$	$6.5±1.71^{c}$

The results in the Table are expressed as mean ±SD (n=31). Mean values with different superscript letters along the columns were significantly different at $p < 0.05$

3.4.6 Preference mapping of soup samples

In preference mapping, the relationship of panellists rating, processing methods of soup samples and the attributes were analysed. Therefore, the correlation variations between soup samples and associated attributes, and the influence that drives the consumer's preferences were explained by mapping (Figure 3.5 and 3.6).

3.4.6.1 Principal component for QDA data of soup samples

Figure 3.5 shows bi-plot with the two first significant principal components from Principal Component Analysis (PCA) on average sensory attributes of tomato soup samples. The obtained outcomes showed that, the Principal Component 1 (PC 1) accounted for 67.55% of the systematic variations while Principal Component 2 (PC 2) accounted for 24.07% of the total variations. PC 1 accounts for most of the variations and was a clear contrast between samples of Fresh_*Asira*, Paste_*Asira*, Fresh_*Imara* and Fresh_*Reogrande* samples correlated with colour, reddish and aroma attributes on one side and Powder_*Asira*, Powder_*Imara*, Powder_*Reogrande*, Paste_*Imara* and Paste_*Reogrande* samples correlated with consistency, viscosity, acidity and saltiness attributes on the other side. The findings indicates that, the variation between samples was explained by attributes aroma, colour and reddishness on the negative side and attributes acidity, consistency, viscosity and saltiness on the other side along PC1. Furthermore, PC 2 was a contrast between Fresh_*Reogrande*, Fresh_*Imara*, Paste_*Imara*, Paste_*Reogrande*, Powder_*Imara*, Powder_*Reogrande* samples correlated with colour, reddish, aroma, saltiness and acidity attributes on one side and Fresh_*Asira*, Paste_*Asira*, Powder_*Asira* samples associated with consistency and viscosity attributes on the other side. Mainly PC2 was described by variation in aroma, colour, reddishness, acidity, and saltiness attributes on the negative side while viscosity and consistency attributes on the positive side.

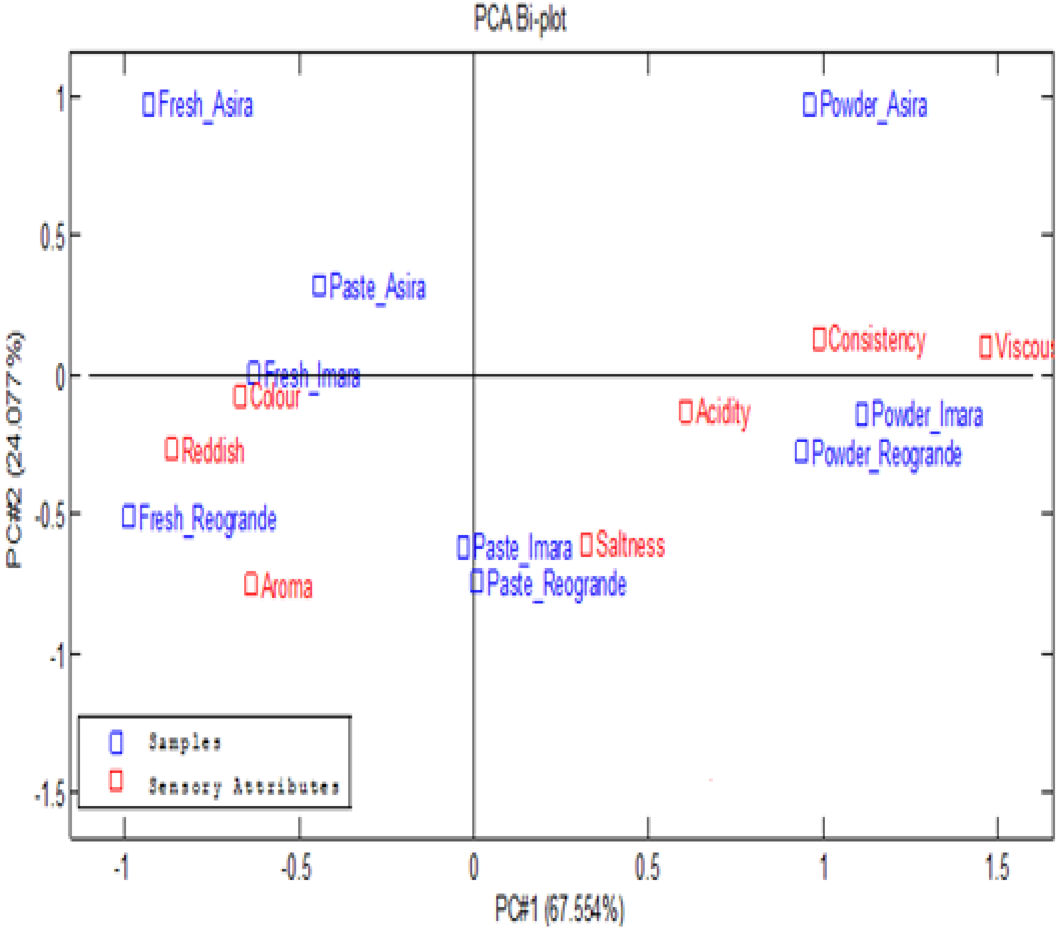


Figure 3.5: PCA Bi-plot showing relationship between tomato soup samples and descriptive attributes

3.4.6.2 Relationship between descriptive data and consumer liking by Plsr of soup samples (PREFMAP)

Figure 3.6 shows the contribution of each attribute on acceptability of tomato soup samples through correlation loading. The drivers for liking of soup samples was positively closely associated with salty, acidic, viscous and consistency attributes related to Paste_*Imara*, Paste_*Reogrande*, Powder_*Imara* and Powder_*Reogrande* soup samples. Thus, these attributes contributed strongly and positively towards soup sample preference and acceptability. On the contrary, colour, reddishness and aroma attributes contributed weakly to the acceptance of soup samples.

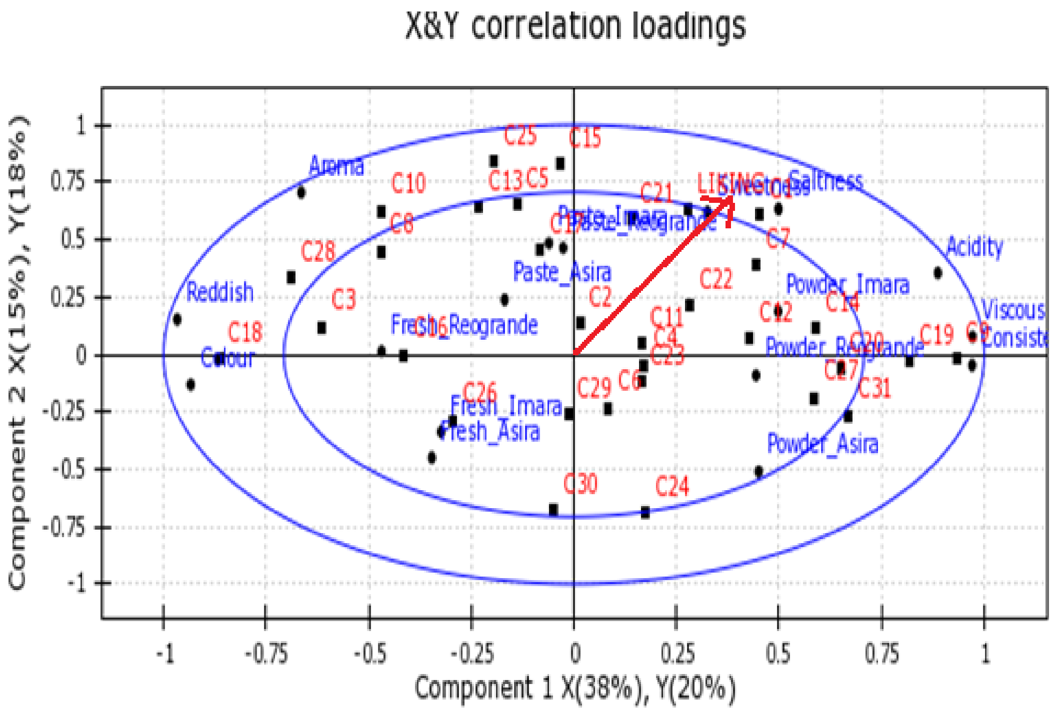


Figure 3.6: Correlation loadings from a partial least squares regression of tomato soup samples with descriptive data as X variables and hedonic rating as Y variables.

According to Sahin *et al.* (2011), consumer demand have been increasing for value added processed products that possess extra attention on sensory acuity and nutritional price, thus, necessitating the optimization of drying conditions so as to attain convinced characteristics interrelated to water content, visual appearance and colour, flavour and texture. Therefore, consumer expectations of food play a significant role in sensory acuity of a given food and the willpower of food acceptability (Hobbs *et al.*, 2014). It was recognized that, consumer's sensitivity and gratitude of utmost food products was vulnerable to the attitudes and beliefs that they grasp towards the precise foodstuffs or portions of such foods (Kim *et al.*, 2013; Doet and Kremer, 2016). Most of the panellist involved in the study were not familiar with tomato juice and soup and were not informed about the nutritional and health benefits of tomato and tomatoes products. Still, tomato was used in their day to day meal preparation as one of the flavouring agents. When making selections about which foods to consume, the perception that a food confers a precise healthy benefit was essential to some extent to stimulate consumer acuity. Besides, several factors can influence a personal liking and choice of food, including inner insight such as appetite, thirst, flavour perception, satiety, hunger; and exterior factors such as visual appearance, economics status, serving time, social and environmental issues, along with familiarity, as well as knowledge of health and nutrition facts about the given food products (Hobbs *et al*., 2014; Doet and Kremer, 2016). Therefore, from the results above all juice and soup made from tomato paste and powder was moderately accepted.

According to Hobbs *et al*. (2014), various groups of consumers were affected by product information inversely reliant on age and gender. Also, it had been suggested that this might be owing to the detail that a declining intensity does not necessarily forecast a decrease in the overall acceptability scores, in the sense that the affiliation among sensory and hedonic decision was not linear (Field, 2016). This was more evidenced from the current study that, the age group selected for sensory evaluation doesn't show a linear effect on product preference.

Several studies have recognized various obstacles that hinder the consumption of vegetables such as insufficient accessibility of raw produce, unpleasant or bitter flavour, unfamiliarity and increased cost, although through processing of tomato these barriers may be reduced (Burton-Freeman and Reimers, 2011). In addition to the precise nutritional paybacks of tomato intake, reassuring superior tomato and tomato product uses may be an easy way and actual approach for growing overall consumption of tomato with cost-effective in a convenience multiple forms (Burton-Freeman and Reimers, 2011). Food product including tomato and tomato products used in this research had attractive sensory properties such as colour and appearance, satisfactory flavour, suitable texture, and optimistic nutritional image that made it to be accepted by consumers. Thus, the quality of tomato juice and soup used were observed from consumer profile and acceptability. Therefore, sensory characteristics of tomato juice and soup used drive the consumer at the points of consumption.

3.4.7 Colour and appearance

Visual appearance of food product was the first impression of consumer which sometimes affects the perception of other sensory characteristic of tomato juice and soup used in the study. It was the visual insight of food colour, shape, size, shine, dullness and clarity that stimulate desire ability and acceptance, before the product tip-offs the mouth lips because we eat by eyes prior to ever smell or taste (Sharif *et al*., 2017). Consistency or smoothness of tomato products was used as an appearance term in one way or as texture term that signifying the product thickness (Barrett *et al*., 2010). The accumulation of *all-trans*-lycopene contributes to the unique colour of a tomato fruit which range from orange to deep red (Vogel *et al*., 2010). From the results the colour of tomato and tomato products (juice and soup) was contributed by the change of carotenoid pigmentation through maturation and ripening of tomato. The alteration of carotenoid shapes during processing contributes to functional quality and antioxidant properties (Ilahy *et al*., 2019). However, one of the most important quality parameters concomitant with dried food products were colour affected due to exposure into air and its preservation stimuluses consumer values, preferences, and ultimately acceptability (Sahin *et al*., 2011). The high temperature, light, and oxygen exposure during drying processes of tomatoes may affect availability of carotenoid such as lycopene thus disturb the eye-catching colour, texture, flavour and nutritive price of the finished foodstuffs (Sahin *et al*., 2011). Therefore, the colour of tomato juice and soup used in this study resembled the colour of the used raw tomato variety (fresh tomato as a control).

3.4.8 Flavour (Aroma and Taste)

Flavouring matters were aromatic compounds which were trapped by the amalgamation of taste and odour and perceived by the mouth and nose (Sharif *et al*., 2017). Thermal treatment of tomato during processing inactivates enzymes such as methylesterase, endopolygalactuonase and lipoxygenase that lead to prevent the degradation of juice and soup texture (Zhu *et al*., 2018). Generally, for the current study cold break tomato juice were used in order to maintain the freshness flavour in the served juice. It has been reported that hot break tomato juice are deliberated not as much of flavour than fresh tomatoes due to inactivation of lipoxygenase and boiled memo generation (Zhu *et al*., 2018). Unfortunately, processed juices from tomato paste for this study were preferred by consumers due to pasteurised aromatic followed by juice from tomato powder. The key components of tomato taste are acids, phenols, sugars, and minerals (Beckles, 2012). Consequently, the flavours of juice from fresh tomato are commonly linked with green/fruity aroma associated with volatile composites and are better indicators for tomato juice and soup acceptance (Zhu *et al*., 2018). The major contributors of aroma of fresh and ripe tomato are more than 400 volatile molecules including (Z)-3-hexenal, b-ionone, hexanal, b-damascenone, 1-penten-3-one, 3-ethylbutanal, (E)-2-hexenal, (Z)-3-hexenol, 6-methyl-5-hepten-2-one, methyl salicylate and 2-isobutylthiazole (Ilahy *et al*., 2019; Patana-anake, 2014). The flavour characteristics of tomato juices and soup in the current study were probably influenced by tomato variety and season of production according to Iijima *et al*., (2016).

3.4.9 Texture

The texture is a precondition for acceptance of food products which comprises the consistency, thickness, brittleness, chewiness, viscosity and the size and shape of components in food (Sharif *et al*., 2017). Visual and hearing signals similarly impact perception of food texture. The texture of tomato juice and soup used in this study was contributed by insoluble solids derived from cell walls of tomato fruit which prescribe the perception of consistency, mouth feel (smoothness), juiciness and viscosity in fruit tissues (Barrett *et al*., 2010).

The consistency of a tomato was predominantly organised by the extent of pectin, size spreading of insoluble constitute and total soluble solids present (Sobowale *et al*., 2012). Although, the core quality constraints of tomato pastes perceived by the consumers were aroma, reddishness, consistency and viscosity in totalling there were compositional values (Sobowale, *et al*., 2012). Tomato powder is hygroscopic that make that tend to absorb water during processing into juice and become enlarged not easy to pass through the filtrate thereby ending up with a clear juice in comparison with other from paste and fresh tomato. For that reasons, juices from tomato powder have been described with high level intensity score of consistency and clarity in relation to other samples.

Viscosity is a vital technological attribute that is associated to insoluble substances in processed foods such in polysaccharides, alcohol, protein and pectin products

(Eke-Ejiofo, 2015). Also, Sobowale *et al*. (2012) reported that the viscosity of tomato products depends on presence of total solids, fibre, protein and fat. According to Eke-Ejiofo (2015) viscosity was the joint outcome of liquid soluble material, insoluble in suspension that donate to the overall consistency of tomato paste. The results shows samples from tomato powder and paste were attributed with viscosity preference by consumer.

3.5 Conclusion

The overall consumer acceptability of juice samples processed from tomato powder and paste were moderately accepted followed by those juice samples from fresh tomato (control) sample. Consumer profiling of juice samples processed from tomato paste and powder were associated with aroma, acidity, viscosity, clarity and consistency attributes while for fresh tomato was due to its colour, aroma, clarity and consistency.

The overall consumer acceptability of soup samples processed from tomato paste was liked followed by soup samples from powder and fresh tomato (control) sample. The consumer profiling of soup samples processed from tomato paste were associated with aroma while for powder was due to its acidity, viscosity and consistency.

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CHAPTER FOUR

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The study has shown that, comparatively tomato powder possesses high nutritional content than fresh tomato and paste. Although, technology of boiling fresh tomato into tomato paste showed better nutrient retention but some were loss due to physical removal of skin and seed from pulp. Therefore, technology of drying fresh tomato using tunnel solar dyer into powder could be helpful to reduce vast postharvest losses that occur due to seasonal, bulkiness and spoilage. Moreover, tunnel solar drying has diverse substantial effects on some nutritional quality attributes (Ascorbic acid, β-carotene and lycopene). Also, tunnel solar drying of fresh tomato into powder has shown high percentage retention of ascorbic acid compared to boiling into tomato paste.

The overall consumer acceptability of juice samples processed from tomato powder and paste were accepted followed by those juice samples from fresh tomato (control) sample. Consumer profiling of juice samples processed from tomato paste and powder were associated with aroma, acidity, viscosity, clarity and consistency attributes while for fresh tomato was due to its colour, aroma, clarity and consistency. The overall consumer acceptability of soup samples processed from tomato paste was liked followed by soup samples from powder and fresh tomato (control) sample. The consumer profiling of soup samples processed from tomato paste were associated with aroma while for powder was due to its acidity, viscosity and consistency. The significance difference in sensory attributes was attributed by genotype, processing method and nature of initial raw materials used.

Tomato is a nutritional perishable crop and seasonal. When produced in bulk it is prone to postharvest losses due to spoilage and limited postharvest technological skills. However, the use of postharvest technology such as tunnel solar drying to powder may extend its shelf life and influence the increase of tomato productivity and income generation to farmers as well as maintains final product quality, safety and consumer acceptability. The technology of drying tomatoes into powder was easy to adapt and operate which help small scale farmers and processors on value-addition of tomatoes. Thus, understanding the quality in terms of nutrients and sensory attributes of tomato and tomato products influence more consumers' satisfaction and increase food security in the community. Knowing the sensory variances and consumer perceptions of tomato juice and soup made from tomato and tomato products was important in efficiently introducing the products in the market.

Conclusively, processing of tomato into powdered form upsurges its applicability thus can be efficiently recycled in diverse tomato products (paste, puree, sauce and ketchup), other food products (juice, jam and soup), supplements mineral combinations and anti-aging products. Nutritionally, the consumption of tomato and tomato products was associated with the accomplishment of great portion of Recommended Daily Intake (RDI) of micronutrients such as vitamins and minerals. However, processed fruits and vegetables including tomatoes were regularly deliberated as not as much of appreciated than the fresh ones owing to the damage of nutritious parameters. In contrast, daily preparation of diet and drinks by using tomato powder facilitate the way of attaining the Recommended Daily Intake (RDI) of vitamin C, β-carotene, lycopene and minerals.

4.2 Recommendations

(a) Consumption of tomato product such as powder improves health by meeting the Recommended Daily Intake (RDI) of vitamin C, A, lycopene and minerals.

(b) Sensory study between cold and hot pulped juice from tomato powder is recommended in order to capture well the associated aromatic characteristics in the final products.

(c) During cooking precaution should be taken into consideration when tomato powder is used to avoid overcooking.

(d) Further studies are required on reconstituted tomato powder into other tomato products like puree, sauce, ketchup and jam.

APPENDICES

Appendix 1: Qualitative Descriptive Sensory Evaluation Form

Sensory Evaluation Form

Quantitative descriptive Analysis (QDA) of tomato juice/soup made from fresh tomato, paste and powder brands

Name …………..…………….. Sex (M/F) ……... Age ……. Time ……...

Please evaluate each coded sample in the order they are listed. Choose appropriate number in a scale from 1 to 9, where 1 is low intensity and 9 is high intensity. How do you find the following characteristics for different tomato juice/soup? Circle the appropriate number against each characteristic.

Sample number …………………

Reddish --

Light red 1 2 3 4 5 6 7 8 9 very red

Colour (red) ---

Faint 1 2 3 4 5 6 7 8 9 very concentrated

Consistence --

Inconsistent 1 2 3 4 5 6 7 8 9 very consistent

Viscosity ---

Not viscous 1 2 3 4 5 6 7 8 9 very viscous

Aroma ---

Not aromatic 1 2 3 4 5 6 7 8 9 very aromatic

Acidity --

Not acidic 1 2 3 4 5 6 7 8 9 Very acidic

What is your total liking of the product?

Don’t like it 1 2 3 4 5 6 7 8 9 Like it a lot

Appendix 2: Consumer test form

Sensory evaluation form

Consumer test of juice/soup made from fresh tomato, paste and powder brands

Name ……………………….. Sex (M/F)…… Age…. Date…….. Time ……

Please evaluate each of the three (3) coded samples from left to right. Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your preference (9-1) in the column against each attribute. Put the appropriate number against each attribute.

Key: **9** - like extremely, **8** - like very much, **7** - like moderately, **6** – like slightly, **5** – Neither like nor dislike, **4**–Dislike slightly, **3** - Dislike moderately, **2** – Dislike very much, **1** - Dislike extremely.

	Sample code		
Attribute	308	718	370
Colour			
Taste			
Aroma			
Texture			
Consistent			
Overall Acceptability			
Would you be interested in Buying /using this product?	Yes No	Yes No	Yes No

Comments ……………………………………………………………………………………
……………………………..…………………………………………………………………
……………………………….…………………………………………………………………
………………………………………………………………………………………………

Appendix 3: Additional questions for consumer test (tomato juice)

Name ………………………………………………………………………………..

Please answer the questions bellow by circling the appropriate answer

1. Education level
   a) Secondary
   b) Diploma
   c) Undergraduate
   d) Post graduate
2. Have you overheard about tomato juice (awareness)
   a) Yes (if yes answer question 3 & 4 below)
   b) No
3. Have you over consumed tomato juice

   a) Yes
   b) No
4. Frequency of consuming the product
   a) Daily
   b) Once in a week
   c) Once in a month
   d) Rarely/Not applicable

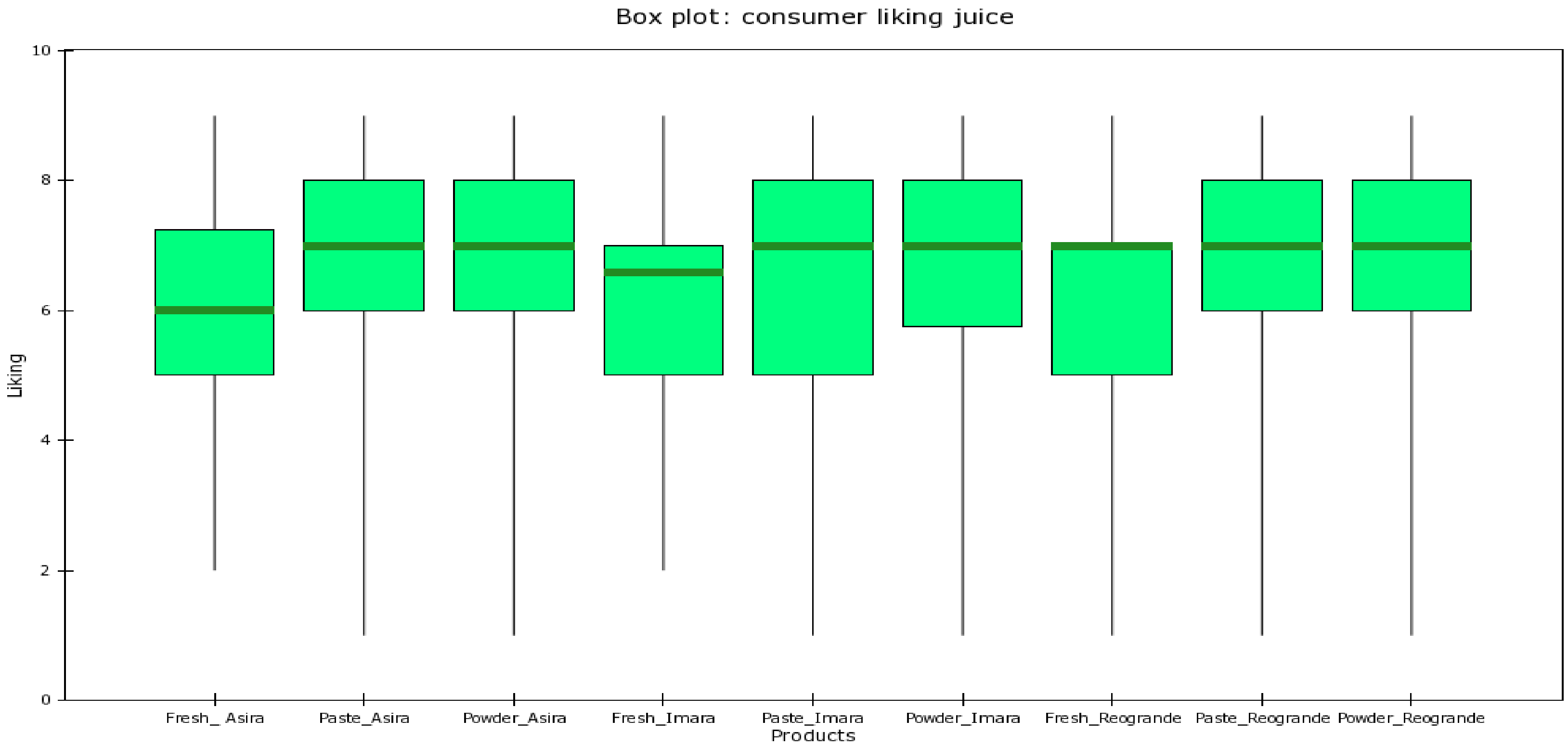
Appendix 4: Additional questions for consumer test (tomato soup)

Name …………………………………………………………………

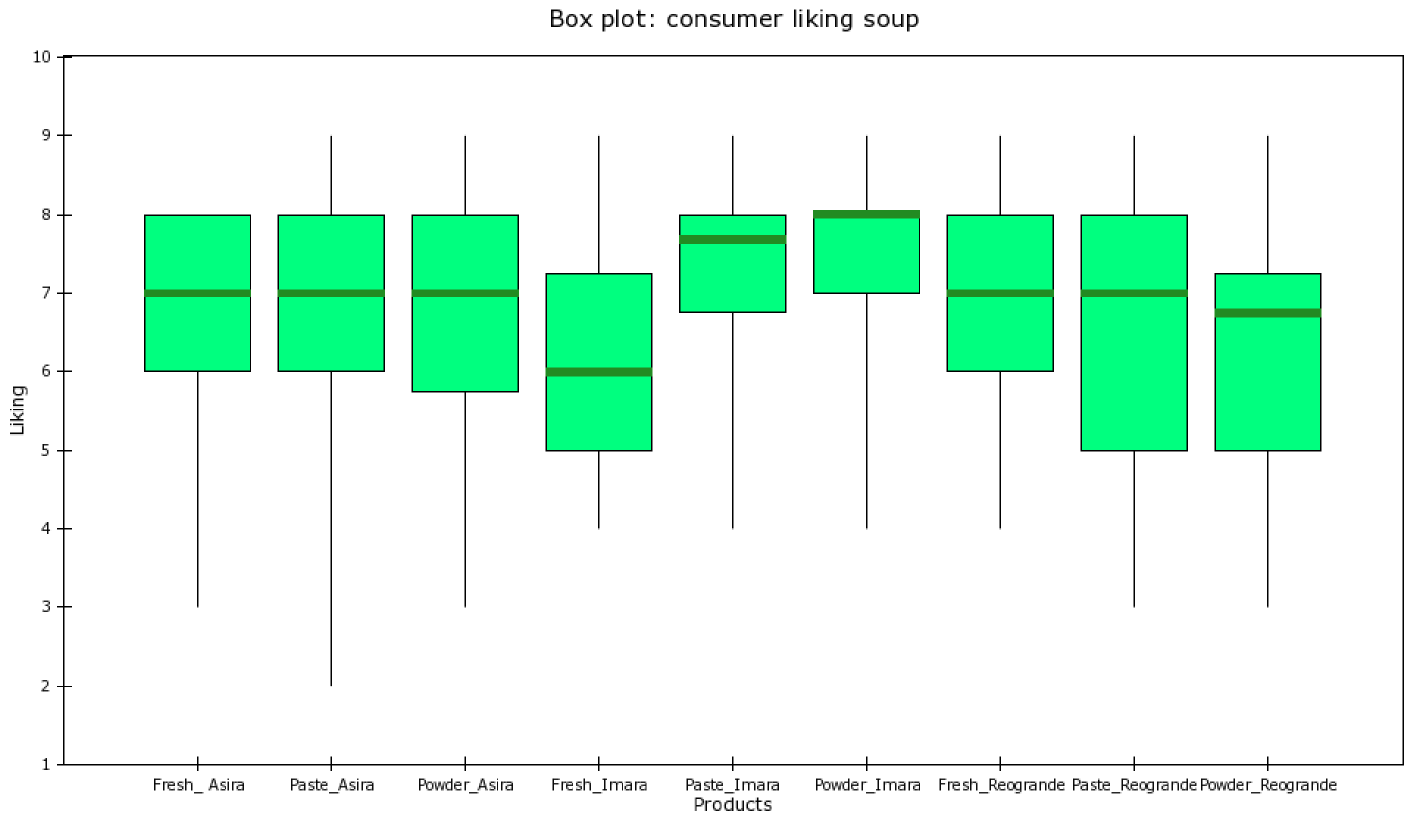
Please answer the questions bellow by circling the appropriate answer

1. Education level
   a) Secondary
   b) Diploma
   c) Undergraduate
   d) Post graduate
2. Have you overheard about tomato soup(awareness)
   a) Yes (if yes answer question 3 & 4 below)
   b) No
3. Have you over consumed tomato soup
   a) Yes
   b) No
4. Tendency of consuming the product
   a) Daily
   b) Once in a week
   c) Once in a month
   d) Rarely/Not applicable

Appendix 5: Box plot showing consumer liking against juice sampls



Appendix 6: Box plot showing consumer liking against soup samples



Appendix 7: **Researcher at work and some equipment used**