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ASSESSMENT OF PHYSICO- CHEMICAL PROPERTIES OF PROCESSED AND UNPROCESSED TOMATO (*Lycopersco esculentum*) VARS MANICA AND POWER

BY

JULIANA AKANLU

SEPTEMBER, 2016

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY (M.Phil.) IN POSTHARVEST TECHNOLOGY

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DECLARATION

I, Juliana Akanlu, do hereby declare that this research work was composed solely by myself, and that the results are based on my own investigations except for references to other peoples' work which have been dully acknowledged.

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DEDICATION

I dedicate this thesis to the Almighty God for granting me special favour throughout my study period and to the entire Akanlu family especially Joana Akanlu for the moral and financial support.

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ABSTRACT

Tomato is an important vegetable that is consumed in various forms by most households across Africa. However, tomatoes are seasonal and very perishable. Consequently, these and other factors have increase the industrial processing of tomatoes into various forms, such as, tomato sauce, ketchup and powder. This study thus was carried out to assess the processing quality of two tomato varieties (power and manica) in Ghana. Fruits of the two varieties were stored under ambient condition and physico-chemical characteristics such as total soluble solids, total titratable acid, vitamin C, pH, moisture content, firmness, mesocarp thickness, colour, and diameter analyzed at the six stages of ripening (matured green, breaker, turning, pink, light red and red-ripe stages). Daily weight loss was also taken for twenty three days and the average weight loss determined. Fully ripe tomatoes of the two varieties were processed into ketchup and stored for three months and biological studies and chemical characteristics such as the pH, Total Soluble Solids, Total Titratable Acidity were determined. A completely Randomized Design was used as experimental design for the study. All treatments were replicated three times. From the results, there was no significant variation ($p>0.01$) among power and manica for physical characteristics of unprocessed tomato, firmness, mesocarp thickness, diameter and colour. Power had 5.40, 3.32, 54.31, while Manica tomato variety had 6.26, 4.13, 49.70 and respectively. For chemical characteristics, PH,,moisture content, vitamin C content, weight loss and total soluble solids did not differ significantly ($p>0.01$) between the two varieties. Power recorded 4.00, 93.29, 38.90 and 5.94 while manica variety had 4.00, 95.21, 42.95 and 3.88 respectively. However, Power variety recorded significantly ($p>0.01$) higher (0.44) total titratable acidity than Manica variety which had the least value

(0.29). Results from the processed tomato showed there was no significant difference ($p>0.01$) between the two tomato varieties for pH and total titratable acidity. Both Power and Manica varieties had pH of 4.00 and TTA of 0.57 and 0.49 respectively. However, total soluble solids of Power variety varied significantly ($p>0.01$) from Manica variety. Power variety recorded appreciable amount of TSS (24.40) than manica variety (18.58). Microbial analysis showed that growth of total viable count of ketchup from the two tomato varieties did not vary significantly ($p>0.01$) for the three months of storage. Comparing the two varieties, it was revealed that although both varieties could be processed into ketchup, using the power variety could produce sweeter ketchup than manica variety.

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CHAPTER ONE

1.0 INTRODUCTION

Tomato, *Lycopersicon esculentum*, a fruit commonly regarded as a vegetable, is a warm season crop reasonably resistant to heat and drought (WU and Nelson, 1997). Tomatoes are highly perishable and very susceptible to mechanical damage with poor handling and transportation. They may be consumed fresh or processed into whole peeled tomato, tomato juice, concentrated tomato juice, tomato puree or tomato paste to extend their shelf life or add value to them. Tomato puree and paste may be marketed directly to the consumer or may be added as ingredient in other products such as tomato ketchup, sauces and soups (Hayes, Smith, Morris, 1998).

Fresh-market tomatoes are a popular and versatile fruit vegetable, making significant contributions to human nutrition throughout the world for their content of sugars, acids, vitamins, minerals, lycopene and other carotinoids, among other constituents (Simonne *et al*., 2006).

Processing of highly perishable non-storable crop such as tomato, is typically promoted for two reasons: as a way of absorbing excess supply, particularly during gluts that result from predominantly rain-fed cultivation, and to enhance the value chain through a value- added process. For Ghana, improving domestic tomato processing would also reduce the country dependence on imported tomato paste and so improve foreign exchange reserves and development opportunities in poor rural areas of the country (Robison *et al*., 2010).

The demand for processed tomato sauce and ketchup is mainly influenced by urbanization, income and change in consumption habit of the population. As income rises and urbanization progresses, a shift towards relatively expensive but conveniently packed foods is inevitable. Another factor that contributes to increasing demand of processing tomato product is the promotion of tomatoes for their nutritious value. Ketchup is a product which has high nutritional value and its solids content and caloric values are boosted by added salt and sugar. Although, tomato processing has been widely studied, the research primarily concentrates on the physico-chemical quality of ketchup and its shelf life.

Tomatoes are the most widely grown and commercially important vegetable crops and are valuable sources of food minerals and vitamins, particularly vitamin A and C. Nutritional values of tomato makes it one of the most widely accepted vegetable by consumers in the world. However, tomatoes are highly perishable with short shelf-life and very susceptible to fungi diseases (Coursey, 1983). Poor handling during transportation and prolonged storage make tomato prone to postharvest diseases caused by various pathogenic fungi. Tomatoes are the leading fruits for processing into food products (Boriss and Brunke, 2005). Tomatoes can easily be processed into several products which are consumed in large amount.

Processed and canned tomato sauces and ketchups are consumed by urban households, restaurants, hotels, hospitals and the like. Processing converts tomatoes into different useful forms that can be traded internationally. In Ghana, tomatoes that cannot be absorbed by the market due to glut, particularly during tomato season could be processed into products with high value. Also, promoting processing would provide employment opportunity for rural people in the country, reduce importation of tomato paste thereby improve upon the economic development of the country.

Tomato products, the humble staple in cuisines across the globe, are emerging as foods that hold particular promises in promoting health. Tomato product- including canned tomatoes, tomato sauce, tomato paste, tomato soup, tomato juice and ketchup are made with ripe tomatoes that are heat processed within house of harvest, (Gustaitis, 2009).

Processing allows tomatoes to be kept longer, provides a more varied diet and it also makes tomatoes available to consumers when they are out of season. For commercial purposes, it is a way of generating extra income and offering more products to consumers.

Consumers demand for highly quality, minimally processed products has increased remarkably in recent years. Preference has shifted towards fresh, healthy and rich flavoured ready to eat food with enhanced shelf life (Osei *et al.*, 2009). High quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest handling and storage. The reliability of the authenticity evaluation of fruits such as tomatoes as raw material for processing depends on various factors such as variety, agricultural conditions, season, degree of maturity, physiological stage and microbial spoilage. However, the components of raw material can also undergo various changes due to the postharvest treatment, storage, production of food products and their storage and distribution (Soukopova *et al.*, 2004). Some newly introduced tomato varieties (manica and power) in Ghana have not been assessed for their processing quality.

On the basis of the above information, the research thus was conducted with the following objectives:

The main objective of the study was to assess the physico-chemical characteristics of processed and unprocessed tomato varieties in terms of suitability for processing.

Specific Objectives

1. To assess the physical characteristics of the varieties
2. To assess the chemical characteristics of the varieties
3. To evaluate the quality of ketchup produced using the tomato varieties

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CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is a popular vegetable with high per capita consumption in Ghana as it is used in almost all Ghanaian homes. It is very nutritious major source of vitamin A,C and riboflavin as well as carbohydrate, protein, calcium, carotene in our diets (Purseglove, 1979: Bull, 1989) Tomato is regarded as the vegetable for the largely poor masses (Adepetu, 2005). It is the world most commercially produced and used vegetable crop (Isack and Lyimo, 2013). It is cultivated in both tropical and temperate zones in the world. Although tomato is perceived as a vegetable because of its main culinary uses, it is actually a fruit belonging to the botanical family *solanaceae.*

Tomato production is a flourishing farming activity in the savanna and forest- savanna traditional belts of Ghana. The major advantage of tomato production include, higher yields, less dependence on seasonal production, higher quality and consistency of fruit, potentially safer food and more regulated processes.

As fruit vegetable, tomatoes are undoubtedly important as they are consumed almost daily and traded by broad range of market participants. Owing to its versatility it has the ability to blend well with eggs, meat, and a wide range of herbs.

The physiological nature of tomato which include, high moisture content, high respiration rate, and soft texture makes it more vulnerable to postharvest qualitative changes and loses. The chemical composition of tomato fruits depends on factors such as, cultivar, maturity, fertilization, irrigation, handling practices, storage and environmental conditions in which they are grown (Rajkumar *et al.*, 2006).

2.1 CLASSIFICATION OF TOMATO

Tomato variety is classified according to growth type, determinate and indeterminate varieties.

Determinate variety of tomatoes also called "bush" tomatoes are varieties that are bred to grow to compact height. They stop growing when fruit sets on the terminal buds; ripen all their fruits at or near the same time and then die.

Examples of determinate varieties are, homestead, oxheart, fourway hybrid and horizon. Indeterminate varieties of tomatoes are also known as vining tomatoes. They will grow and produce fruit all year round until killed by harsh weather conditions like frost. Examples of these varieties include big boy, beef master, cherry types, heirloom type, and many more. Determinate varieties do not require staking but indeterminate varieties require substantial staking because of their height (Hanson *et al*., 2000). Both large and small scale farmers use bamboo or wood for staking.

Staking increases fruit yield, reduces the proportion of unmarketable fruit and facilitate chemical spraying and harvesting. (Kader and Morris,1976). Another way of classifying tomato is according to its fruit shape, which are, globe shape, beefsteakbiggest fruit type, paste-those with thick walls, and the cherry-the smallest fruit. Heirloom and hybrid tomatoes varieties are also used to classify tomato, heirloom tomato are old varieties that have been passed down from generation to generation without cross breeding. They are not recommended for large-scale production for reasons such as, lack of firmness, uneven ripening, disease susceptibility, and indeterminate growth rate. As the name goes, hybrid tomatoes are cross between two different varieties. They are cultivated commercially because of their desirable quality.

2.1.1 Varieties of Tomato

Farmers grow a wide range of varieties of tomato that are mainly open pollinated and of foreign origin. Factors that influence the choice of varieties by farmers include, access to seeds, growing technologies, available market, yield potential, price and risk.

The most popular varieties grown by farmers are power Laurano, cultivated under rain fed in the southern part of Ghana and Pectomeck also called "no name" is grown in the Upper East and Burkina Faso under irrigation.

Robison and Kolavalli (2010) found out those tomato growers in Ghana are constrained by the absence of national seed strategy that provides farmers with a reliable source of appropriate seeds and technical support. The choice of tomato variety also depends on its ability to withstand harsh environmental factors such as drought and temperature. Tomato traders from southern Ghana, dubbed "market queens" often refuse to purchase fresh tomato directly from tomato producers in Ghana but rather cross into Burkina Faso to purchase the produce because of the variety.

2.2. TOMATO PRODUCTION IN GHANA

Tomatoes are grown in many places in Ghana and serve both as staple crop and as important sources of vitamins and nutrients in the Ghanaian diet. In Ghana, tomato is grown on a large scale in the Upper East (Tono and Vea areas), Ashanti (Akomadan, Kumawu, Agogo areas), Brong –Ahafo (Techiman, Derma and Techimantia areas) and the greater Accra regions. There are several varieties of tomato in the world but the popular ones produced in Ghana are, pectomeck or "no name" cultivated in Upper East, Rano and power produced in the southern sector. It is also a high value crop providing inputs for a variety of processed tomato products. Tomato production is mainly a smallholder activity and provides income to farmers and all other agents involved in its production and marketing (Tambo and Gbemu, 2010).

The southern sector of the country produce in the raining season and the northern part, notably, the upper east region, produces only in the dry season using irrigation. The employment potentials and income generation for both rural and urban dwellers gives the impression of a viable sector Production of tomato is affected by the choice of varieties more than other factors yet farmers in Ghana have historically appeared reluctant to purchase improved seeds (Orchard and Suglo, 1999).

2.3. NUTRITIONAL VALUE OF TOMATOES

Nutrition is both a quantity and a quality issue, and vegetables in all their many forms ensures an adequate intake of most vitamins and nutrients, dietary fibers, and phytochemicals which can bring a much needed measure of balance back to diets contributing to solve many of these nutrition problems, (Britt and Kristin, 2011) .

Tomatoes are non-starchy vegetables that contain lycopene, one of the most powerful flavonoid antioxidants. This antioxidant is mostly concentrated in red varieties of tomato. Together with carotenoids, lycopene helps prevent prostate cancer and improve the skin’s ability to protect itself from harmful ultra violet rays. (Bramley, 2000).

Lycopene is the pigment principally responsible for the characteristic deep-red colour of the ripe tomato fruit and tomato products. It has attracted attention because of its biological and physico-chemical properties, most particularly its effects as a natural antioxidant.

Tomato and tomato products are the major source of lycopene compounds, and also considered as an important source of carotenoids in human diet,(Shi and Maquer, 2000).

Aside from being tasty, they contain a significant amount of vitamins A, C and E (Karen,2007). Vitamin A is important for bone growth, cell division and differentiation and maintaining surface linings of eyes. Vitamin C contain folic acid and is also good in forming collagen, a protein that gives structures to bones, cartilage, muscles and blood vessels.

2.4. ECONOMIC IMPORTANCE OF TOMATO

Tomato production is a major source of employment and income to both rural and urban dwellers. It contributes significantly to the economic growth of Ghana and source of foreign exchange. In the year 2003, 4,368 metric tonnes of tomatoes were exported, accruing a foreign exchange of $427,000 to the country (Rowell, 1994; Franzoi, 1996; FAO, 2005). Its production is dominated by small-scale farmers who favour this crop because of its relatively high cash value which contribute
significantly to their livelihood.

Tomato is a good source of dietary lycopene intake in humans and its intake in high proportions could therefore be a cheap and easy way of preventing degenerating diseases in developing countries.

A high consumption level of tomatoes in Ghana also makes it appear as an economically viable sector. Large quantities are regularly consumed in every household by both the rich and poor. Tomato production has been an important agricultural venture in the Upper East region, and has a great potential for growth and employment generation. A survey report by Trade Aid Integrated, an NGO, pointed out that tomato production gave employment to about 11,728 farm families from the region and with an average of family size of five persons, it is estimated that 58,640 persons benefit from its production (Clottey *et al*, 2009).

2.5 TOMATO CONSUMPTION

Tomatoes and tomato products are well known by adult and children alike and have the unique advantage of meeting consumer demands on cost, convenience,
availability, and taste, while delivering a healthful food option with flexibility for inclusion in a variety of culturally diverse dishes. Tomato is used as a basic ingredient in stews, sauces, soups, vegetable salads, and many others. The versatility of tomato fruit as a food source is exhibited by the range of products produced from it such as tomato juice, tomato paste, tomato puree, tomato ketchup, canned whole tomato and dehydrated tomatoes (Goose and Binsted, 1964).Igniting interest in tomatoes may increase vegetable consumption directly as well as improve vegetable consumption in general by prompting individuals to explore other vegetables for improved health. As a vegetable, tomato is highly perishable; spoiling within 4-6 days after harvest, however, its rate and extent of spoilage depends on several factors including poor handling practices, storage conditions, microbial infection and high temperature (Ellis *et al*., 1998).

2.6 TOMATO PROCESSING

Raw fruits and vegetables are typically touted as superior to their processed (that is, canned frozen) counterparts. However, in the case of tomatoes, processing adds value by increasing the availability of lycopene for absorption (Freeman and Reimers, 2010).World-wide, tomatoes (*Lycoperscon esculentum*) constitute an important agriculture crop and an integral part of the human diet. Although, tomatoes are commonly consumed fresh, over 80% of the tomato consumption comes from processed products (Rao *et al*., 1998, Thakar *et al*., 1996). Consumption of tomato concentrate rises each year in Ghana during the off-season for fresh tomatoes (Schurmann, 1967).

Processed tomatoes, and in particular tomato paste, have always been considered "poor" product with low added value destined for use as a basic ingredient in more elaborate products (sauces, ketchup), both for domestic and manufacturing purposes. These semi-processed products are seen as commodities dominated by price rather than finished products which can command a premium in the market through their intrinsic qualities.

Today, the consumer faces new socio-economic and therefore food factors which tend to favour service (or convenience) quality. A service which, first of all, meets the requirements of new life system but which also take into account the renewed attention to hygienic and dietary aspects of food; that is, its nutritional quality, particularly in the light of the supposed antioxidant activities of some microcomponents, particularly lycopene. Tomato products are important foods from sensory point of view, with good service quality and positive effects awards the prevention of the most important common diseases of the modern world. For Ghana, improving domestic tomato processing would reduce the country dependence on imported tomato paste and so improve foreign exchange reserves, as well as provide employment opportunities and development opportunities in rural areas of the country (Robison *et al*, 2010).

2.7 CONCEPT OF QUALITY

The term quality implies the degree of excellence of properties or its suitability for a particular use. Quality is a human construct comprising many properties. Quality of produce encompasses sensory properties (Abbott, 1999).Produce quality is a complex characteristic that depends on several factors and include both objective measurable quality traits as well as subjective sensory characteristics (Auerswald *et al.*, 1999).

Sensory characteristics of quality are properties that can be observed or measured by the human senses. For instance, the textural quality can be determined by both finger and mouth feels. The word quality is used in various ways in reference to refresh fruits and vegetables, such as, marketable quality, edible quality, table quality, dessert quality, shipping quality, nutritional quality, internal and appearance quality(Kader, 2002).Sensory qualities and hence marketability of tomato products depend upon their consistency. Products with low consistency may be sold at lower prices or graded unacceptable (Kertesz and Loconti, 1994).

Trends in consumption of fresh produce are influenced by consumer perception of quality fruit and value. For tomato products, objective measurement of fruit chemical constituents, together with sensory evaluation of numerous organoliptic properties have been developed to help identify and optimize levels of the attributes that best define appearance, taste, aroma, and texture and contribute to overall fruit quality (Shewfelt, 1999).

2.7.1. Quality Components

There are various components of tomato quality that are used in relation to specifications for grades and standards, selections in breeding programs, and evaluation of fruit responses to various environmental factors and postharvest handling procedures.

2.7.1.1. Appearance factors

Colour, size, shape, defects, decay are influenced by both genetic and environmental factors, such as temperature, light, nutrients and water supply, and the presence of diseases insects. Colour and the severity of defects and decay are also affected by postharvest conditions.

2.7.1.2 Colour

External colour of tomatoes is the result of both flesh and skin colours. A pink tomato has a colourless skin and red flesh while a red tomato has yellow skin and red flesh. Fruits of some tomato genotypes have pink, purple, orange, dark yellow, light yellow, yellow with pink end, and other colours. However, most consumers prefer the deep, uniform red –coloured tomatoes. Colour is an indicator of tomato ripeness stage (Stevens *et al*, 1974).

2.7.1.3 Size

Preference for a given size of tomatoes varies among consumers and depends, to some extent, on the intended use of the fruits. The range of fruit sizes varies among cultivar when tomatoes are picked green, the smaller fruits will likely be more immature. Thus, ripening and ethylene production rates are highly correlated with fruit size within a given cultivar. But if fruits are harvested at the breaker stage or more advanced stages of ripeness, no effect of size is noticeable on the ripening rate or composition and flavor at the table-ripe stage. Fruit shape has no direct effect on flavor or textural quality of tomatoes. It may have an indirect effect because of the internal fruit structure (pericarp/locular material ratio) associated with a given shape.

(Robison *et al*, 2010).

2 .7.1.4 Defects

Appearance quality of tomatoes is greatly influenced by the presence and magnitude of defects. Minor blemishes that would not detract from eating quality are acceptable, but more serious defects can influence appearance, firmness, shriveling, and susceptibility to decay. Defects originating before harvest include puffiness, catfacing (blossomed-end scab) and other scabs, gold fleck syndrome (Ilker *et al.*, 1977), radial and concentric growth cracks, insect and bird damage, sunscald, excessive softening, and irregular ripening (Kader,1984)). Physical damage can occur during harvest and postharvest handling steps. It includes surface injuries such as scuffing, abrasions, cuts and punctures, and internal bruising due to impact, vibration, or compression (Kasmire and Kader, 1978).Physical damage is not only unsightly, but also increases rate of respiration, ethylene production, moisture lose, and decay, and can result in less desirable flavor(MacLoed *et al.*, 1976).

2 .7.1.5 Decay

The presence of decay is a very serious defect which renders tomatoes unmarketable. Most pathological disorders found during postharvest handling of tomatoes originate in the field before harvest. Incidence and severity of decay are increased by physical damage and chilling injury which make the fruits more susceptible to decay. The most important postharvest diseases of tomatoes include alternaria rot, gray mold rot, phytopthora rot, rhizopus, and bacteria soft rot (McColloch *et al.*, 1968).

2 .7.1.6 Firmness

Next to visual appearance, the most important factor in tomato quality is firmness which is closely associated with ripening stage. Most consumers prefer firm fruits which do not lose too much juice when sliced and which do not have tough skins. Firmness affects susceptibility of tomatoes to physical damage and consequently their shipping ability. Textural quality of tomatoes is influenced by skin toughness, flesh firmness, and internal fruit structure (pericarp/locular material ratio) which vary greatly among cultivars (Kader, 1984).

2 .7.1.7 Flavour

Tomato flavor involves perception of the taste and aromas of many chemical constituents. Sugars, acids and their interactions are important to sweetness, sourness, and overall flavor intensity in tomatoes (Jones, and Scott, 1983).Fructose and citric acids are more important to sweetness and sourness than glucose and malic acid, respectively. High sugars and relatively high acids are required for best flavour. On the other hand, high acids and low sugars will produce a tart tomato while high sugars and low acids will result in a bland taste. When both sugars and acids are low, the result is a tasteless, insipid tomato.

2 .7.1.8 Nutritional value

As mentioned earlier on, tomatoes are important sources of vitamins A and C because of the large amount consumed than their average content of these two vitamins. A 100g tomato can supply about 20% and 40% of the United State recommended daily allowances of vitamins A and C respectively for adults (Blot *et al*, 1993).

2 .7.1.9 Safety

Safety factors include naturally occurring toxicants and contamination with chemical residues, heavy metals, and microorganisms of public health significance. The various components of tomato quality as mentioned above are related to their composition at harvest and compositional changes during postharvest handling (Kader *et al*., 2000). Since the initial tomato fruit quality at harvest can only deteriorate during subsequent handling, the final quality and shelf- life of the fruits will always be dependent upon their initial quality, destination handlers should take extra care to avoid damage.

2.8 CHEMICAL CHARACTERISTICS OF TOMATO

2.8.1 Total Titratable Acidity

The major organic acids in tomato are citric and malic acid, with citric acid predominating (Davies and Hobson, 1981). Acidity influences storability of processed tomato. The range of total titratable acid content varied from 0.256% to 0.353% (Hossain *et al*, 2010).High acidity according to Wahem, (1990) is essential for satisfactory heat processing by customary methods at atmospheric pressure, whereas low acidity is conducive for the activity of thermophilic, anaerobic bacteria which cause spoilage.

2.8.2 Total Soluble Solids

Total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. Sugars constitute 80% to 85% of soluble solids. Increased in total soluble solids during ripening is due to degradation of polysaccharide to simple sugars (Naik *et al*, 1993). Campos *et al*. (2006) reported minimum value of soluble solids to be around 4.5%, which is considered low for industrial tomatoes.

2.8.3 Moisture content

Norman (1992) indicates that, tomato fruits contain about 93% moisture content. Thakur and Kausha (1995) also observed 94% to 95.5% moisture in tomatoes. In most fleshy or succulent postharvest produce, moisture content is often closely tied to product quality and a decrease in moisture content is counter-productive.

2.8.4 pH

According to George *et al*, (2004), pH below 4.5 is a desirable trait, because it halts proliferation of microorganisms in the final product during industrial processing. Saimbhi *et al*, (1987), reported a wide range of variation of pH content from 3.6 to 4.6 in different tomato varieties.

2.8.5 Vitamin C

Vitamin c is a water- soluble, antioxidant vitamin. It is important in forming collagen, a protein that gives structure to bones, cartilage, muscles and blood vessel. Vitamin C also aids in the absorption of iron, and helps maintain capillaries, bones, and teeth. (Pisoschi *et al*, 2009).

Ascorbic acid content is usually adopted as the quality index of nutrients in food processing and storage. (Marquesa *et al*, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.0 VARIETIES AND SOURCE OF FRESH TOMATO VARIETIES

The study was carried out in the Horticulture department laboratory and the Biological laboratory of Kwame Nkrumah University of Science and Technology. Fruits of two tomato varieties (power and manica) were used for the study. The tomato fruits of the varieties were purchased in two phases from two different locations,a local farm at Amanchia in the Atwima Nwabiagya Districts of Ashanti Region and the greenhouse at the Department of Horticulture, Kwame Nkrumah University of Science and technology, Kumasi. In the first phase, tomato fruits of both varieties (power and manica) were purchased in the matured green stage and physicochemical characteristics analysed. Fully ripe tomato fruits were obtained in the second phase from the same sources and processed into ketchup and chemical characteristics and quality of the ketchup was assessed.

3.1.1 Preparation of Ketchup:

Tomato ketchup was prepared following the formulation composition described by Mudgil, *et al*, (2011) as in Table 3.1.

Table 3.1: Formulation of Tomato Ketchup

Ingredient	Quantity
Tomato	4kg
Onion	64.30g
Ginger	4.40g
Garlic	2.79g
Black pepper	0.87g
Sugar	150g
Salt	30g
Vinegar	250g
Sodium Benzoate	0.08g

Red ripe tomatoes were washed, cut into pieces and the seeds removed. The sliced tomatoes were boiled for ten minutes and the pericarp removed. Ginger, onion, garlic and black pepper were added to the tomatoes and blended (with electric blender) to pulp and cooked with constant stirring. Three quarters of the total sugar was added to intensify the colour of the tomatoes. The remaining sugar, salt and vinegar were added to the mixture towards the end of the preparation and the mixture heated till the final total soluble solids content was obtained. Sodium benzoate was then added as a preservative.

3.3 PARAMETERS STUDIED FOR THE PHYSICO-CHEMICAL PROPERTIES

3.3.1 Fresh Tomatoes

3.3.1.1 pH

Samples of tomatoes were taken at each ripening stage and blended into pulp. 20g of the pulp was taken and its pH value measured using a glass electrode attached to Elico pH meter Model L1-10T (India)

3.3.1.2 Vitamin C

Samples of fresh tomatoes were blended into pulp. The pulp was strained through a cheese cloth and the filtrate was poured into a graduated cylinder and diluted with distilled water to 100ml. 1Mole of starch indicator was added to 20ML of sample in a 25ML Erlenmeyer flask and titrated against standardized iodine solution to end point when a dark blue-black colour was observed.

3.3.1.3 Total Titratable Acidity

The Total titratable Acidity was determined according to Sadler and Murphy (2010).

A Hundred grams (100g) of tomato juice was diluted with 100ml of distilled water and titrated against 0.1N NaOH solution to pink end point using phenolphthalein as indicator.

3.3.1.4 Total Soluble Solids

The total soluble solids content was determined using the procedure described by Seyoum *et al*, (2009) with slight modifications. Twenty grams (20g) of tomato juice at the various stages of ripening was placed on the prism of the refractometer and the refractive index taken and recorded. Between samples, the prism of the refractometer was washed with distilled water and dried before use.

3.3.1.5 Moisture Content

The moisture content was determined by the oven dry method. Samples were taken at the various stages and placed in a container and their weight was recorded. The samples were placed in hot air dry oven and moisture content determined at 105^0C for a number of times until a constant weight was recorded (Minton, 1996; Dadzie and Orchard, 1997).

3.3.1.6 Firmness

A penetrometer was used to determine the firmness of the tomatoes at every stage of ripening (matured green, breaker stage, turning stage, pink red and red-ripe stage). The penetrometer was punched into the flesh of the tomatoes and the readings were taken.

3.3.1.7 Weight

The weight of ten randomly selected tomatoes of each variety was place on an electronic balance each day and average weight loss taken till the end of their shelf life (23days).

3.3.1.8 Mesocarp Thickness

Samples of fresh tomato fruits from each variety at the various stages were cut into two halves and the mesocarp measured three times using a pair of Vernier calipers.
The actual mesocarp value was determined by taken the average mark.

3.3.1.9 Diameter

A pair of Vernier calipers was used to measure the diameter of each of the selected fruits. The diameter of the middle portion of the fruit was measured several times and the average value taken as the actual diameter.

3.3.1.10 Colour

The colour of tomatoes at every ripening stage was measured by comparing them with standard colour chart (Dadzie and Orchard, 1997; Kader, 1992).

3.3.2 Processed Tomatoes (Ketchup)

3.3.2.1 pH

An aliquot of the ketchup was taken from each bottle into beakers. Elico pH meter, model L1-10T (India) was then used to take the pH values of the processed tomatoes (ketchup).

3.3.2.2 Total Soluble Solids (TSS)

Total soluble solids content was determined using the procedure described by Waskar *et al*, (1999) with slight modifications. 20g of samples were taken from each bottle and strained through cheese cloth. The filtrate was placed on a refractometer prism and the total soluble solids content was determined.

3.3.2.3 Total Titratable Acidity

Filtrate (10ml) from a 1:3 dilution by weight of concentrate was transferred into 250ml Erlenmeyer flask and 1ml of phenolphthalein added as indicator. The filtrate was then titrated against 0.1 standard laboratory solution to pink end point. (Sadler, 2010).

3.3.3 Microbial Load Count

3.3.3.1 Total and fecal coliform

Most probable number (MPN) was used to determine total and fecal coliforms in the samples. Serial dilutions of 10^{-1} to 10^{-4} were prepared by picking 1ml of the sample into 9ml sterile distilled water. One millilitre aliquots from each of the dilutions were inoculated into 5ml of MacConkey Brock and incubated at 35°C for total coliform and 44°C for faecal coliforms for 18-24 hours. Tubes showing colour change from purple to yellow after 24hours were identified as positive both for total and faecal coliforms.

Count per 100ml was calculated from most probable number.

3.3.3.2 *Escherichia coliform (E. coli)*

From each of the positive tubes identified, a drop was transferred into a 5ml test tube of tryptone water and incubated at 44°C for 24hours. A drop of Kovas' reagent was then added to the tubes of tryptone water. All tubes showing a red ring colour development after gentle agitation denoted the presence of indole and recorded as presumptive for E.coli. Counts per 100ml were calculated from Most Probable Number tables.

3.3.3.3 Total viable count

Total viable count were isolated and enumerated by pour plate method and growth on plate count agar (PCA). Serial dilutions of 10-2 to 10-4 were prepared by diluting 10g of the sample into 10ml sterilized distilled water. One millilitre aliquots from each of the dilutions were inoculated on petri dishes with already prepared PCA. The plates were incubated at 35°C for 24hours. After incubation, all white spots or spread were counted and recorded as total viable counts using the colony counter.

3.3.3.4 Mould (fungi) and yeast

Mould and yeast were isolated and purifiers enumerated by pour plate method and growth on potato Dextrose Agar (PDA). Serial dilution of 10-1 to 10-4 were prepared by diluting 10g of the sample into 9ml sterilized distilled water pucifier enumerated. Similarly, one millilitre aliquots from each of the dilutions were inoculated on petri dishes with already prepared PDA. The plates were the incubated at 35°C for 24hours. After incubation, all white spots or spread were counted and recorded as mould yeast using the colony counter.

3. 4 EXPERIMENTAL DESIGN

A Completely Randomized Design (CRD) was used as the experimental design for the study. All treatments were replicated three times.

3. 5 DATA ANALYSIS

The differences between treatment means was determined using the student's T-test ($p=0.01$).

CHAPTER FOUR

RESULTS

4.0 PHYSICO- CHEMICAL CHARACTERISTICS OF MANICA AND

POWER VARIETIES

4.1 Physico-Chemical Characteristics of manica and power tomato Varieties at Green Stage

From the results (Table 4.1), there was no significant difference ($p>0.01$) between the two tomato varieties for Total Soluble Solids (TSS) at the matured green stage. Power variety had 3.65 TSS content while Manica had 3.00 TSS content.

At the matured green stage, there was no significant ($p>0.01$) variation between the two varieties of tomatoes for Total Titratable Acid. Both varieties, Power and Manica, recorded the same value of 0.37 as shown in Table 4.1.

For firmness, the two tomato varieties significantly ($p<0.01$) varied in their firmness at the matured green stage. Comparison indicated that the Power variety recorded significantly higher firmness (9.60) when compared with Manica variety which recorded the least (9.00) (Table 4.1).

The values recorded for diameter in Table 4.1 shows that the two tomato varieties studied did not vary significantly ($p>0.01$) at the matured green stage. Diameter of Manica variety was 58.79cm while the diameter of Power variety was47.87cm.

Similarly, mesocarp thickness of the power variety did not differ significantly ($p>0.01$) from mesocarp thickness of Manica(Table 4.1). Mesocarp thickness of power was 2.65cm while that of Manica variety was 3.35cm.

Moisture content of the tomato varieties (Table 4.1) did not vary significantly ($p>0.01$) at the matured green stage. The moisture content was 94.00% and 94.25% for Power and Manica respectively.

The pH of the two varieties of tomatoes studied did not differ significantly (p>0.01). Both varieties recorded 4.00 for pH and maintained that throughout the various stages of ripening.

Table 4.1: Physico- chemical characteristics of tomato varieties at matured green stage

Tomato Varieties	TSS(° Brix)	TTA(m Eq)	Diameter (cm)	Firmness (N)	Mesocarp thickness (cm)	Moisture content (%)	pH
Power	3.65a	0.37a	47.87a	9.60a	2.65a	94.00a	4.00a
Manica	3.00a	0.37a	58.79a	9.00b	3.35a	94.25a	4.00a
P-value	0.47	1.00	0.25	0.00	0.00	0.09	1.00

4.2 Physico- Chemical Characteristics of Tomato Varieties at Breaker Stage

From Table 4.2, the Total Soluble Solids showed significant (p<0.01) variation between the two tomato varieties at the breaker stage. Power variety had total soluble solids content of 6.60 and that of Manica variety recorded a value of 3.00.

Significant variation (p<0.01) existed between the two varieties for Total Titratable Acids (Table 4.2). Power recorded a higher value of 0.42 TTA while Manica recorded the least value of 0.32.

Results from Table 4.2 showed that there were no significant difference (p>0.01) for diameter between the two tomato varieties. Power and Manica varieties recorded values of 51.50cm and 51.43cm respectively.

From the results (Table 4.2), the values indicated that no significant difference (p>0.01) occurred among the two tomato varieties for firmness. Power variety had 7.60 whereas Manica variety had 7.33.

Table 4.2 showed that mesocarp thickness significantly (p<0.01) differed between the two tomato varieties. Manica variety recorded a higher value of 7.25cm while power variety had 3.13cm.

For moisture content, Power variety had significantly higher moisture content (94.0%) at the breaker stage while Manica variety had significantly the least (91.0%).

The pH of the two varieties of tomatoes studied did not differ significantly (p>0.01). Both varieties recorded 4.00 for pH and maintained that throughout the various stages of ripening. (Table 4.2).

Table 4.2: Physico-Chemical characteristics of tomato varieties at breaker stage

Tomato Varieties	**TSS (°Brix)**	**TTA (mEq)**	**Diameter (cm)**	**Firmness (N)**	**Mesocarp thickness (cm)**	**Moisture content (%)**	**pH**
Power	6.60a	0.42a	51.50a	7.60a	3.13b	91.00b	4.00a
Manica	3.00b	0.32b	51.43a	7.33a	7.25a	94.00a	4.00a
P-value	0.00	0.00	0.44	0.68	0.01	0.01	1.00

4.3 Physico- Chemical Characteristics of Tomato Varieties at the Turning Stage

From the results (Table 4.3), there were no significant difference (p>0.01) between Power and Manica varieties in terms of total soluble solids. Both varieties recorded the same value of 3.90.

For total titratable acids content recorded for Power and Manica varieties (Table 4.3), there were significant (p<0.01) variation between the two tomato varieties. Power variety had TTA content of 0.42 significantly higher than Manica variety which recorded TTA value of 0.32.

Table 4.3 shows there were no significant difference (p>0.01) between the two varieties of tomatoes for diameter. The diameter recorded for Power variety was 50.00cm and Manica had 51.28cmas for diameter.

From the results (Table 4.3), firmness of Manica variety (7.40) was significantly higher than that of Manica variety which recorded 4.95.

Results showed that there were no significant difference (p>0.01) between the two tomato varieties for mesocarp thickness. The values of mesocarp thickness recorded for the two varieties were 3.50cm for Power variety and 2.63cm for Manica variety.

From Table 4.3, the results showed that Power variety recorded a moisture content of 94.00% while Manica variety recorded moisture content of 95.50%. However, moisture content between the two varieties did not differ significantly (p>0.01).

There was no significant difference (p>0.01) between the two varieties for pH. Each of the two tomato varieties (Manica and Power) recorded pH value of 4.00 as shown in Table 4.3.

Table 4.3: Physico- Chemical characteristics of two tomato varieties at the turning stage

Tomato Varieties	**TSS (°Brix)**	**TTA (mEq)**	**Diameter (cm)**	**Firmness (N)**	**Mesocarp thickness (cm)**	**Moisture content (%)**	**pH**
Power	3.90a	0.42a	50.00a	4.95b	3.50a	94.00a	4.00a
Manica	3.90a	0.32b	51.28a	7.40a	2.63a	95.50a	4.00a
P-value	1.00	0.00	0.83	0.00	0.21	0.81	1.00

4.4 Physico-Chemical Characteristics of Tomato Varieties at Pink Stage Total soluble solids content of Power variety (Table 4.4) was observed not to vary significantly (p>0.01) from Manica variety. The Power variety had TSS content of 6.40 while Manica had 4.20 of TSS.

The results recorded for total titratable acids showed significant difference (p<0.01) between the two varieties (Table 4.4). Higher total titratable acids content was observed in power (0.44) than Manica which had a lower value (0.26).

Diameter values from the results (Table 4.4) showed there was significant (p<0.01) variation between the two tomato varieties. Manica had significantly higher diameter value of 51.79cm compared to Manica which recorded the least (39.04cm).

Table 4.4 showed that, firmness did not vary significantly (p>0.01) between the two varieties of tomatoes. Firmness value of Manica was 6.40 while power variety had 3.90at the pink stage of ripening.

From Table 4.4, the two tomato varieties studied did not differ significantly (p>0.01) in mesocarp thickness at the pink stage of ripening. Mesocarp thickness of power variety was 3.29cm while Manica variety recorded 2.55cm

There was no significant difference (p>0.01) between the two varieties of tomato for moisture content. Power variety recorded moisture content of 93.25%and 95.25% for Manica variety.

There was no significant difference (p>0.01) between the two varieties for pH. Each of the two tomato varieties (Manica and Power) recorded pH value of 4.00 as shown in Table 4.4.

Table 4.4: Physico-Chemical characteristics of tomato varieties at the pink stage

Trt	TSS (°Brix)	TTA(mEq)	Diameter (cm)	Firmness (N)	Mesocarp thickness (cm)	Moisture content (%)	pH

Power	6.40a	0.44a	39.04b	3.90a	3.29a	93.25a	4.00a
Manica	4.20a	0.26b	51.79a	6.40a	2.55a	95.25a	4.00a
(P= 0.01)	0.02	0.00	0.00	0.01	0.27	0.07	1.00

4.5 Physico-Chemical Characteristics of Tomato Varieties at Light Red Stage Total soluble solids values did not show significant (p>o.o1) variation between Power and Manica varieties. However, power variety had TSS content of 6.10 and that of Manica was 4.40 (Table 4.5).

There were significant difference ($p<0.01$) between the two varieties of tomato studied for total titratable acid. Power variety had higher TTA (0.49) while Manica had lower value of 0.24 (Table 4.5).

From the results (Table 4.5), power variety had diameter value of 59.59cm and Manica variety recorded diameter of 61.36cm. There were no significant differences ($p>0.01$) between the two varieties.
The two tomato varieties studied did not vary significantly ($p>0.01$) in terms of firmness (Table 4.5).Power variety had 3.61 value of firmness while Manica had firmness value of 5.30.

Mesocarp thickness values shown in Table 4.5were 3.85 and 4.98 for Power and Manica tomato varieties. There were no significant differences ($p>0.01$) between the varieties of tomatoes

Table 4.5 shows the moisture content of the two tomato varieties. Manica variety recorded significantly higher value (96.00%) than power variety which had the least (92.75%).

There was no significant differences (p>0.01) between the two varieties for pH. Each of the two tomato varieties (Manica and Power) recorded pH value of 4.00 as shown in Table 4.5.

Table 4.5: Physico-Chemical characteristics of tomato varieties at the light red-ripe stage

Tomato Varieties	TSS (°Brix)	TTA (mEq)	Diameter (cm)	Firmness (N)	Mesocarp thickness (cm)	Moisture content (%)	pH
Power	6.10a	0.49a	59.59a	3.61a	3.85a	92.75b	4.00a
Manica	4.40a	0.24b	61.36a	5.30a	4.98a	96.00a	4.00a
(P=0.01)	0.04	0.00	0.04	0.04	0.12	0.00	1.00

4.6 Physico- Chemical Characteristics of Tomato Varieties at Red-ripe Stage Table 4.6 showed results for total soluble solids of the two tomato varieties at the redripe stage. Total soluble solids differed significantly (P<0.01) among the Power and Manica varieties. Power variety had higher TSS content of 9.00 than Manica variety which had 4.80.

From the results (Table 4.6), there were significant differences (p<0.01) between the two tomato varieties (Power and Manica) for Total Titratable Acids. Power variety had higher total titratable acid (0.49) at the red-ripe stage than Manica variety which recorded the least (0.20).

Diameter values of the two tomato varieties did not differ significantly (p>0.01) between the two tomato varieties. The diameter of Power was 50.20cm while Manica was 51.18cm.

From the results of the study (Table 4.6), there were no significant difference (p>0.01) between the two varieties of tomato for firmness at the red-ripe stage. Power had firmness of 2.75 whereas Manica recorded 2.15 as firmness.

There were no significant differences (p>0.01) between the varieties of tomato for mesocarp thickness. Power and Manica recorded mesocarp thickness of 3.50 and 4.02 respectively (Table 4.6).

The two tomato varieties did not vary significantly (p>0.01) in terms of moisture content(Table 4.6).Moisture content for Power was 94.75% while that of Manica was 96.25%

There was no significant difference (p>0.01) between the two varieties for pH. Each of the two tomato varieties (Manica and Power) recorded pH value of 4.00 as shown in Table 4.6. Both tomato varieties had a constant pH from the matured green stage to the red stage of ripening.

Table 4.6: Physico-Chemical characteristics of tomato varieties at the red-ripe stage

Tomato Varieties	TSS (°Brix)	TTA (mEq)	Diameter (cm)	Firmness (N)	Mesocarp thickness (cm)	Moisture content (%)	pH
Power	9.00a	0.49a	50.20a	2.75a	3.50a	94.75a	4.00a
Manica	4.80b	0.20b	51.18a	2.15a	4.02a	96.25a	4.00a
(P=0.01)	0.00	0.00	0.16	0.50	0.42	0.14	1.00

4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF TOMATOES FROM THE GREEN TO THE RED-RIPE STAGE

4.1.1 Total Soluble Solids (TSS)

Total soluble solids of the two tomato varieties did not differ significantly (p>0.01) between the mean values from the green stage to the red-ripe stage (Table 4.7). The Power variety recorded a mean value of 5.94 while Manica variety had a mean value of 3.88.

Table 4.7: Total Soluble Solids (TSS) of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	3.65	6.6	3.90	6.40	6.10	9.00	**5.94a**
Manica	3.00	3.00	3.90	4.20	4.40	4.80	**3.88a**
						(P=0.01)	2.727

4.1.2 Total Titratable Acidity (TTA)

Table 4.8 shows significant (p<0.01) differences between the two tomato varieties for Total Titratable Acid from the green stage to the red-ripe stage of ripening. Power variety recorded higher mean value of 0.44 while Manica variety had the least mean value of 0.29. It was observed that the TTA of Manica variety decreased from the green to the red stage while Power variety increased in value.

Table 4.8: Total Titratable Acidity of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	0.37	0.42	0.42	0.44	0.49	0.49	**0.44a**
Manica	0.37	0.32	0.32	0.26	0.24	0.20	**0.29b**
						(P=0.01)	0.100

4.1.3 Diameter

From the results (Table 4.9), there were no significant differences (p>0.01) in diameter for the two tomato varieties from the green to the red-ripe stage. The mean values for the diameter were 54.3 and 49.70 for Power and Manica varieties respectively.

Table 4.9: Diameter of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	47.87	51.5	50.00	39.04	59.59	50.20	**54.31a**
Manica	58.79	51.43	51.28	51.79	61.36	51.18	**49.70a**
						(P=0.01)	10.379

4.1.4 Firmness

From the results (Table 4.10), the mean values of firmness did not vary significantly (p>0.01) between the two varieties of tomato. Power variety had mean value firmness as 5.40 while mean Manica variety had 6.26. Firmness of both varieties reduced steadily as the progressed from matured green stage of ripening to red stage. Firmness of power variety reduced from 9.6 to 2.75 while that of Manica reduced from 9.00 to 2.15.

Table 4.10: Firmness of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	9.6	7.60	4.95	3.90	3.61	2.75	**5.40a**
Manica	9.00	7.33	7.40	6.40	5.30	2.15	**6.26a**
						(P=0.01)	4.591

4.1.5 Mesocarp Thickness

Mesocarp thickness of the two tomato varieties increased with changed in colour (Table 4.11). A comparison between the two varieties showed that Manica variety which had a mean value of 4.13 mesocarp thickness was not significantly different ($p>0.01$) from power variety which recorded mean value of 3.32.

Table 4.11: Mesocarp Thickness of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	2.65	3.13	3.50	3.29	3.85	3.50	**3.32a**
Manica	3.35	7.25	2.63	2.55	4.98	4.02	**4.13a**
						(P=0.01)	2.361

4.2.6 Moisture Content

Moisture content of the two tomato varieties increased slightly as the tomatoes changed from the green stage to the red-ripe stage. However, the mean values of both varieties did not vary significantly ($p>0.01$) from each other. The mean value of Power variety was 93.29% whereas Manica variety had 95.21% (Table 4.12).

Table 4.12: Moisture Content of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	94.00	91.00	94.00	93.25	92.75	94.75	**93.29a**
Manica	94.25	94.00	95.50	95.25	96.00	96.25	**95.21a**
						(P=0.01)	2.075

4.1.7 pH

The pH of the fresh fruits of the tomato varieties was constant (4.00) from the matured green stage to the red-ripe stage of ripening. The mean values of both power and manica varieties did not differ significantly ($p>0.01$) as ripening advances.

Table 4.13: pH of tomatoes from the green stage to the red-ripe stage

	Ripening Stages						Mean
Tomato Varieties	**Green**	**Breaker**	**Turning**	**Pink**	**Light red**	**Red**	
Power	4.00	4.00	4.00	4.00	4.00	4.00	**4.00a**
Manica	4.00	4.00	4.00	4.00	4.00	4.00	**4.00a**
						(P=0.01)	1.355

4.1.8 Vitamin C

Similarly, significant (p>0.01) variation were not shown in vitamin C content between the two tomato varieties. However, Power variety produced 38.9 as mean value of vitamin C while Manica variety had 42.95 (Table 4.14)

Table 4.14: Vitamin C content of tomatoes from the green stage to the red-ripe stage

Tomato varieties	**Mean**
Power	**38.9a**
Manica	**42.95a**
P-value	**0.028**

4.1.9 Weight loss and colour

From Table 4.15, there was no significant difference (p≥0.01) in weight loss for both Manica and power varieties of tomatoes at the end of the experiment (23 days). Manica variety had mean weight loss of 6.67% while power variety had mean weight loss of 5.34%.

For colour change, similarly no significant difference (p≥0.01) was observed between the two varieties. Manica had 4.91 whereas power variety had 5.13.

Table 4.15: Mean values for weight loss and colour changes of tomato varieties +

	Mean Weight loss (%)	**Mean Colour**
Manica	6.67a	4.91a
Power	5.34a	5.13a
p-value (0.180)	0.044	0.803

4.2 CHEMICAL CHARACTERISTICS OF PROCESSED TOMATOES (KETCHUP)

Table 4.16 shows no difference ($p>0.01$) was observed between the ketchup from the two tomato varieties for pH. Both Manica and Power recorded the same value (4.00).

From the results, the Total Soluble Solids of the ketchup from Manica variety (24.40) was significantly higher ($p<0.01$) than that of the power variety (18.58).

For the Total Titratable Acidity, there were no statistical difference ($p>0.01$) between the ketchup from the two varieties of tomato. The Manica variety had 0.57 while power variety had 0.49 (Table 4.).

Table 4.16: Chemical characteristics of processed tomatoes

Tomato Varieties	pH	TSS(°Brix)	TTA(mEq)
Manica	4.00a	24.40a	0.57a
Power	4.00a	18.58b	0.49a
(p=0.01)	1.00	0.00	0.38

4.3.1 Microbial Analysis of Processed Tomatoes

4.3.1.1 Total viable count

From the table, there was no growth of total viable count in the ketchup from both varieties in the first month of storage. However, the second and third month had total viable count growth in the ketchup produced from the two tomato varieties. There was no significant variation ($p>0.01$) between the two tomato varieties for total viable count growth. Manica variety recorded total count of 1.21×10^5 while total count for power variety was 1.0×10^5.

Table 4.17 Microbiological Quality of ketchup

Tomato variety	Total viable Count (cfu/g)	E.coli (cfu/)	Total count (cfu/g)	Feacal coliform (cfu/g)	Mould and Yeast(cfu/g)
Manica	Nil	Nil	1.21×10^5a	Nil	Nil
Power	Nil	Nil	1.0×10^5a	Nil	Nil
P- 4.604					

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CHAPTER FIVE

DISCUSSION

5.0 PHYSICO- CHEMICAL CHARACTERISTICS OF FRESH TOMATOES

5.1 Total Soluble Solids (TSS)

From the results, both Power and Manica varieties of tomatoes showed no significant differences ($p>0.01$) for total soluble solids. Total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. Increased in total soluble solids during ripening is due to degradation of polysaccharide to simple sugars (Naik *et al*, 1993). Campos *et al* (2006) and Kader *et al* (1989) have reported minimum value of soluble solids to be around 4.5%, which is considered low for industrial tomatoes.

Pascale *et al.* (2001) reported total soluble solids content of tomato fruits (fresh) ranged from 4% to 6%.Power variety had a higher total soluble solids increased from the mature green stage to red stage of ripening than Manica variety which had total soluble solids lower than the optimum range which is from 4% to 6%. This could be due to the differences in genetic potential and growing conditions.

5.2 Total Titratable Acidity

The major organic acids in tomato are citric and malic acid, with citric acid predominating (Davies and Hobson, 1981). Acidity influences storability of processed tomatoes. From the study, Total Titratable Acidity varied significantly ($p<0.01$) between Power and Manica varieties. Manica variety had higher Total Titratable Acidity as ripening advanced from the mature green stage to the red ripe stage.

According to Hossein *et al*. (2010), the range of total titratable acidity content of tomatoes varied from 0.256% to 3.53%. George *et al*. (2004) also reported that Total Titratable Acidity in fruits of 12 different tomato genotypes varied from 0.25 to 0.70. However, the TTA of Power and Manica varieties ranged from 0.29 to 0.44 and were within the range reported by other research works, however, power variety will perform better in terms of storage period than Manica variety. This is because higher acidity inhibits the growth of microorganisms. These findings will help both consumers and processors to choose varieties to suit their needs.

5.2. Firmness

Firmness is one of the major factors contributing to shelf quality of tomato fruit. Consumers judge the quality of fresh tomatoes by their firmness, colour and taste (Roseneld *et al*, 1994).

There was no significant variation ($p>0.01$) of firmness between Power and Manica tomato varieties but Power variety had marginally higher reduction in firmness from the mature green stage to the red stage of ripening than the Manica variety. This difference in firmness might be associated to the difference in genetic makeup of the two varieties.

However, comparing the two varieties, Manica variety would be considered to be of more quality than Power variety. This might be because fruit firmness is a factor often used to evaluate fruit quality which is directly related to storage potential and the likelihood of bruising when fruits are subjected to impact during transportation or handling.

5.4. Weight loss

From the results, weight loss did not vary significantly ($p>0.01$) between the two tomato varieties during the storage period (23days). Power variety had mean weight loss of 5.34% while manica variety had mean weight loss of 6.67%

This result is in agreement with the previous findings by Tigist, *.et al,* (2012) in which significant increase in fruit weight loss was shown as ripening progressed from mature green to red ripe stage. Higher fruit weight losses are also the main cause of quality losses in fruits due to dehydration and worsened appearance. Reduction in fruit weight could be linked to actions of several factors such as genetic and environmental factors.

5.5. Colour of Fruits

For colour change during the observation period, there was no significant variation ($p>0.01$) between the tomato varieties. Power had 5.13 whereas manica had 4.91. Fruit colour has a strong effect on consumer perception of quality and is an acceptable maturity index for many fruits such as tomatoes (Ghaffari, *et al,* 2015). Colour of tomato fruits contributes significantly to the grade of both raw and processed products (Boe and Saunkhe, 1967).Ripened tomato fruits become soft and susceptible to various forms of defects that affect the shelf life of the fruits. Among the quality parameters consumer look out for in tomatoes is shipping quality. Comparing the two varieties, although, both varieties were not fully ripe during the observation period, products from power will be better than manica. However, manica fruits will have longer shelf life than power.

5.6. Moisture Content

The results showed there was no significant ($p>0.01$) variation of moisture content among the tomato varieties.

Norman (1992) indicates that, tomato fruits contain about 93% moisture content. Thakur and Kausha, (1995) also observed 94% to 95.5% moisture in tomatoes. In most fleshy or succulent postharvest produce, moisture content is often closely tied to product quality and a decrease in moisture content is counter-productive.

Moisture content of Manica variety increased from the mature green stage to the red stage of ripening, whereas the power variety had decreased in moisture content. The variation in genetic makeup and environmental conditions of the two tomato varieties might be the cause of the difference in moisture content. Loss in moisture content leads to a reduction in appearance quality including wilting, shriveling, less gloss, and limpness, which reduce market value. Thus, the Power variety could be stored a longer period and still maintain its freshness.

5.7. pH

From the result, pH did not vary significantly ($p>0.01$) from the mature green stage to red stage of ripening in the two tomato varieties. According to George *et al*. (2004), pH below 4.5 is a desirable trait because it halts proliferation of microorganisms in the final product during industrial processing. The pH content of Manica and Power varieties was constant (4.00) at various stages of ripening but was within the normal pH range. This could mean that increase of microorganisms during processing into ketchup would be reduced and the shelf-life could be prolonged. Saimbhi *et al*. (1987) also reported a wide range of variation of pH content from 3.6 to 4.6 in different tomato varieties. The insignificant variation could also be due to storage condition.

5.8. Vitamin C Content

The results showed that the Vitamin C content did not differ significantly ($p>0.01$) among the two tomato varieties. Vitamin C is a water- soluble, antioxidant vitamin. It is important in forming collagen, a protein that gives structure to bones, cartilage, muscles and blood vessel. Vitamin C also aids in the absorption of iron, and helps maintain capillaries, bones, and teeth (Pisoschi *et al.*, 2009).

Ascorbic acid content is usually adopted as the quality index of nutrients in food processing and storage, (Marques *et al*, 2011). The high presence of Vitamin C content in the two varieties indicates they contain quality index of nutrients. The quality of the tomatoes can also be maintained during ripening and storage when the storage environment is conducive.

5.2 CHEMICAL CHARACTERISTICS OF PROCESSED TOMATO KETCHUP

5.2.1 Ketchup pH

Results from the study revealed there was no significant variation ($p>0.01$) between ketchup from the two varieties. The pH of mature tomatoes may exceed 4.6, tomato products are generally classified as acid food ($pH<4.5$), which require moderate conditions of processing to control microbial spoilage and enzyme inactivation (De Lira and Barrett, 2011), Hayes *et al*,(1998).

Thomson, (2009) reported that the pH for tomato ketchup ranges from 4.1to 4.3. The pH values of ketchup from the Power and Manica tomato were within the range reported in the findings above. Retain of the pH values may be attributed to minimum heat treatment on the tomatoes before cooking. pH is very important because acidity influences the heat processing conditions required for producing safe products.

5.2.2 Total Soluble Solids

There was statistical variation ($p<0.01$) among ketchup from the power and Manica varieties for Total Soluble Solids (Table 4.2.1). Increase in total soluble solids could be partly due to heat treatment during blanching of tomatoes that could cause the breakdown of tissues and result in high soluble solids in the product (Temesgen *et al*, 2011). According to Brasil,.*et al*, (1995) the addition of common salt during processing dissolves some of the pectin and thereby results in the increase in total soluble solids. Total soluble solids content is a key parameter in tomato processing. Tomato products are sold based on their soluble solids content, therefore, ketchup from power variety will be preferred because ketchup produced was sweeter than manica variety. Also, processing tomatoes with high levels of soluble solids is less expensive in terms of energy use since less water needs to be evaporated to obtain the desired total soluble solids content. The difference might be as a result of variation in individual cultivar reaction to the ingredients, processing duration and the storage condition.

5.2.3 Total Titratable Acidity

From the results, total titratable acidity did not vary significantly between the two varieties after processed into ketchup. The total titratable acidity of Power and Manica were 0.49 and 0.57. There had been an increase in the TTA content of the processed tomatoes and this could be attributed to the ingredients used in the preparation of the ketchup. However, processing of Manica would require addition of more vinegar as a preservative compared to the power variety because it was less acidic.

5.3 MICROBIAL ANALYSIS OF PROCESSED TOMATOES (KETCHUP)

Microbial analysis was carried out to isolate, Total coliform, E. coli, mould, yeast, faecal coliform and total viable count. However, total viable count was the only microorganism present. The results showed no significant difference (p>0.0.1) for total viable count in the ketchup from both varieties when stored for three months.

Due to acidic nature and presence of oil in the spices, the growth of microorganisms in ketchup could be fully inhibited. Furthermore, addition of acid (vinegar) could denature microbial protein and preserve the ketchup for the required period of storage (Temesgen *et al*, 2011)

The heat treatment and preservatives might have destroyed the mould, yeast, E.coli, Total coliform and Faecal coliform in the samples because, the ingredients that are mostly added to ketchup such as vinegar, salt and spices, make the product highly acidic in nature. It could also be associated to the fact that, the packaging bottles were also sterilized in order to prevent post-processing contamination and spoilage.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.0 CONCLUSION

Results from the study have shown that, there was no significant difference ($p>0.01$) for physical characteristics (firmness, mesocarp thickness, colour and diameter) of power and manica tomato varieties.

From the results, the chemical characteristics (moisture content, vitamin c content, weight lost, total soluble solids, pH) did not vary significantly ($p>0.01$) among tomato varieties as they progressed from one maturity stage to the other. Nevertheless there was significant variation ($p<0.01$) between tomato varieties for total titratable acidity, power variety recorded a higher value than manica which had the least total titratable acididty. This suggests that power variety was more acidic and consequently could be more resistant to microbial deterioration. There was no significant difference ($p>0.01$) between chemical characteristics (Total titratable acidity and pH) of ketchup produced from tomato varieties. However, Total soluble solids differed significantly ($p<0.01$) among ketchup produced using tomato varieties. Power variety recorded more total soluble solids than manica variety. During the first month of storage, E.coli, total coliform, mould, yeast, Feacal coliform and Total viable count was not present. However, there was Total viable count growth in the second and third month of storage.

The study showed that as far as both manica and power could be processed into ketchup although power produced sweeter ketchup, ketchup produced using the two varieties of tomato were of acceptable quality.

6.1. RECOMMANDATION

Based on the study, the following recommendations have been made:

*Further studies should be carried out by processing tomato varieties into different forms.

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Elico pH meter, model L1-10T (India).

APPENDICES

Two-Sample T Tests for diameter by trt

trt	N	Mean	SD	SE
manica	6	54.305	4.5474	1.8565
power	6	49.700	6.6087	2.6980
Difference		4.6050	5.6725	3.2750

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

Method	Variances	DF	T	P	99% CI for Difference Lower	Upper
Pooled	Equal	10	1.41	0.1900	-5.7744	14.984
Satterthwaite	Unequal	8.9	1.41	0.1938	-6.0786	15.289

Homogeneity of Variances DF F P

Folded F Test 5,5 2.11 0.2157

Cases Included 12 Missing Cases 0

Two-Sample T Tests for firmness by trt trt

N Mean SD SE manica 6

6.2633 2.3573 0.9624 power 6

5.4017 2.6518 1.0826

Difference 0.8617 2.5089 1.4485

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF T P Lower Upper

Pooled Equal 10 0.59 0.5651 -3.7290 5.4524

Satterthwaite Unequal 9.9 0.59 0.5653 -3.7432 5.4665 **Homogeneity of Variances DF F P**

Folded F Test 5,5 1.27 0.4012

Cases Included 12 Missing Cases 0

Two-Sample T Tests for mesothick by trt

trt N Mean SD SE manica

6 4.1300 1.7790 0.7263 power 6

3.3200 0.4078 0.1665

Difference 0.8100 1.2906 0.7451

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF T P Lower Upper

Pooled Equal 10 1.09 0.3025 -1.5514 3.1714

Satterthwaite	Unequal	5.5	1.09	0.3221	-2.0529	3.6729

Homogeneity of Variances	**DF**	**F**	**P**
Folded F Test	5,5	19.03	0.0029

Cases Included 12   Missing Cases 0

Two-Sample T Tests for moisture by trt

trt	**N**	**Mean**	**SD**	**SE**
manica	6	95.208	0.9140	0.3731
power	6	93.292	1.3174	0.5378
Difference		1.9167	1.1338	0.6546

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF
T P Lower Upper

Pooled	Equal	10	2.93	0.0151	-0.1579	3.9912
Satterthwaite	Unequal	8.9	2.93	0.0170	-0.2162	4.0495

Homogeneity of Variances	**DF**	**F**	**P**
Folded F Test	5,5	2.08	0.2207

Cases Included 12   Missing Cases 0

Two-Sample T Tests for tss by trt

trt N Mean SD SE manica

6 3.8833 0.7441 0.3038 power 6

5.9417 1.9719 0.8050

Difference -2.0583 1.4903 0.8604

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF

T P Lower Upper

Pooled Equal 10 -2.39 0.0378 -4.7853 0.6686

Satterthwaite Unequal 6.4 -2.39 0.0513 -5.1689 1.0522

Homogeneity of Variances DF F P

Folded F Test 5,5 7.02 0.0259

Cases Included 12 Missing Cases 0

Two-Sample T Tests for tta by trt

trt N Mean SD SE manica

6 0.2850 0.0625 0.0255 power 6

0.4383 0.0462 0.0189 Difference -

0.1533 0.0550 0.0317 **T-Tests for Mean**

Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF

T P Lower Upper

Pooled Equal 10 -4.83 0.0007 -0.2539 -0.0527

Satterthwaite Unequal 9.2 -4.83 0.0009 -0.2559 -0.0508

Homogeneity of Variances DF F P

Folded F Test 5,5 1.83 0.2616

Cases Included 12 Missing Cases 0 **Two-Sample**

T Tests for PH by trt

trt N Mean SD SE manica

3 4.0000 0.1000 0.0577 power 3

4.0000 0.5000 0.2887

Difference 0.0000 0.3606 0.2944

T-Tests for Mean Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF
T P Lower Upper

Pooled Equal 4 0.00 1.0000 -1.3554 1.3554

Satterthwaite Unequal 2.2 0.00 1.0000 -2.5834 2.5834

Homogeneity of Variances DF F P

Folded F Test 2,2 25.00 0.0385 Cases

Included 6 Missing Cases 0

Two-Sample T Tests for VITC by trt

trt N Mean SD SE manica

4 42.947 2.2152 1.1076 power 4

38.088 2.5364 1.2682 Difference

4.8600 2.3812 1.6838 **T-Tests for Mean**

Difference

Null Hypothesis: difference = 0

Alternative Hyp: difference <> 0

99% CI for Difference Method Variances DF
T P Lower Upper

Pooled Equal 6 2.89 0.0278 -1.3825 11.102

Satterthwaite Unequal 5.9 2.89 0.0284 -1.4292 11.149

Homogeneity of Variances DF F P

Folded F Test 3,3 1.31 0.4146

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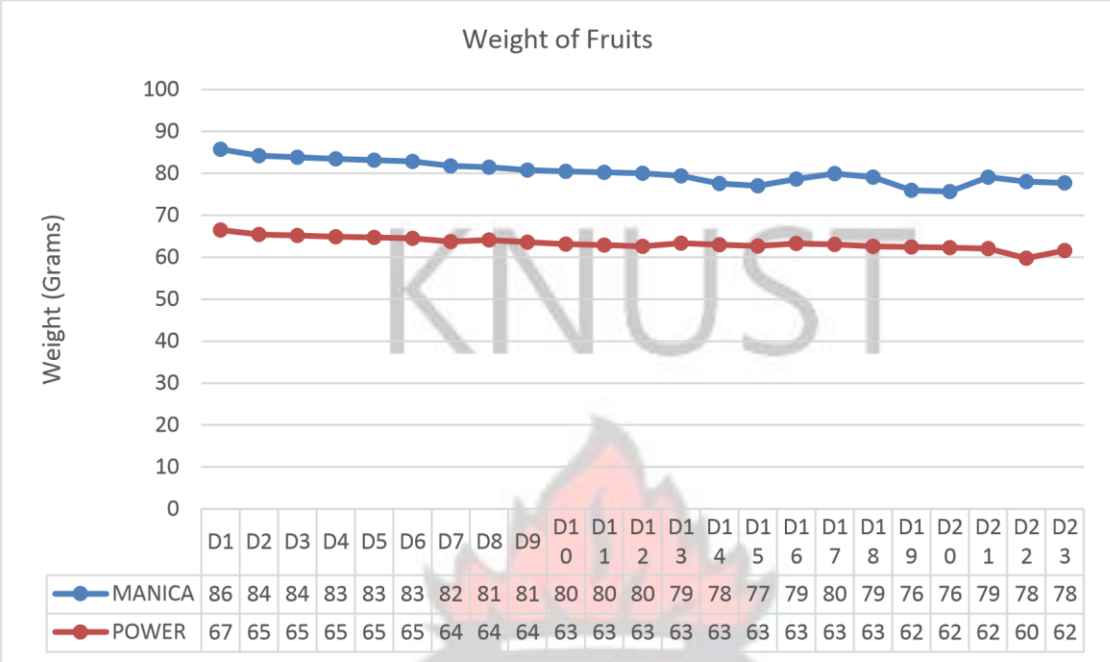
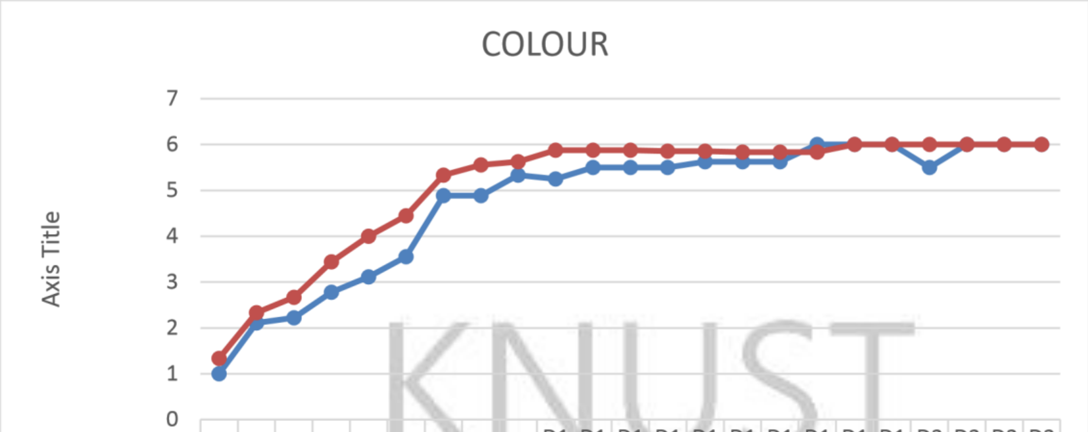
Cases Included 8   Missing Cases 0



Weight of tomato varieties during storage period



	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23
MANICA	1	2	2	3	3	4	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6
POWER	1	2	3	3	4	4	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Colour changes of the two tomato varieties during storage period

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