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QUALITY CHARACTERISTICS AND FORMULATION PROTOCOL FOR RECONSTITUTING TOMATO POWDER INTO PASTE

A thesis submitted to the Department of Food Science and Technology, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi in partial fulfilment of the requirement for the degree

MSc Food Science and Technology

BY

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DECLARATION

I hereby declare that this submission is my own work towards the M.Sc. Food Science degree and that to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my partner, David Tetteh whose words of encouragement and push for tenacity rings in my ears. My sisters Catherine, Florence, Philomena, Freda and my brothers Henry and Eric have never left my side and are very special. My lovely parents, Eric and Rebecca Avorkpo, thank you for your emotional, physical, spiritual support and companionship. Thank you all for your inputs in my life.

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ABSTRACT

Tomato powder has been developed as a way of mitigating postharvest challenges associated with fresh tomatoes. However, there is limited information on the quality characteristics and formulation protocol for reconstituting tomato powder into paste. This study therefore sought to determine the proximate composition, physicochemical properties (pH, Brix, titratable acidity, colour) and consumer acceptance (scale of 1-7) of reconstituted tomato powder. The solar dried Roma tomato flour were formulated into tomato paste with different proportions of water and binder (cassava starch). A canned commercial tomato paste was used as control. Moisture, crude protein, ash, crude fat, crude fibre and carbohydrate content of the reconstituted powder ranged from 73.01 - 73.93, 0.57 - 0.58, 4.90 - 5.07, 0.46 - 0.62, 13.73 - 17.38 and 2.57 - 7.11, respectively. That of the control was 71.61, 0.30, 3.30, 0.42, 10.94 and 13.44, respectively. pH, º brix, titratable acidity and colour (redness index) of the tomato paste samples ranged from 4.11 - 4.25, 1.95 - 2.25, 0.23 - 0.26 and 10.40 - 13.70 respectively, compared with 4.25, 2.25, 0.23 and 13.7 for the control. The tomato pastes from the reconstituted powder was generally liked by consumers with average score of 5.02 compared to the control with an average score of 6.10. Consumers' willingness to use the pastes reconstituted from the tomato powder was also high with an average score of 4.51 compared to the average score of 5.97 for the control. The present findings suggest that the method of processing the tomato powder induced some structural changes, which were reflected in the fibre and carbohydrate content. The consumer assessment further indicates a good market potential for extending the use of tomato powder.

Key words: Tomato powder, reconstituted tomato powder/tomato paste, cassava starch

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CHAPTER ONE

1.0 Introduction

1.1 Background

Tomato (*Solanum lycopersicum*) fruit is a widely grown vegetable crop used in various food products such as sauce, ketchup, squash and jam (Boumendjel *et al*., 2011). It is a basic ingredient of many meals in Ghana especially, the sauces and stews which accompany most traditional dishes. The fruit can also be consumed raw in salads or used to make juices (Alam *et al*., 2007; Tambo and Gbemu, 2010). Tomato is rich in essential nutrients such as vitamins and minerals (Bradley, 2003).

Tomato has very high moisture content and water activity which makes it susceptible to microbial growth and senescence, resulting in about 30 % post-harvest losses every year in Ghana (Aidoo *et al*., 2014). To mitigate these challenges, Owureku *et al*. (2017) produced consumer-acceptable and shelf-stable tomato powder by use of a solar drier. This drying technique (solar drying) is less expensive and can effectively and efficiently reduce postharvest losses (Anthon *et al*., 2008). However, the food use of tomato powder is limited; generally being used as an additive (thus, for flavour, taste and colour) during food preparation rather than a main ingredient for soups and stews as desired by the Ghanaian consumer (Lavelli *et al*., 2001).

Tomato paste on the other hand is highly consumed in Ghana - an average of twenty-five thousand (25,000) tonnes per year, since the product is suitable for the food preparation needs of consumers (Aryeetey, 2006). Thus, due to the absence of infrastructure to produce the paste locally, Ghana is the second largest importer of tomato paste globally (Aryeetey, 2006).

For enhanced utilization of tomato powder, recent studies have proposed its potential reconstitution into other products such as the tomato paste, jams and ketchup (Boumendjel *et al*., 2011; Owureku *et al.,* 2017). Thus, with the high demand for tomato paste, and limited foreign exchange earnings, investigations on the formulation protocol and quality characteristics of tomato powder reconstituted into paste, could be a cost-effective value addition to the shelf-stable tomato powder for domestic use and particularly, for use by small scale food vendors.

1.2 Problem statement

There is a dearth of information on the quality characteristics and formulation protocol for reconstituting tomato powder into paste.

1.3 Justification

Reconstituting tomato powder into paste is an effective way to explore alternate food uses of the powder and enhance patronage. Such utilisation if promoted, could ultimately contribute to the reduction of post-harvest losses of the crop and importation of tomato paste.

1.4 Objective

To determine the formulation protocol (water-powder-binder ratio) and assess the quality characteristics of paste from reconstituted tomato powder.

Specific Objectives

1. To determine the water-powder-binder ratio for reconstituting tomato powder into paste.
2. To determine the proximate content and physicochemical properties (soluble solid, Brix, pH, colour and titratable acidity) of the formulated paste.
3. To assess the consumer acceptability of the formulated paste.

CHAPTER TWO

2.0 Literature Review

2.1 Introduction

This chapter reviews literature that relates to the topic "physicochemical and sensory properties of reconstituted tomato powder into paste. The chapter seeks to capture some key concepts underpinning the research topic as well as empirical studies that have been undertaken by other researchers which relates to the topic under study.

2.2 Brief description of Tomato

Tomato which is scientifically known as *Solanum lycopersicum* is a vegetal crop grown globally. It belongs to the *Solanaceae* family together with potato, tobacco, pepper and eggplant (aubergine) (Van Dam *et al*., 2005). Regarding areas where vegetables are produced on a large scale, tomato is cultivated mainly in the tropical, sub-tropical and temperate climate. Globally, tomato is ranked as the third most produced vegetable fruit (FAO, 2009). In Ghana among the few most common vegetables grown in the country which include onion, okra and eggplant, tomato is the most popularly grown vegetable. Tomato is a common fruit that is largely produced in Ghana for its functional purposes. Tomatoes being a seasonal crop grown in the country are usually cheap during the glut season. During the glut season, consumers are left with lot of tomatoes in the market to make choice out of, hence the cheap pricing of the produce. Because of its high moisture content, the shelf-life of tomato is shortened due to microbial deteriorate. Fully ripened fresh tomato fruit deteriorate faster when left on the market for longer periods or when left under ambient conditions (Purseglove *et al*., 2001). Hence forcing farmers to sell their produce at a cheaper price in the attempt to reduce tomato wastage. Lack of infrastructural facilities for preservation is among the factors contributing to the low pricing and post-harvest loss of this lycopene rich produce (Arah *et al*., 2015)

Ghanaians derive their main source of lycopene from diets rich in tomato (Owureku-Asare *et al*., 2017). The common usage of tomato in meals has called for the processing of this produce into more shelf stable products. Fresh tomato fruit is packed with minerals (phosphorus and iron), vitamins such as B and C vitamins, essential amino acids, dietary fibres, sugars and antioxidants hence making tomato crop healthy food in improving the health of its consumers (Jones, 2007).

The listed nutrients are beneficial for the human body where they help in body building, erythrocyte formation and as antioxidants (Jones, 2007). Fresh tomatoes are used for vegetable salads, and other dishes rich in tomato such as meat or fish dishes where it contributes to the sweetness of the dish (Zahedi and Ansari, 2012). The bright red colour of the fruit contributes to the appearance and attractiveness of dishes made from them. Sauces, soup and meat or fish dishes are examples of foods made with fresh tomato.

This red pigment contributes to the deep-red colour of fully ripe tomato and food products processed from tomato. Hence, tomatoes are a rich source of lycopene. Tomatoes and food products processes from tomato are the major source of antioxidants (lycopene). Lycopene which is an antioxidant contribute to the reduction and protection against certain chronic disease such as cancer (Naika *et al.,* 2005).

Tomato products are the primary contributors of carotenoids to animal and human. Due to the inability of humans and animals to make their own lycopene, it must therefore be provided from their diet (Rao and Rao, 2007).

Tomato fruits are also processed into tomato powder, tomato juice or tomato concentrates, among these processed products, are tomato paste, tomato purée etc (Gupta *et al.*, 2011).

Tomato concentrates serve as food ingredient in other food products such as ketchup, soups and sauce.

2.2.1 Tomato processing

Tomato fruit has lot of qualities and contributes significantly to human health when consumed, but cultivation of the crop has few challenges mainly due to its inability to tolerate certain climatic conditions (Ullah, 2009). Even though it is a popularly grown vegetable, it suffers huge post-harvest challenges because of its climacteric nature as well as high moisture content making it susceptible to microbial deterioration and reducing its shelf-life (Mertz *et al*., 2001). Fully ripened fresh tomato fruit deteriorate faster when left on the market for longer periods or when left under ambient conditions (Purseglove *et al*., 2001). Hence forcing farmers to sell their produce at a cheaper price in the attempt to reduce tomato wastage. Lack of infrastructural facilities for preservation is among the factors contributing to the low pricing and post-harvest loss of this lycopene rich produce (Arah *et al*., 2015). This leads to tomato producers receiving unsatisfactory rewards from their produce in comparison to the resources invested.

However, tomato fruits can be processed into more convenient and shelf stable food products such as tomato powder, tomato juice, tomato concentrates, tomato paste and tomato purée as a means of preservation and ensuring availability (Fieldhouse, 2013; Gupta *et al*., 2011). Tomato concentrates serve as one of the base ingredients in other food products such as ketchup, soups and sauce. The quality characteristics of fresh tomato such as its bright red colour, texture and aroma influence tomato paste acceptance when processed into tomato concentrates. Canned and dried tomatoes are economically important processed products since they have longer shelf life as compared to fresh tomatoes.

Tomato processed into tomato powder are currently underutilised in Ghana. They are mainly used as additives instead of base ingredient in meal preparation. Tomato powder can be used as an ingredient in preparing products such as, spices, sauces, soup and instant noodles. As a food colour, tomato powder can also be used as a natural food colouring agent in making pasta and flour mixes such as bleached flour and enriched flour (Cumarasamy *et al*., 2002). Tomato powder when added to food products improves not only the colour but also flavour and nutritive value of the product partly due to its high levels of lycopene (Monteiro, 2013).

Tomato fruits are also processed into products such as concentrates, paste and powder among others, hence as a means of preservation and promoting the crop cultivation and increasing its availability all year round (Fieldhouse, 2013). Drying is one of the major ways of preserving tomato fruit. It is also an efficient and cheap way of extending the shelf life of the fruit and making the produce available all year round to satisfy consumers.

Most developed countries process fresh tomato into tomato paste, puree, and ketchup, thus a convenient food for export and preservation purpose (Siddique *et al.*, 2000). Unfortunately developing countries like Ghana lack processing structures resulting in postharvest losses. The use of tomato powder in pizza topping snacks and other savoury dishes all over the world has increased tomato powder production. Mostly in less developed countries like Ghana, tomatoes are preserved using economical methods such as solar and sun dryers (Anthon *et al*., 2008). Where the crop is exposed directly to the sun, the high temperatures evaporate moisture from the tomato hence reducing its moisture content, lowering deterioration rate of the tomato and finally extending its shelf life.

There are different drying methods used in preparing tomato powder where the nutritive value of the product is still maintained (Roy *et al*., 2006). Few of these drying methods are the sun drying and solar drying methods. Sun drying is quicker traditional method of drying. Sun drying even though is economical and less stressful as compared to solar drying, sun drying is faced with many challenges which reduces the potential of the products from this drying method to meet market standards.

Few of these short comings are: the produce being contaminated by disease, infected by insects, dusts and disturbed by rainfall. All these mentioned factors lead to the reduction of the quality of the product making it lose it market value. To control or reduce these risks factors, the produce can be covered with muslin cloth or net to prevent insect and dust contamination.

During drying the moisture level of the fruit is reduced to levels that limits the growth of hydrophilic microorganisms. Surface colour changes in dried products such as tomato powder can be attributed to the drying process used. During drying of tomato fruit, the red bright colour of the fruit derived from the carotenoids and red pigment content could have some colour changes as a result of heating and oxidation reaction. High drying temperature and longer drying time speeds up discolouration of the product surface as much as the product pigment keeps reducing (Aziah and Komathi, 2009). This discolouration could be the cause of oxidation reaction of reducing sugar in the produce, in the presence of oxygen while exposed to atmosphere air.

The particle size and solubility of tomato powder among other properties are necessary for controlling the quality of tomato paste (Dirim and Caliskan, 2012). In that, particle size of the powder influences the smoothness of the final paste while its ability to soak well in water or absorb moisture also contributes to the thickness and bulkiness of the paste. The shelf life of dried tomato products is affected by several environmental factors including relative humidity and temperature due to their hygroscopic nature (Satimehin and Alakali, 2009). The rate the produce loses moisture during drying can be used in determining the shelf stability of tomato products that are sensitive to moisture (Mayor *et al*., 2005). Hence, if more water is lost during drying, it is an implication of product having a longer shelf life since it does not favour the growth of water loving microorganism which speed up deterioration processes.

2.2.2 Impact of chemical pre-treatments and dehydration method and its effect on the quality of tomato powder and its end products

Pre-treatment with sulphiting agents prior to drying is practised with the aim of minimising adverse changes in colour and other essential qualities of the tomato during drying and subsequent storing of tomatoes. The methods also preserve and maintain colour and flavour (Davoodi *et al*., 2007). During drying, non-enzymatic browning occurs because of the reaction between the reducing sugar and amino compounds found in tomato leading to the production of melanoidins which are brown in colour. There is also break down of ascorbic acid, thus in the presence of oxygen, ascorbic acid breaks down to dehydroascorbic acid which is converted to brown coloured compounds via 2, 3- diketogulonic acid (Bradshaw *et al*., 2011).

The use of sulphiting agent such as metabisulphite, calcium chloride or salt due to their multiple functioning nature and how economical they are compared to other chemicals in preventing browning of fresh tomato resulting from enzyme reactions, is the most common way of reducing browning in dried tomato products (Hameed, 2014). Thus, preservation of tomato product colour, flavour etc. The presence of sulphiting agents controls pigment degradation and the quality parameters of the produce (Davoodi *et al*., 2007). Fresh tomato fruits sliced into quarter, free from tomato seeds and tomato juice are also treated with sulphur dioxide before drying (Hameed, 2014). The chemical protects the carotenoid pigment, retains the colour of the produce during drying as well as removes partial total moisture of the slice tomato before drying leading to reduction in drying time. The effect of pre-treating with potassium meta-bisulphite, thus reducing deterioration of the red pigment of tomato fruit which is a contributing factor in maintaining the natural bright red appearance of tomato products is more known during processing of the dried tomato slice or powder. This is where the colour of the finish product is being influenced by the colour of the raw material used in production (Hameed, 2014).

Drying of tomato fruit and some vegetables as a way of preserving these fruits and vegetables possess some unique challenges on the quality of their products (fruit and vegetables). The structural nature of tomato exposes the fruit to various physical and chemical damages in the process of reducing the moisture content and hence the need to employ best preservation methods that are less detrimental to the structural integrity of the tomato fruits and tomato products. The quality of dried tomato products such as tomato powder is dependent on some quality parameters, few of which include the size of the fresh tomato fruit, the temperature of air surrounding the fruit during drying, the variety of tomato used, the drying system employed, among others. Low humidity around the produce allows rapid drying due to faster loss of moisture from the produce (Goul and Adamopoulos, 2005).

A tomato variety with high moisture content takes a longer time to dry under same temperature than one with less water content. Drying rate and drying temperature affect the quality of the finally dehydrated tomato product. (Aziah and Komathi, 2009).

Blanching of tomato with calcium chloride or potassium metabisulphite (pre-treatment technique) before drying helps to reduce the loss of lycopene, colour and other quality parameters of tomato powder when using solar drying and tunnel dryer as compared to spray drying for dehydration of the fruit (Goula and Adamopoulos, 2005).

2.2.3 Solar drying of tomato

One of several efficient methods of drying tomato is the use of solar. Different foods have been dried using solar drying technique. Sola drying, even though a promising technology - less expensive, efficient and proven to be one of the promising drying techniques for fresh tomato dehydration, it is rarely used for drying tomato. Dehydrating using electric (convection) ovens seems to be more practised as compare to other drying methods. Due to the high moisture content of the tomatoes crop, drying using electric oven does not make this drying method cost efficient but rather expensive; considering the high moisture content of fresh tomatoes and the associated energy costs, the use of electric oven for drying would be cost-intensive. In developing countries such as Ghana, which are battling with energy supply, drying using a solar dryer is one of the best way to reduce the cost of operation when drying tomato to save_resources (Belessiotis and Delyannis, 2011; Ekechukwu and Norton, 1997).

A common and suitable solar dryer for tropical communities is the passive solar dryer which operates independent of electrical energy (Belessiotis and Delyannis, 2011). They are simple to operate, very economical as well as efficient in terms of work output. To increase the efficiency of the passive solar dryer, it only needs to optimize the dryer_design to increase insulation, airflow and drying speed for the product (Sivakumar and Rajesh, 2016; Anupam, 2016).

During solar drying, heat is transferred into the product via heating component more so during the drying process, moisture migrate from the centre of the tomato fruit to the surface where it is evaporated. Solar energy is the source of heat for drying using solar dryer. The heating process involves preheated air passing through the product directly or indirectly or a combination of the two which exposes the product to solar radiation.

Through convection and conduction processes, heat is transferred to the product containing moisture from the surrounding air mass at a temperature above the temperature of the tomato product by means of radiation. Thus, from the sun and the surrounding hot surface or heated surface in contact with the product through conduction to some extend serves as the main requirement (Gbaha, 2007). Air mass surrounding the produce during the drying process is to remove moisture from the product to an acceptable level.

As the tomato product absorbs heat, it provides energy needed for the water in the product to vaporise from the product resulting in drying. The energy absorbed by the produce keeps increasing in temperature to levels enough for the water pressure of the product moisture to exceed the vapour pressure of the surrounding air (Gbaha, 2007). At this point vaporization of water from the moist product surface continues till drying is completely achieved.

The dried product of tomato has a dark, red and leathery piece with a very strong tomato flavour aroma which is rich in lycopene. Dried tomatoes can be kept for future use or ground into tomato powder and stored over months. This shelf stable product from drying has very little use in cooking especially in Ghana even though it can be used in cooking meals that are tomato based (pizza topping). Solar dried tomato is more nutritious in terms of lycopene content, ash content and ascorbic acid retention as compared to oven dried tomato (Mongi, 2013). Lycopene is very sensitive to excessive heat and light. However, its content is better retained when a solar drier is used in drying as when compared to similar drying methods (Martínez-Hernández *et al*., 2016). The drying of tomato causes damage owing to heat produced from oxidation of the product, shown by both a loss of ascorbic acid and an increase in 5-hydroxymethyl-2-furfural (HMF) content. As a result, undesirable changes with respect to colour and appearance occur in dried tomato (Arslan and Özcan, 2011).

2.2.4 Roma tomato cultivar

Roma tomatoes (plum tomatoes), has an oval- plum shaped which are normally medium in sized. The Roma tomato is a kind of tomato which is meaty in nature. The varieties of these tomato commonly available are the yellow and red types which also has a shape like that of an egg-or pear-shaped tomato. The acid content of most roma tomatoes is low and they are also less juicy with higher flavour concentration as compared to other varieties of tomatoes.

This unique characteristic makes the roma tomato more suitable for sauce, paste and stew preparation. Roma tomatoes have relatively lower moisture content making it more suitable for drying. (Maedeh, 2011). Due to the less seeds content of roma tomato, the roma tomato is equally considered an appropriate tomato variety for canning and preparation of sauce. The Roma cannot be considered as heirloom tomato. Other common name for the roma tomato are the Italian tomatoes and Italian plum tomatoes. Generally, Roma tomato has a thicker fruit wall with less seeds making it more suitable variety for processing into tomato paste or tomato concentrates. However, in salads and sandwiches making, roma tomato is most appropriate and can be slice and eaten raw due to it thick fruit wall and less moisture content. These fresh roma tomatoes gives a refreshing and very appetizing feeling to products made from them. They are very good source of antioxidant such as vitamin C. Most tomato products are made from Tomato pulps are commonly use as the base ingredient for most tomato products.

2.2.5 Brief description of tomato paste

Tomato paste is a processed product. Fresh tomato is usually consumed in many institutions, households and restaurants. Tomato concentrates, typically tomato paste, is a concentrated tomato juice produced from tomato which does not contain the tomato skin and seeds but rather contains more of the natural tomato soluble solids (NTSS). Unfortunately, most of the flavanols in tomatoes are known to be present in the skin (chief source of lycopene) and water-soluble fraction of the pulp disposed of during processing of tomato paste (Stewart *et al*., 2000; George *et al*., 2004). Tomato puree is a lower concentration of tomato paste made up of less than 24 % (NTSS). Tomato serum is a tomato juice filtered to remove all available solid material. Tomato syrup is a form of concentrated tomato serum. Tomato pulp is a suspended material in tomato juice, puree or paste which can be separated. Tomato concentrates are a good source of lycopene, vitamin C, polyphenols and small quantities of vitamin E (Charanjeet *et al*., 2004).

2.2.6 Brief history on tomato paste processing in Ghana

Three state run enterprises which were built by a Yugoslavian company took over the food processing industry in Ghana in the year 1967. These enterprises were constructed and opened as part of president Nkrumah's developmental plan to transform Ghana (Ablorh-Odjidia, 2003). These enterprises included; The Pwalugu Tomato Factory at Pwalugu in the Upper East Region, The Ghana Industrial Holding Corporation Cannery at Nsawam in Eastern region, and The GIHOC Tomato Cannery (TOMACAN) at Wenchi in the Brong Ahafo Region. By late 1980, structural reforms which were pioneered by both The World Bank and The International Monetary Fund saw to the collapse and closure of the enterprises due to the unavailability of spare parts, competent technicians, financial and marketing experts at the time. There's been efforts to reopen these factories to process tomatoes domestically after they collapsed, but they've all been characterized by multiple failures.

Three state-run enterprises dominated the food processing industry in Ghana; all built by a Yugoslavian company in 1967 and set up as part of President Nkrumah led government's overall development plan for Ghana (Ablorh-Odjidia, 2003). These were the Ghana Industrial Holding Corporation Cannery at Nsawam (Eastern Region), Pwalugu Tomato Factory at Pwalugu (Upper East region), and the GIHOC Tomato Cannery - TOMACAN of Wenchi (Brong Ahafo region). By the late 1980s, a combination of structural reforms, promoted by the World Bank and International Monetary Fund, frequent breakdowns resulting from a lack of spare parts and obsolete machinery, lack of technical competence and financial management, and poor marketing, resulted in the closure of these three factories. The following two decades can be characterized by multiple failed efforts to reopen the factories to process domestically grown tomatoes.

2.2.7 Tomato paste processing mechanism

Tomato paste is a concentrated tomato juice or pulp without seeds and skin, containing not less than 25 % tomato solids. Tomato ketchup is a thick paste-like product of tomato and tastes like sauce. Tomato concentrate and ketchup are potable foods used in hotels, restaurants and homes. Tomato ketchup has a delicious taste, flavour and a bright red colour. It is liked by all persons and is used widely with other eatables to give very good taste and flavour. It has very good domestic use, highly demanded in hotels and restaurants for preparation different dishes to serve the customers (Bower, 2007). This makes tomato paste and ketchup production a very good business venture that can be considered by entrepreneurs.

Fully matured fresh tomato, free from insect attack and mould infections are harvested and transported to the plant where it is cleaned by washing in water. Tomatoes infected with mould and other defects lead to quick deterioration and loss in quality of products developed from them. Initial microbes present in the raw material are transferred to the finished product hence leading to poor quality finished products. The washing is done using a specially designed machine responsible for washing the fruit to allow preservation of the fresh natural qualities of the fully ripe tomato (Vercet *et al*., 2002). Washed tomatoes are crushed into tomato pulp, which is strained and filtered. After preheating, a heat exchanger plant is used to concentrate the tomato pulp to a volume of about one-third of the initial. Concentration is then achieved in a very short time. Immediate concentration is necessary to reduce oxidation reaction which will otherwise give the product an undesirable dark- reddish colour, as contrasted with the colour of naturally grown tomato fruit. The tomato pulp concentrate is then homogenized and thereafter, spices and flavouring ingredients such as sugar, salt and vinegar are added to give it the characteristic sensory appeal associated with tomato sauce and tomato paste. The final products are then packaged (either bottled or canned) and later packed for storage or transportation.

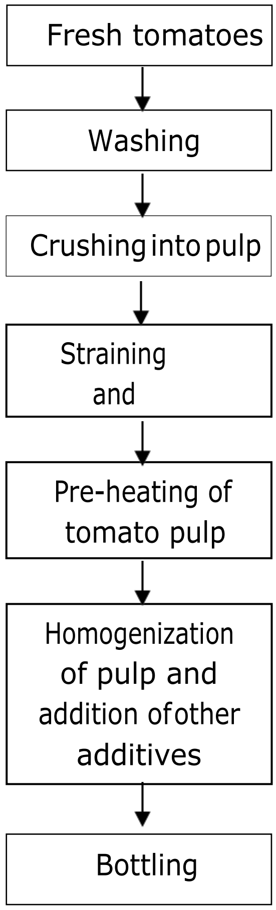

Figure.2.1: A flow chart of tomato paste processing

2.2.8 Effect of processing on tomato concentration

During the process of concentrating tomato paste, series of steps are involved. One of these steps is heat application which is a key stage in the process. Heating leads to the reduction of the moisture content to the recommended level of about 20-24 % (Thakur *et al.,* 1996). This regulates and reduces the load of heat labile pathogenic and spoilage microbes. There is the possibility for non-enzymatic browning to occur during concentration through heating (Vercet *et al*., 2002). This is due to the presence of non-reducing sugar present in the tomato fruit reacting with oxygen when exposed to the atmosphere. Research shows that the earliest stage of degradation of lycopene in tomato fruit and tomato powder is reversible isomerization of all-trans lycopene to less coloured, more oxidizable cis-isomers (Lavelli *et* *al*., 2013). Autoxidation of all-trans lycopene and the cis-isomers occurred parallel to trans-cis isomerization causing a division of the lycopene molecule into smaller pieces,_such as volatile aldehydes and ketones developing hay or grassy off-flavours. Some studies have shown that that certain storage environment may enhance cis-trans re-isomerization and intensifying the colour of the tomato powders (Lavelli *et al*., 2013; Goula and Adamopoulos, 2005). A major characteristic of tomato paste is colour, which also is associated with lycopene content. Minimal values of colour and ˚Brix are high requirements for tomato paste.

Quality parameters such as colour, acidity, Brix, pH and consistency are critical in the processing of tomato paste. Tomato product consumers mostly consider colour as the first quality factor. Hence, an appealing profound red colour is a key quality trait for tomato products (Garcia and Barrett, 2006). Lesser Agtron E readings link to deeper red colour. Readings of 48 or smaller for Agtron relate to thoroughly coloured tomatoes (Garcia and Barrett, 2006).

However, elevated drying temperatures and extended drying times aids greater pigment losses of dried tomatoes since the red pigment is a contributing factor to final colour of product from tomato powder (Aziah and Komathi, 2009). This may result in undesirable colour changes in final product if not regulated.

Tomato, fresh or canned is primarily priced for its colour which is due to the presence of the pigment lycopene. Lycopene is a terpene, richest in the tomato fruit. Lycopene is a carotenoid made up by an acyclic symmetrical structure comprising of eleven conjugated double bonds and two unconjugated imparting red colour to the molecule (George *et al*., 2004). The amount of lycopene indicates the quality of tomato paste. Thus, the colour in addition to the soluble solids content of tomato paste are key characteristics of tomato products (Shi and Maguer, 2000; Peiris *et al*., 1998). Also, the flavour of tomato paste is directly linked to the ˚brix and titratable acidity content. Of all the factors, consistency is the most important trait component of tomato paste, sauce and ketchup, influencing the rheological properties of the finished and semi-finished products. Consistency defines the flow property of non-Newtonian fluids with suspended particles and dissolved long chain molecules (Garcia and Barrett, 2006).

2.3 Sensory evaluation of tomato paste

Sensory evaluation is a systematic discipline used to suggest, measure, analyse and explain reactions to those features of foods and materials as they are perceived by intellect of sight, smell, taste, touch and hearing according to the Sensory Evaluation Division of the Institute of Food Technology (Stone, 2012). The sensory test used for an analysis depends on the objective of the analysis. They are two types of sensory test namely objective and subjective tests. A wide spectrum of sensory features including appearance, texture, flavour and aroma are used by consumer to make procuring and consumption choices related to foods (Ruiz *et al*., 2002). The major quality parameters of tomato pastes perceived by patrons are colour, consistency and flavour. Less emphasis is laid on the nutritional and health benefits derived from consuming the processed tomato in terms of their lycopene content.

Colour is determined by non-destructive methods such as visual or physical measurements. Light either reflected from the surface of a product or conveyed through it are the basis of evaluation for the methods.

Three components necessitate the perception of colour. These components are source of light, an entity that modifies light by either reflection or transmission and the eye or brain blend of an observer (Hall, 2012). Straightforward colour charts are regularly used in the retail store, packing house or field. Analytical sensory methods of assessing colour are quicker and simpler in diverse ways than instrumental methods. They have the benefit of demanding no specialized apparatus but may be standardized using colour charts or discs. The shortcomings are that these procedures may differ considerably due to human disparities in perception and human blunder. Poor or inadequate lighting may also affect exactness (Stone, 2012).

Multivariate statistical analyses such as discriminant analysis and logistic regression can usefully be applied to study the consumer acceptability of innovative food products (Arvanitoyannis *et al*., 2008; Henshaw *et al*., 2009; Sivakumar *et al*., 2008b). Whereas the discriminant analysis aids in identifying the sensory factors which differentiate unlike types of food products. Logistic regression emphasizes the sensory and consumer factors which determine their acceptability. These data help the sales person to identify the potential consumer sectors for promoting these products.

Colourimeters or spectrophotometers may be used to instrumentally determine colour. Colourimeters give measurements that can be correlated with human eye-brain perception and give tristimulus (L, a and b) values directly (HunterLab, 1995). Colourimeters are usually desirable for repetitive quality control measurements. Spectrophotometers offer wavelength spectral analysis of the reflecting or transmitting properties of objects and commonly operated in research and development laboratories (HunterLab, 1995).

2.3.1 Tomato Colour

Tomatoes are recognised for their intense red colour which gives an indication of maturity, flavour and concentration of antioxidants. Light red or pink colour might indicate immaturity. Together with appearance, colour is the major factor that influences purchasing decisions (López Camelo & Gómez, 2004). Colour is an important consideration for both raw and processed tomatoes. For processed tomato products, ripening and processing are the main factors that affect colour. The USDA Processed Products Standards & Quality Certification Programme dedicates 30 points out of 100 to colour (Frances, 2004).

Unripe tomato is green in colour due to the presence of chlorophyll. During maturation, however, chlorophyll degrades, and carotenoids are synthesised. The carotenoids include yellow, orange and red pigments such as β-carotene, lycopene and xanthophylls (Su *et al*., 2015). The red colour of tomato is because of the accumulation of carotenes namely lycopene (90 %) and β-carotene (10 %) after carotenoid composition is shifted from xanthophylls (mainly lutein and neoxanthin). Concentrations of lycopene from standard varieties varies between 7.8 to 18.1 mg 100 g^{-1} fresh weight. The lycopene/β-carotene ratio accounts for the varying colourisation in tomato varieties (Duma *et al*., 2015).

It is believed that the ripe red tomato has the highest concentration of carotenoids. Carotenoids in tomato have been investigated for their antioxidant properties. High carotenoid intakes have been associated with a lower risk of prostate and lung cancers, slow ovarian tumor growth and intraperitoneal metastatic load, inhibit cell production, attack of human head and neck squamous cell carcinoma, treat oral diseases such as leukoplakia, oral submucous fibrosis, lichen planus and oral squamous cell carcinoma (Gupta *et al*., 2015; Holzapfel *et al*., 2017; Ye *et al*., 2016; Story *et al*., 2010). Research shows that decreased serum lycopene concentration predicts poor outcomes of cardiovascular disease (Petyaev, 2016).

Before 1976, tomato was visually inspected before processing. Maxwell's spinning disc was the first device to be used to semi-quantitively measure the colour of a tomato. Agtron E-5M was used to determine the colour of homogenized samples. D25 A™ was viewed as the gold standard by the United States Agriculture Department in the 1970s. Tomato paste, sauce, ketchup and juice colour have been measured with illuminant D 65, 10^{o} Observer with either XYZ (Hunter) or CIELAB (BYK Gardner). Spectrophotometry and High-Performance Liquid Chromatography are used to measure lycopene (Barrett & Anthon, 2008).

2.3.2 Aroma / flavour of tomato concentrate

Tomato has several factors contributing to its flavour such as taste and aroma sensations. The taste of food products is made up of five primary components which are sour, salty, sweet, bitter and umami. Instruments can be used to measure these fundamental taste components. Sweetness can be assessed by HPLC determination of individual sugars or more quickly but less accurate by a refractometer or hydrometer that assess total soluble solids (Barrett *et al*., 2010). Sour, salty, sweet, bitter and umami are detected by the tongue whereas volatiles are detected by the olfactory nerve endings of the nose (Reed and Knaapila, 2010). Major components impacting tomato paste are sugars, organic acids, free amino acids and salts. The sugar and organic acid contents also contribute to the sweet-sour taste which is transferred to its processed products. The characteristic sweet-sour taste of tomato is due to a combination of the sugars and organic acids present. About 50 % of the dry matter is composed of sugars, primarily the reducing sugars glucose and fructose. Hence a sweet-sour taste could be experienced in a product provided enough sugar and organic acid combinations are present in the raw material used for processing and vice visa (Arvanitoyannis *et al*., 2010). Tomato farmers devote a significant amount of effort to making tomato lines with high ˚brix levels. Whereas some wild tomato records attain very elevated (11–15 %) concentrations of ˚brix (Garcia and Barrett, 2006). Widespread tomato cultivars suitable for processing show moderate ˚brix contents varying between 4.5 and 6.25 % (Bui *et al*., 2010). Seasonal variation along with horticultural practices may affect tomato ˚brix content (Arvanitoyannis *et al*., 2010). This sugar levels in the final product of tomato influences it taste and hence consumer acceptance of the product. Thus, the higher the brix level the sweater the paste and the lower brix level the sourer the paste.

Tomato paste aroma is attributed to the amount of complex volatile compounds (Furaneol) found in tomato fruit (Baldwin *et al*., 2008). The amount of this volatile compound varies in tomato cultivars and contributes to the overall sensory quality of tomato concentrate (Garcia and Barrett, 2006). The unacceptable aroma of tomato concentrate perceived by consumers can be attributed to insufficient aromatic compound present in raw material used for processing aside other known factors such as the processing methods and the type of cultivar ref.

Flavour characteristics of tomatoes are important purchasing criteria. One of the key factors that influences consumer's behaviour toward the purchase or choice of tomato concentrate is the aroma of the product (Krumbein *et al*., 2004). However, most tomato paste processed commercially do not meet these desired aromas for its consumers (Batu, 2004; Krumbein *et al*.; 2004; Serrano-Megías and López-Nicolás, 2006). This is because of poor harvesting, where mature-green stage tomatoes are harvested with the view of extending its life span (Sammi and Masud, 2007). Cultivation of tomato with sufficient volatile compounds responsible for contributing to the flavour and aroma of processed tomato products has gained little attention since tomato produce with firm texture and large size are of more interest (Forney *et al*., 2009).

2.3.2 Texture/ consistency of tomato paste

Information on rheological properties of fluid foods are useful for engineering application, equipment design (agitator heat exchanger, evaporator), designing of transport system, determining pump capacity and power needed for mixing (Rao and Anantheswaran, 1982; Dodeja *et al*., 1990; Leong and Yeow, 2002). One important technological factor related to the content of substances insoluble in alcohol, protein, fat, total solids, pectin and polysaccharides is viscosity (Cámara-Hurtado *et al*., 2002; Anthon *et al*., 2008; Sobowale *et al*., 2011). The viscosity of tomato paste involves the combination of soluble and insoluble materials in suspensions, which depends on the fibre, fat, protein, and total solids content

(Sobowale *et al.*, 2011). This contributes to the overall consistency of the tomato paste (Hawbecker, 1995; Tiziani and Vodovotz, 2005).

Rheological properties of fruit concentrate appear to be very much dependent on their varieties, method of juice extraction (cold-break or hotbreak), concentration of juice/ pulp, climatic and seasonal variation.

2.4. Chemical composition of tomato paste

2.4.1 pH/Titratable Acidity

The pH and the titratable acidity (TA) of tomatoes serves as factors which influence the quality of tomato concentrates. These two are key factors when processing tomato. Foods with low acid (pH > 4.6) may encourage the growth of certain spoilage microorganisms unlike tomato which requires less thermal treatment to ensure its safety. It has been suggested that pH 4.4 is the maximum desirable pH for safety and the optimum target pH should be 4.25 for tomato concentrates (Anthon *et al.*, 2011). In California, commercial processors of tomato concentrate specify a pH of 4.2 or 4.3 in their processed products. The pH of tomatoes is determined primarily by the acid content of the fruit. Acidity of the fruit also contributes to the flavour of the tomato product. Among the acids present in tomato, the most abundant acid is citric acid ref. The titratable acidity (TA) of tomato concentrates are influenced largely by the citric acid level in the raw material used. As the citric acid content increases in the tomatoes, the TA level of the tomatoes paste also increases accordingly (Paulson and Stevens, 1974). The acid level of the fruit starts to decrease as the fruit matures and this continue reducing as the fruit ripens gaining its sweet taste. Two other acids that contribute significantly to the TA are malic and glutamic acid. Malic acid is typically present at only one tenth the level of citric acid, although the ratio of malic to citric can vary considerably between different tomato cultivars (Baldwin *et al.*, 2008). Glutamic acid levels have been shown to increase 10-fold as the fruit ripens from the green to the red stage (Neily *et al.*, 2011). Glutamic acid is also an important contributor to tomato flavour. Higher Soluble solids levels in tomatoes is attributed to the ripening and maturity stage of the tomato fruit. (Gautier *et al*., 2008).

Table 2.1. Required standard for tomato paste as at May 2011 by Wfp.org. and CODEX STAN 57-1981.

pH	Concentration (Brix)	Colour (at 12 Brix)	Consistency by Bostwick	Acidity	Sugar (at dry matter)	Colour
4.6 maximum	4-11 cm/30s	2 minimum Gardener	4-11 cm/30s	7 % maximum	42 % minimum	Fairly Red colour

CODEX STAN 57-1981 Standard for processed tomato concentrate

Table 2.2: Proximate Composition (%) of some selected tomato paste in Asia market 2016

N	C1	C2	C3	C4
Moisture	72.00 ± 1.30^{a}	71.80 ± 2.8^{b}	72.40 ± 0.15^{c}	93.80 ± 3.00^{abc}
Crude protein	4.20 ± 0.49^{dg}	4.16 ± 0.78^{eh}	4.83 ± 0.42^{fgh}	1.00 ± 0.49^{def}
Crude fibre	6.16 ± 0.99^{i}	5.64 ± 0.57^{i}	4.97 ± 0.21^{k}	1.21 ± 0.99^{ijk}
Crude Ash	3.83 ± 0.00^{r}	3.20 ± 0.01^{s}	2.48 ± 0.04^{t}	0.85 ± 0.01^{rst}

Values are Mean + standard deviation. (Abdullahi et al., 2016), Where n=number of samples used, C4 is fresh tomatoes. Values in the same row with different superscripts differ significantly.

2.5 Cassava starch

There are several advantages of cassava starch over corn starch and a key advantage is the absence of undesirable cereal flavour which makes cassava starch most preferred in many food applications. Cassava starch when cooked in aqueous dispersion, produces high clarity and high viscosity pastes with low gelatinization temperature and high resistance to retrograde as compared to using cereal starches (Che *et al*., 2007). In processing sausage and many ham-like products, cassava starch is mostly preferred, a common country that mostly uses cassava starch in the production of such foods (ham and sausage) is Brazil. High usage of cassava starch in most food products is attributed to the product’s (cassava starch) low retrogradative nature helping in maintaining the quality of the product such as tomato paste. The temperature at which cassava starch gelatinizes and its obvious viscosity are relatively higher than that of corn starch at equal concentrations, which denotes a merit for some applications. Cassava starch paste has a lower probability to retrograde and this is in most cases, a desirable characteristic. Even though cassava starch has numerous merits compared to corn starch, it also has limitations in its usage such as instability to acidity and cooking, just like other natural starches (Takizawa et al., 2004). The significance of starches that are chemically modified may be gathered as the cross-link that are formed by reaction with reactants that are bi-functional, also known as thick-boiling starches. The replaced or stabilized starches made by the derivatization of hydroxyl groups and the transformed starches (altered by oxidative treatments or acid) are known as thin-boiling starches. Granules of starch become more resistant to processing conditions like high shear, low pH and high temperatures and show higher viscosity when cooked, in comparison to natural starch granules – in terms of cross-linkage. In contrast, the substituted or derivatized starches were mainly innovated to present constancy to cold storage. The implication is that there is a small tendency for retrogradation and syneresis to occur. A lot of substituted starches show properties that are good for emulsification with interfacial activity (Bemiller, 2009). These starches may be presented to the food market in the form of granules or after they are pre-gelatinized.

2.6. Proximate analysis

The variation in nutrient content is important because of the effects it can have in meeting nutritional requirements. It is therefore important to analyse the composition of new products for comparison with already existing products (Huyghebaert, 2005). The various components of food are determined by proximate analysis which outlines major components (moisture, ash, carbohydrate, fats and protein) of food (Pomeranz, 2000).

The most fundamental and important procedures that can be performed on the food product is the assay for moisture. The dry matter that remains after moisture removal is commonly referred to as total solids. The stability and preservation of some food products is dependent on moisture content. Computation of the nutritional value of foods require that you know the moisture content. The ease of the water removal from foods depends on how it exists in the food product (Bradley, 2010). This is because water exists in food in three forms known as free water (water that can be extracted easily from food by squeezing or cutting or pressing), adsorbed water (water held tightly to the proteins and in cell walls or protoplasm) and water of hydration (this water is bound chemically) (James, 2013; Vaclavik and Christian, 2008). The oven drying method is one of the commonest ways of determining moisture content of food. In this method, the sample is heated under specified conditions, and the loss of weight is used to calculate the moisture content of the sample. The amount of moisture determined is highly dependent on the type of oven used, conditions within the oven, the time and temperature of drying (James, 2013).

Crude ash refers to any inorganic residues remaining after either ignition (dry ashing) or complete oxidation (wet ashing) of organic matter in a foodstuff ref. Dry ashing refers to incineration at high temperature (525°C and above) using a muffle furnace ref. Ash content represents the total mineral content in foods. The crude ash content of food materials can include both essential minerals (potassium and calcium) and toxic minerals like mercury. The ash constituents include potassium, sodium, calcium and magnesium in large amount, whereas minerals like aluminium, arsenic, copper, iron, manganese, zinc, fluorine, iodine, among others, are in trace amounts. Ash content analysis is a key aspect of proximate analysis, for the assessment of nutritional content of food materials (James, 2013). Ashing is the initial process carried out for the preparation of food samples prior to a particular elemental analysis. Usually, the content of an element from ashed sample of animal food sources are constant, but that from plant source is variable (James, 2013).

Lipid is a major class of food class that are normally soluble in organic solvents and but not completely miscible with water. 'Lipids', 'oils' and 'fats' are word expressions that are interchangeably used. In general terms, fats are lipids which when at room temperature exist in the solid state whiles oils are liquid at room temperature. Precise qualitative and quantitative analysis of crude fat is vital for proper labelling of the nutritional profile of food products. Crude fat analysis is also needful for food regulation authorities and manufacturing companies to know if the food product meets the set standard or production specifications. In the determination of the total crude fat content of food samples, the following methods are used: acid or alkaline hydrolysis and organic solvent extraction. According to James (2003), "Gas chromatography is usually used in the determination of total fat content for the sake of nutritional labelling.

Vaclavik and Chriatian (2008) assert that proteins are the utmost abundant biomolecules in cells, with a percentage constituent of 50 or more, in dry basis. Except storage proteins, almost all proteins are essential for the function of biological systems and the structure of cells. Analysis of the protein content of developed food products is very necessary not only for nutritional content labelling but also for the study of the functional property, pricing, and determination of biological activity (Chang and Zhang, 2017). Crude proteins are also used in calculating the amount of carbohydrate in food.

Crude fibre denotes indigestible constituents of carbohydrate from plant sources. This notwithstanding, they are useful in human nutrition. Crude fibre is somewhat used to distinguish between the various types of fibre. Importantly, the total amount of the non-digestible food constituents are classified as dietary fibre. Usually, the determination of the dietary fibre content of foods stuffs or products is required for making claims about food labels. The measurement of the quantity of insoluble fibre in a food sample is vital for calculating the number of calories possessed. Sufficient intake of dietary fibre from various foods aids in the protection of the body against colon cancer, as well as keeping the lipids in the blood within their normal range. Consequently, this reduces the risk of several diet-related diseases such as obesity, high blood pressure and heart diseases in general (Nielsen and Chuang, 2010).

Carbohydrates form a major class of food nutrients which are essential energy sources and have some useful functional properties in food systems (Vaclavik and Christian, 2008). The total content of carbohydrates in a food material is usually done by subtracting the total percentage of crude protein, moisture, total fat and crude ash from 100 (Nielsen and Chuang, 2010).

2.7 Factors influencing tomato paste purchase and consumption

The consumption and purchase of tomato paste is greatly influenced by factors such as consumer knowledge on the health benefits of tomato product like preventing chronic disease, consumption, the increasing consumption of food outside the home the abundance of Mexican and Italian meal which are mostly tomato based and the increasing availability of different varieties of tomato products in the marketplace (Hongsoongnern and Chambers, 2008; Lee *et al*., 2000; Lucier, 2003).

2.8 Health benefits of processed tomato

Lycopene is a carotenoid mainly found in tomatoes hence make up about 83% out of the total red pigments present in tomato (Gould, 2013). Although lycopene is present in several fruits and vegetables, its main dietary sources (about 90 %) are the tomatoes and tomato products (Arab and Steck, 2000; Rao *et al*., 1998). The extensive use of tomato paste nationwide makes lycopene an important natural plant pigment since humans and animals lack the ability to synthesize it. Tomato fruits with deep red colour contains high concentrations of lycopene, and serves weight reducing purpose when used in meal (Bielig and Werner, 1986).

Tomato products contribute greatly to the carotenoids contents in human diet. Consumption of meal rich in lycopene has the potential of preventing cardiovascular disease and some cancers (Arab and Steck, 2000). The consumption of variety of meal such as tomato juice, tomato sauce and pizza which are rich in lycopene regularly reduces one's chances of being exposed to prostate cancer (Giovannucci *et al*., 1995). In the human system, lycopene neutralizes harmful radicals, which are implicated in cancer, heart disease, macular degeneration and other age-related illnesses. Also, canned tomato and ketchup contain more lycopene than fresh tomato because cooking at high temperature breaks down cell walls leading to increased availability of lycopene (Nguyen and Schwartz, 1998).

CHAPTER THREE

3.0 Materials and Methods

3.1 Source of materials

Freshly harvested Roma tomato was purchased from Wa market in the Upper West region of Ghana on the 6th of June 2017 and transported to KNUST sensory laboratory. Cassava was bought from Kumasi central market.

3.2 Preparation of tomato powder

The method described by Owureku *et al*. (2017) was followed with slight modification.

3.2.1 Cleaning of working surfaces and equipment

Working surfaces were washed with water and soap and further cleaned with 1 % (w/v) sodium metabisulphate prior to use.

3.2.2 Sorting

Fully ripe and firm tomato free from bruises were hand-selected for further use.

3.2.3 Washing and pre-treatment

The tomatoes were thoroughly washed in three (3) changes of potable water. The washed and cleaned tomatoes were weighed and transferred into a 1 % (w/v) sodium metabisulphate solution for 30 min. This treatment was done to preserve the colour of the tomato slices and also prevent infection by microorganisms while drying.

3.2.4 Preparation of tomato slices/ pre-treatment prior to dehydration process

Each tomato was cut into half, deseeded and the flesh sliced into thickness of 8mm using a stainless-steel knife. The tomato slices were then dipped in 1 % sodium metabisulphite for 10 min to reduce undesirable discolouration and contamination.

3.2.5 Drying of tomato slices

Aluminium trays were washed with soap and water and disinfected with 0.1 % sodium meta-bisulphate. The drying trays were lined with disinfected plastic cling film using 0.1 % sodium meta-bisulphate for easy product recovery. The drained tomato slices were then arranged on the drying tray with 0.8 cm space in-between each slice and dried for 48 hours at a temperature range of 45-65 °C.

The dried tomatoes were milled into fine tomato powder using a dry blender (model MG-216, Preethi Aries, India, 2014) at the KNUST Food Product Development Laboratory. The powder was then sieved using a 200-micron sieve, packaged in a zip lock bag wrapped with aluminium foil and stored under freezing conditions (approximately 0 °C) for subsequent analysis.

3.3 Preparation of Starch (Binder)

The traditional method for starch preparation as followed. The cassava was peeled, washed and ground into dough using a wet blender in the KNUST Food Product Development Laboratory. The cassava dough was de-watered, and the expressed liquid obtained from the cassava dough was kept for 48 hours for the starch to sediment. The starch was then recovered by decanting the supernatant. The starch extract was further allowed to stand on the kitchen shelf for three days to remove residual water and air dried. The dried powder was then stored in a zip-lock bag in a cool dry place for further use.

3.4 Formulation protocol for reconstituted tomato powder

Trials were conducted to determine the appropriate cooking conditions and water-powder-binder ratios for reconstituting the tomato powder into paste.

Sample preparation

Tomato powder was poured into a crucible, mixed with salt and starch added in different proportions (based on trials) and then mixed with water. The mixture was thoroughly stirred for uniformity, and then heated for 7 min at a temperature of 80-85 ºC while stirring periodically. It was subsequently covered, allowed to cook for 2 min and stirred again to obtain a consistent smooth thick paste.

A ranking test (elaborated in 3.4.1) was then conducted to determine the optimal conditions (water-powder-binder ratios, temperature and heating time) for the reconstitution. A commercial canned tomato paste (small-sized Salsa tomato paste) was used as control. The respective quantities of the resultant ingredients are detailed in Table 3.1. Details of the results are presented in Appendix 1.

Table 3.1. Formulation protocol for ranking test.

Sample code	Tomato powder	Water; Salt	Binder ; Soaking time	Heating time	Cooking Temperature	Cooling
345	12.035 g	60 ml ; 1.165 g	0.084 g ; 12 m	6 m	80/85	40 m
453	12.634 g	60 ml ; 1.177 g	0.238 g ; 12 m	6 m	80/85	40 m
534	12.046 g	60 ml ; 1.126 g	0.179 g ; 12 m	6 m	80/85	40 m
435(Control)	-	- -	- -	-	-	-

N.B. sample code 435 was used as the control and was not subjected to any treatment.

Table 3.2. Final formulations for reconstituted tomato powder.

Factors	Tomato powder	Water	Salt	Binder	Soaking time	Heating time	Cooking temperature	Cooling time
With binder	12.049 g	60 ml	0.964 g	0.179 g	16 m	7 m	85	40 m
Without binder	12.049 g	60 ml	0.964 g	-	16 m	7 m	85	40 m
Control	-	-	-	-	-	-	-	-

The control was not subjected to any treatment.

3.4 Sensory analysis

The method described by Stone *et al*. (2008) was followed.

3.4.1 Ranking test

A preliminary sensory analysis (ranking test) was done at the Food Science and Technology sensory laboratory. Eleven (11) untrained panellists (6 females and 5 males) aged between 22 and 36 were asked to rank the coded tomato paste samples in terms of thickness (viscosity) and smoothness (both mouth feel and hand feel). Samples were prepared in the sensory kitchen, cooled for 50 min to the same temperature as that of the control and served. Potable water at room temperature was provided as the palate cleanser. This method was used to select the most preferred formulation to reduce the number of samples for the consumer acceptance test.

3.4.2 Affective test

In assessing the consumer acceptability of the formulated tomato pastes, a sensory analysis was done at KNUST basic school in the staff common room, individual classrooms and the school canteen between 10:30 to 4:30 p.m. A seven-point hedonic scale was used with 64 untrained panellists (females and males) who were teaching and non-teaching staff, non-smokers, aged between 25 and 35. Panellists were requested to evaluate the coded tomato samples in terms of their preference of the colour, aroma, thickness, smoothness, bitter after taste, overall likeness and willingness to use the product. The staff common room and classrooms used had satisfactory lighting from florescent tube bulbs and panellist sat far away from each other. Sample preparation was as described in section 3.4.1 above. The panellists were served with three differently coded tomato samples including the control (Table 3.2). Samples were presented in a plain disposable plastic bowl. Potable water at room temperature was provided as palate cleanser.

3.5 Proximate analysis

The protocol described by the AOAC (2000) was followed.

3.5.1 Moisture Content

Five (5) g of each sample was weighed and allowed to dry in an air oven at 105 °C for 4 hours. The Petri dish containing the sample to be analyse were removed, cooled after in a desiccator and re-weighed. Analysis was performed in duplicates and percentage moisture content was calculated as follows;

$$\% \text{ Moisture} = \frac{weight\ of\ flour\ before\ druying - weight\ of\ flour\ after\ drying}{weight\ of\ sample\ before\ drying} \times 100$$

3.5.2 Crude Ash

Exactly three (3) g of each sample was weighed into porcelain crucible and placed in furnace for 4 hours at a temperature of 550 °C. The furnace was then allowed to cool at temperature below 200 °C and maintained for 20 minutes. Ash crucible was then taken out of the furnace, placed in a desiccator to cool and weighed. Crude ash content of the formulated tomato paste was calculated using the below formula

$$\% \text{ Ash} = \frac{weight\ of\ ash}{weight\ of\ sample} \times 100$$

3.5.3 Crude Fat

An extraction flask was placed in an oven to dry for about 5 min at 110 °C, cooled and weighed. A piece of filter paper was folded into a packet to contain the sample. The sample in the second filter was wrapped around and left open at the top like a thimble. A piece of cotton wool was placed at the top to allow for even distribution of the solvent as it dropped on the sample during extraction. The sample packet was then placed in the tubes of the soxhlet extraction apparatus. Extraction was done with petroleum ether for 4 hours without interruption by gentle heating. The extraction flask was allowed to cool and dismantled. The residual ether was allowed to then evaporate in an air oven dryer. The flask containing extract was cooled and weighed. Crude fat content was calculated as follows;

$$\% \text{ Crude Fat} = \frac{weight\ of\ \ extract}{weight\ of\ sample} \times 100$$

3.5.4 Crude Fibre

Residue from the ether extract was transferred into a digestion flask and 100 ml of H_2SO_4 solution was added. The digestion flask was instantly connected to the condenser and heated. After 30 min. of heating, the flask was removed, and the mixture filtered immediately through linen and washed with distilled water to remove the acid. Residue was washed back into the flask with 100 mL of the NaOH solution and flask connected to reflux condenser and allowed to boil for exactly 30 min. The mixture was immediately filtered into the Gooch crucible. After thorough washing with distilled H_2O, the residue was again washed with about 15 ml of 95 % ethanol. Crucible with contents was dehydrated at 110 °C to a constant weight, later cooled and weighed, content of crucible was incinerated in a muffle furnace at 550 °C for 30 min until the carbonaceous matter has been consumed. The crucibles with the ash were cooled using a desiccator and finally weighed. Crude fibre content of the formulated tomato paste was calculated using the formula below;

$$\% \text{ Crude Fibre} = \frac{weight\ of\ \ dried\ sample - weight\ of\ ash}{weight\ of\ defatted\ sample} \times 100$$

3.5.5 Crude Protein

Two (2) g of the formulated tomato paste sample was weighed and transferred in a 50 mL digestion flask to which 10 mL distilled water was and one digestion to act as catalyst was added. About 20 mL of concentrated H_2SO_4 was also added. Boiling chips was added, and digestion was allowed to take place till the solution became colourless. After the digest was adequately cooled, it was diluted by means of adding a small quantity of distilled ammonia which was free from water up to 100 mL mark. The Kjeldahl flask was rinsed with distilled water and 10 mL of the digest was pipetted into a distillation flask and 90 mL of distilled water added . About 20 mL of the 40 % NaOH was then added. A conical flask which contains 10 mL of boric solution with a few drops of mixed indicator was used to collect the distillate in the form of liquid ammonia. The obtained distillate was titrated against standard 0.1 N HCl until the first appearance of pink colour, i.e. the end–point. A reagent blank was run with equal volume of distilled water and the titration volume for the blank was then subtracted from that of the sample titration volume. Crude protein content was calculated as follows;

% Crude Protein = % Nitrogen × 6.25

$$\% \text{ Nitrogen} = \frac{(Titre - Blank) \times 0.19057 \times 14.01}{weight\ of\ sample \times 10}$$

3.6 pH

The pH of the formulated tomato paste was measured using a pH meter (Seven Compact pH/ion S220, Mettler Toledo AG, Switzerland) from KNUST Food Science and Technology laboratory. The pH was calibrated using buffers of pH 9, pH 7 and pH 4. In a test tube, 0.5 g of each tomato paste sample was dissolved in 5 mL of distilled water, and the pH was later measured. The reading was recorded directly from the pH-meter.

3.7 Total soluble solids (Brix) / refractive index

The Brix was measured using a digital refractometer. Exactly 0.5 g of tomato paste was dissolved in 5 mL distilled water. The homogenised samples were picked with the aid of a dropper from the conical flask and dropped on the dried and clean prism of the refractometer. The results were directly read on the numerical part of the refractometer at a temperature of 20 °C for all samples. The refractive index was also recorded from the same refractometer at the same time.

3.8 Titratable acidity

The titratable acidity was measured by dissolving 5 g of tomato paste in 50 mL of distilled water in a 200 mL conical flask. The sample was than titrated against 0.5N NaOH solution using phenolphthalein as indicator until a pale pink end–point was observed. Titratable acidity value was then calculated using the following formula;

$$\text{Titratable acidity (\%)} = \frac{\text{titre x Normality of titrant x 64 x100}}{\text{Weight of sample x 100}}$$

3.9 Colour Measurement

Colour was measured by filling tomato paste in a petri dish and placing the petri dish in the chroma meter. The colour (redness index; a*) of the tomato paste was determined using the chroma meter (model CR-410, Konica Minolta, INC, Japan).

3.10 Statistical Analysis

Friedman test was used to discriminate the most preferred sample for the data obtained from the ranking test. The finding was used to scale down the number of sample for the final sensory analysis for a larger group. The final sensory data, proximate composition data and physicochemical data were all analysed. The means and standard deviations of each test parameter were calculated using Excel 2013. Using the Statistical Package for Social Sciences (SPSS, IBM SPSS Statistics v20), one-way analysis of variance (ANOVA) was employed to compare the means of all determined parameters. Multiple comparison of all test parameters was carried out using Tukey's test. All statistical tests were carried out at 95 % confidence level.

CHAPTER FOUR

4.0 Results and Discussion

4.1 Proximate Composition of Reconstituted Tomato Paste

The proximate composition of the reconstituted tomato powder is provided in Table 4.1.

4.1.1 Moisture Content

There was no significant difference among the moisture contents of the three tomatoes paste samples at $p < 0.05$ (Table 4.1). The moisture contents for all tomato paste samples were above 70 %, comparable to the results reported by Abdullahi *et al*. (2016). The reconstituted tomato powder pastes with no binder (NB) recorded the relatively highest moisture content (73.93 ± 0.08 %). Fresh tomato fruit has a high moisture content of 95 % and could contribute to the high moisture content of its products. Both reconstituted tomato powder pastes (with and without starch binder) had very high moisture contents compared to the tomato powder owing to the addition of water to the tomato powder in the reconstitution process and the short heating time.

Although the moisture contents of the tomato paste without starch binder (NB) and the tomato paste with starch binder (B) were statistically the same, their water activities would vary. Work done by Jenkins and Donald (1998) indicated that "Individual starch granules imbibe water and in the presence of heat, they gelatinize.'' By implication, the tomato paste with starch binder would have a lower water activity and relatively more shelf-stable than the tomato paste without a binder. Drying of tomato at high temperature leads to the destruction of the cell structure resulting in more pectin released from fruit cell wall hence reducing the water holding ability of tomato. According to Abdullahi *et al*. (2016), the presence of more pectin in fruits leads to more water binding capacity in their dried products. Nevertheless, the moisture level for the three-paste conform moisture content of commercial tomato pastes reported by Abdullahi *et al*. (2016).

Table 4.1: Proximate Composition of Reconstituted Tomato Powder

Parameter (%)	B	NB	C
Moisture Content	73.01 ± 1.47[a]	73.93 ± 0.08[a]	71.61 ± 0.73[a]
Crude Protein	0.57 ± 0.01[a]	0.58 ± 0.00[a]	0.30 ± 0.00[b]
Ash	5.07 ± 0.25[a]	4.90 ± 0.64[ab]	3.30 ± 0.07[b]
Crude Fat	0.46 ± 0.01[ab]	0.62 ± 0.02[b]	0.42± 0.06[a]
Crude Fibre	13.73 ± 1.50[ab]	17.38 ± 0.11[b]	10.94 ± 0.17[a]
Available Carbohydrate	7.11 ± 0.26[a]	2.57 ± 0.0.46[b]	13.44 ± 0.76[c]

Values are Mean ± Standard Deviation. B = Tomato Paste with Binder (cassava starch), NB= Tomato Paste with No Binder, C = Control. Values in the same row with different superscripts are significantly different p<0.05

4.1.2 Crude Ash Content

Crude ash content recorded for the three-tomato pastes ranged from 3.30 – 5.07 % (as shown in table 4.1). The tomato paste with starch (B) recorded the highest ash content (5.07 %), followed by the tomato paste without binder (NB) (4.90 %). The control sample (C) recorded the lowest ash content of (3.30 %). The ash contents of reconstituted tomato powder pastes in this study are higher than the 0.85-3.83 % reported for commercial tomato paste by Abdullahi *et al*. (2016). Statistical analysis carried out at 5 % significance level indicated significant differences among the ash contents of the three-tomato paste ($P < 0.05$).

Difference in ash content obtained could be due to geographical difference, varietal difference of tomato, different chemical composition, different maturity and different growing site of tomato cultivar under similar processing which could also influence ash content. Fertilizer that acted on the tomato fruit on the field could also influence ash content of processed tomato (Oke *et al*., 2005). Iron, potassium, B vitamins present in tomato fruit could be present in the reconstituted tomato paste since it had increased ash content. Addition of salt (sodium chloride) to the reconstituted tomato paste added up to the initial salt content because of the concentration of the fresh tomatoes hence, the increased ash content of the paste.

Processing conditions where the fresh tomatoes were solar-dried for hours, processed into powder and heated within 7 min could also contribute to the high ash content recorded for the reconstituted tomato paste. According to Kassah (1997), “Longer cooking time reduces the amount of heavy metals in food.”

4.1.3 Crude Fibre Content

The lowest fibre content was 10.94 % recorded in the control sample (C) whilst the highest fibre content being 17.38 % was recorded in reconstituted tomato paste without cassava starch (NB) (Table 4.1).

The crude fibre content of the control sample and the reconstituted tomato paste with no binder varied significantly ($p < 0.05$). However, there was no significant difference between the crude fibre contents of the two reconstituted tomato powder pastes. The tomato paste with cassava starch (B) had a relatively lower fibre content of 13.73 %. High fibre content is nutritionally beneficial since it promotes health and aids digestion of food. Hence reconstituted tomato powder with relatively high fibre contents could provide health benefits to its consumers. The low fibre content in the commercial tomato paste could be attributed to the removal of tomato skin via pulping during processing contrary to the processing protocol of the tomato powder (detailed in 3.2.4).

4.1.4 Crude Fat Content

Crude fat content (Table 4.1) was at low levels for all tomato paste samples. The crude fat values ranged from 0.42 % for the control sample to 0.62 % for the reconstituted tomato powder paste without starch binder. There was no significant difference in crude fat contents of the reconstituted tomato paste. However, there was a significant difference between crude fat content of tomato paste without binder and the commercial tomato paste (Control). The differences in the crude fat contents of the tomato pastes could be attributed to varietal difference as explained by Gupta *et al*. (2011). The low crude fat content agrees with the fact that tomato fruit is a low-fat fruit (0.19 – 0.51 %) as reported by Badejo *et al*. (2016). The low-fat content makes the tomato paste nutritionally healthy for low fat diets.

4.1.5 Crude Protein Content

Crude protein content in the three tomato paste samples ranged from 0.30 % (Control) to 0.58 % in reconstituted tomato powder paste with binder. The tomato paste without binder had comparable protein content (0.57 %) to the tomato paste without binder (NB). There was a significant difference between the crude protein of reconstituted tomato pastes (with and without binder) and the control tomato paste. The difference in crude protein contents could be attributed to varietal differences as well as differences in the processing conditions of the pastes. The low protein content observed could be attributed to the low protein content of fresh tomato fruit which has been reported as 0.31 – 0.51 % by Badejo *et al*. (2016).

4.1.6 Carbohydrate Content

The carbohydrate content for the formulated tomato pastes is presented in Table 4.1. The control tomato paste had the highest carbohydrate content and the reconstituted tomato powder without a binder had the least; 13.44 % and 2.57 %, respectively. There were significant differences observed in carbohydrate contents of the formulated tomato pastes ($p < 0.05$). The relatively high carbohydrate content (13.44 %) of the commercial tomato paste was due to its low moisture and fibre contents compared to the reconstituted tomato pastes. Addition of sweeteners such as sugars to tomato pastes by some commercial tomato paste producers could also account for its relatively higher carbohydrate content compared to reconstituted tomato paste. High fibre and moisture content in the tomato paste could have also contributed to the low carbohydrate content of the reconstituted tomato pastes. Also, the absence of binder (cassava starch) could be attributed to the low carbohydrate content in tomato paste with no binder (NB).

4.2 Physicochemical Properties of Reconstituted Tomato Powder

The results for the physicochemical properties of reconstituted tomato powder is provided in Table 4.2.

4.2.1 pH

The pH of the tomato pastes ranged from 4.11 to 4.25. The lowest pH of 4.11 was obtained for tomato paste without binder (cassava starch) and the highest being 4.25 for the control sample. The pH of the tomato pastes analysed differed significantly from each other ($p < 0.05$). This may be attributed to varietal differences, differences in chemical composition such as organic acid contents and maturity or level of ripening. Variations in processing conditions could equally contribute to the higher pH in the commercial tomato paste (Gancedo and Luh 1986; Monti 1980). The pH levels obtained in the formulated tomato paste were at suitable levels to prevent the survival and growth of spoilage microbes in the tomato paste during storage since most spoilage organism does not thrive in acidic conditions (Ullah, 2009). Hence the shelf life of the tomato pastes could be maintained for a longer time during storage owing to their low pH levels. The levels of pH in the reconstituted tomato paste also contributes to the good flavour of the paste (Serrano-Megías).

4.2.2 °Brix

The °Brix of the reconstituted tomato powder was the same (1.95 °Brix) and lower than the 2.25 °Brix recorded for the control tomato paste. This result obtain could be attributed to the use of sweetener (sugar) in improving the taste of commercially processed tomato paste and other additives which increase the product total soluble solid content, difference in processing condition is equally a contributing factor that could be attributed to the difference in data recorded for °Brix. Difference in growing season of tomato fruit could contribute to the sugar content of tomato fruits. In a previous study, tomato fruits cultivated in bright daylight in summer contained extra sugar as compared to ones cultivated during the winter season (Mabengwa, 2013). This could account for the significantly different °Brix obtained for the control tomato sample. Also, differences in cultivar, ripening stage/maturity and storage time of tomato fruit contribute to the differences in the °Brix contents of the tomato pastes (Duma *et al*., 2015). In their study, it was revealed that Brix of tomato fruit increased with ripening.

Table 4.2: Physicochemical Properties of Reconstituted Tomato Powder

Parameter	**B**	**NB**	**C**
pH	4.16 ± 0.01[a]	4.11 ± 0[b]	4.25 ± 0.01[c]
Brix (°)	1.95 ± 0.07[a]	1.95 ± 0.07[a]	2.25 ± 0.07[b]
Titratable Acidity (%)	0.24 ± 0.00[a]	0.26 ± 0.00[a]	0.23 ± 0.01[a]
a* (Redness Index)	10.4 ± 0.4[b]	10.40 ± 0.02[b]	13.70 ± 1.2[a]

Values are Mean ± Standard Deviation, B = Tomato Paste with Binder (starch), NB = Tomato Paste with No Binder, C= Control, values with different superscripts are significantly different p<0.05.

4.2.3 Titratable Acidity (TA)

There was no significant difference among the three titratable acidity for the tomato pastes. The reconstituted tomato powder with no binder had the highest titratable acidity and the control tomato paste had the least; 0.26 % and 0.23 %, respectively. Titratable acidity for tomato pastes in this study are lower than 0.50 – 0.63 % reported for fresh tomato fruits by Duma *et al*. (2015). The lower titratable acidity levels in the tomato paste could be attributed to differences in maturity as well as level of ripening of fresh tomato used as raw material. As the fruit gets to fully ripe and at its full maturity stage, TA level decreases as observed in the study of Duma *et al*. (2015).

4.2.4 Redness Index (a*)

Colour is an imperative quality attribute in the food industry and affects consumer preferences (Pathare *et al*., 2013). Colour measurement was taken as a* indicating the level of redness of the tomato paste products. The redness value (a-value) is from –a (greenness) to +a (redness). The a* value for colour which indicates redness was significantly different (p-value of 0.030) for all the tomato pastes.

For the best postharvest life of tomatoes, colour of tomatoes is mostly geared towards the a* which shows how fully the tomatoes has ripened. The colour expression in numerical form comes as L*, a* and b* axes (from white to black, green to red and blue to yellow, respectively) with Chroma colour sphere typically combined to produce the colour indices (Barrett and Anthon, 2008). From the three components of the tomato colours in this current study, the commercial tomato paste showed a reddish colour which is readily accepted by most consumers (Barrett and Anthon, 2008). This could however, result from the addition food colours to commercial tomato paste to enhance its appearance and consumer acceptance, as asserted by some reports. Moreover, tomatoes fruits are frequently consumed at its maximum organoleptic quality which takes place when they reach their full red bright colour (Barrett and Anthon, 2010). Fraser *et al*. (1994) indicated that the reddish colour comes because of chlorophyll deprivation and also the synthesis of cancer and chronic disease preventing compound (lycopene and other carotenoids), thus; chloroplasts are converted into chromoplasts.

The B and NB had similar a* values which were significantly different from the control. This may be attributed to the processing technique employed. Drying of fresh tomato into tomato powder can cause browning or darkening of the red bright colour because of non-enzymatic browning occurs, hence reducing the redness of the paste (Bradshaw *et al*., 2011). The red pigment which contributes to the bright red colour of most tomato produce gets darkens when also exposed to high cooking temperature. Concentrating reconstituted tomato paste at a hot break, to retain its pectin to improve the consistency of the tomato paste could equally be a contributing factor in the reduction of the redness of the paste.

According to Thai *et al*. (1990), 'The sensitivity of colour development of tomatoes depends wholly on temperature with important plastic change occurring above temperature of 12 °C and underneath 30 °C.' Thus, drying at temperature above the stated temperatures could equally be a contributing factor leading to the reduction in the redness in the reconstituted tomato pates.

4.3 Sensory Evaluation of Tomato Paste Samples

The findings of the consumer preference test are presented in Fig. 4.1. There were significant differences observed between the commercial tomato paste and the reconstituted tomato paste attributes assessed. The next most preferred tomato paste was the tomato paste with binder (cassava starch).

These differences could be attributed to the different processing technique employed with regards to the solar drying of tomato into powder before reconstituting into paste. During solar drying of tomato fruit, non-enzymatic browning reaction takes place which darkens the colour of the final product (Abe-Inge *et al*., 2018).

Some commercial tomato pastes are processed by adding various food additives such as food colour, thickening agents and fibre to improve the texture, colour and overall quality of the paste for consumer acceptance. All these factors could contribute to panellists' preference of commercial tomato paste to the reconstituted tomato paste.

Between the two reconstituted tomato paste, in terms of smoothness, bitter after taste and willingness to use product, tomato paste 'B' (tomato paste with binder) was more preferred. This could be attributed to the presence of cassava starch which binds water and therefore enhance the product smoothness. The texture of tomato paste is one of the key factors that influence consumers' willingness to buy product and hence this could be related to their willingness to use tomato paste 'B' as compared to tomato paste 'NB' (tomato paste without binder).

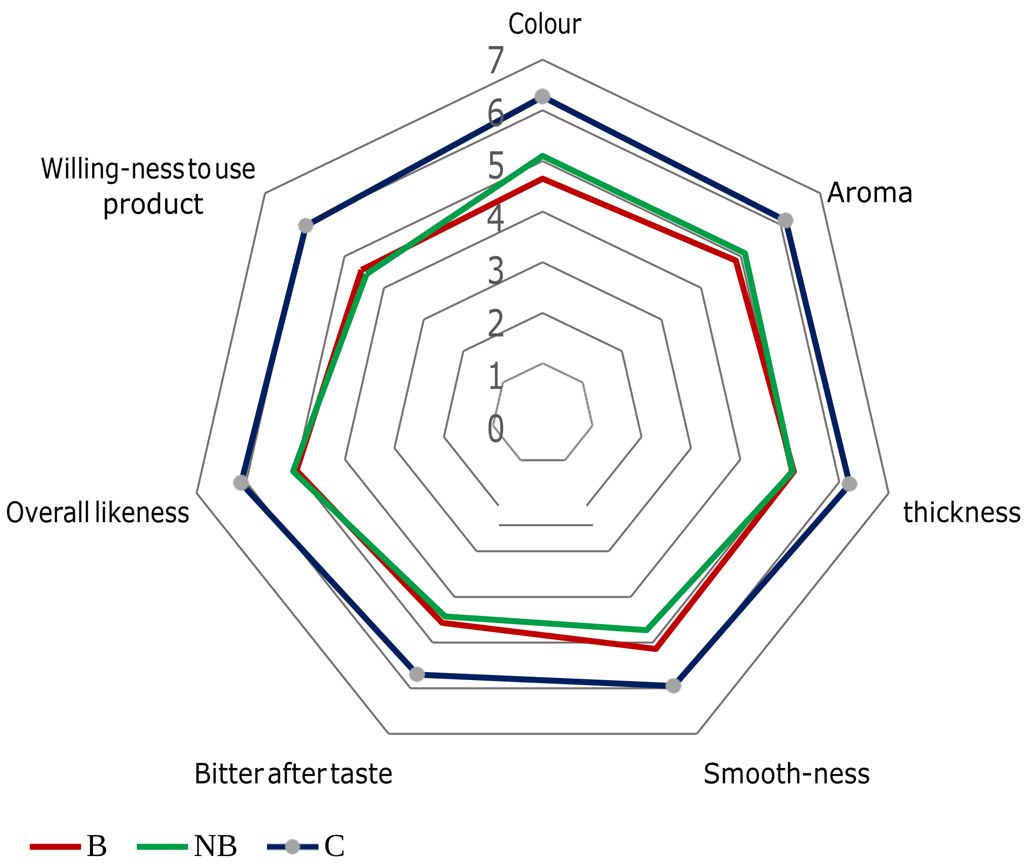

Figure 4.1: Consumer acceptability test for the three different tomato pastes

B = Tomato paste with binder (cassava starch); NB = Tomato paste without binder; C = commercial tomato pastes in the market

Consumers preferred the aroma and colour of tomato paste ‘NB’ to ‘B’. This could be as a result of the natural nature of the paste, that is, absence of additives thereby maintaining the natural colour and aromatic compounds present. The thickness and overall likeness of tomato paste ‘B’ and ‘NB’ were equally preferred by the panel with no significant difference between them. Both had appreciable overall likeness with NB having an average score of 5.05 compared with 6.10 for the control. This indicates a potential market viability for the reconstituted tomato powder.

CHAPTER FIVE

5.0 Conclusion and Recommendation

5.0 Conclusion

The reconstituted tomato paste contained relatively lower amount of fat contents (0.46 ± 0.01) which makes it healthy for low fat diet. The tomato pastes also had considerably high amounts of crude fibre further enhancing its nutritional value.

The use of cassava starch as a binding agent in the reconstituted tomato powder played a significant role in reducing the moisture content of the paste ($P < 0.05$). pH and Brix of the reconstituted tomato powder were relatively lower than that of the control. The titratable acidity was however lower in the control. The redness index was also higher in the control (13.70 ± 1.2) than the reconstituted samples (10.4 ± 0.40, 10.40 ± 0.02 for B and NB, respectively).

The reconstituted tomato powder samples were generally liked by panellists even though the control (reference sample) was better accepted. Reconstituted tomato paste gave a better natural aroma of tomato paste compared to the control. Furthermore, the overall willingness of consumers to use the reconstituted tomato products were at satisfactory levels; average scores of 4.57 and 4.44 for B and NB, respectively, compared to the control with an average score of 5.97.

5.1 Recommendation

It is recommended that, other studies be done on the lycopene content, microbial load and shelf life of the reconstituted tomato paste.

Other food additives such as food sweeteners, spices could be added to the formulation to improve taste while reducing the amount of salt used in this formulation.

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APPENDICES

APPENDIX 1:

RANKING TEST DATA (FRIEDMAN TEST)

Sample	Thickness (Viscosity)	Smoothness (mouth feel)	Smoothness (hand feel)
345 (0.0837 g binder)	2.27	2.82	3.09
453 (0.237 g binder)	3.09	3.00	3.00
534 (0.1785 g binder)	2.00	2.64	2.91
435 (control)	2.64	1.55	1.00
Asymp.sig	0.022	0.037	0.000

APPENDIX 2:

INFORMED CONSENT FORM

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

PHYSICOCHEMICAL AND SENSORY PROPERTIES OF RECONSTITUTED TOMATO POWDER INTO PASTE

INFORMED CONSENT

Title: Physicochemical and Sensory Properties of Reconstituted Tomato Powder in Paste

Principal investigator: Miss Christabel Irene Deha

Address: Department of Food Science and Technology

General Information about Research

The intention of this study is to access the consumer acceptability of a new tomato paste. The study is part of the research activities of **CHRISTABEL IRENE DEHA**, an MSc. student at the Department of Food Science and Technology, KNUST.

If you agree to be part of this study, you will access the characteristics of the reconstituted tomato powder. You will be provided with cucumber and water to rinse your mouth after assessing every sample.

Benefit to society: You will indirectly contribute to knowledge in the field of food product development using indigenous crops. Your involvement is strictly voluntary. Please feel free to leave the study anytime you want.

Health concern: The samples are not known to have any ill effects and there are no known risks in partaking in this assessment. However, if you are allergic to tomato and root crops such as cassava and yam, please decline to participate**.**

Anonymity: Your personal data will never be displayed in any presentation or publication with your identity revealed by name or initials.

The content of this form will be explained in the local dialect to all potential participants.

Should you need further clarification on any aspect of the study, please feel free to ask now or later via mobile, **+233207508128**; email, ibok.oduro@gmail.com, **dehairene.id@gmail.com**

Statement of Consent:

Relevant information on the product to be assessed has been explained to me. I have received answers to all questions I asked. I consent to participate in the study.

Name……………………………………………………………………………………………….……

Locality…………………………………………………………………………………………….………

District……………………………………………………………….

Phone Number……………………………… Email……………………………………………

Signature/Initial…………………………

Date………………………………………

APPENDIX 3a: INTRODUCTORY LETTER

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF INTRODUCTION: MS CHRISTABEL IRENE DEHA

The bearer of this letter**, CHRISTABEL IRENE DEHA**, is an MSC. Student of the Department of Food Science and Technology, KNUST.

As part of her research studies, she need to conduct acceptability studies (consumer sensory evaluation) of a newly developed tomato paste. There are no known risks associated with these assessment and potential assessors will be asked to participate voluntarily.

I will be grateful if consenting workers (preferably female) on your staff (University primary, KNUST) could assist in the assessment of the product. Attached for your consideration is a copy of the consent form to be completed by voluntary assessors.

Counting on your cooperation.

Thank you.

Sincerely,

Ibok Oduro, College of Science Provostand supervisor

APPENDIX 3b: CONSUMER SURVEY QUESTIONNAIRE

Ref. No.____________ Sex: [ ] M [ ] F

You have been presented with coded samples of tomato paste to asses. Please taste where appropriate. Cleanse your mouth with cucumber and water after tasting each sample and wipe spoon before each assessment. Take time to relax before assessing the next sample

Kindly assess each sample based on your degree of likeness for the stated attributes using the scale below:

<u>Scale:</u>

1 2 3 4 5 6 7

Scale 1

1. Dislike very much
2. Dislike moderately
3. Dislike slightly
4. Neither like or dislike
5. Like slightly
6. Like moderately
7. Like very much

Scale 2

1. Never likely
2. Not very likely
3. Not likely
4. Neutral (Not sure)
5. Likely
6. Very likely
7. Very much likely

	SCALE 1						SCALE 2
Sample Code	**Colour**	**Aroma (smell)**	**Thickness (viscosity)**	**Smoothness (mouthfeel)**	**Bitter after taste**	**Overall likeness**	**Willingness to use the product**

Which product do you prefer most and why?

………………………………………………………………………………………………………
…………………………………………………

Any other comments on the products

……………………………………………………………………………..………………………
………………………………………………………..

APPENDIX 4: PHOTOGRAPHS FROM THE STUDY

Plate 1. Solar drying of tomato slices

Plate 2. Solar dried tomato slices (left) and solar dried tomato powder(right)

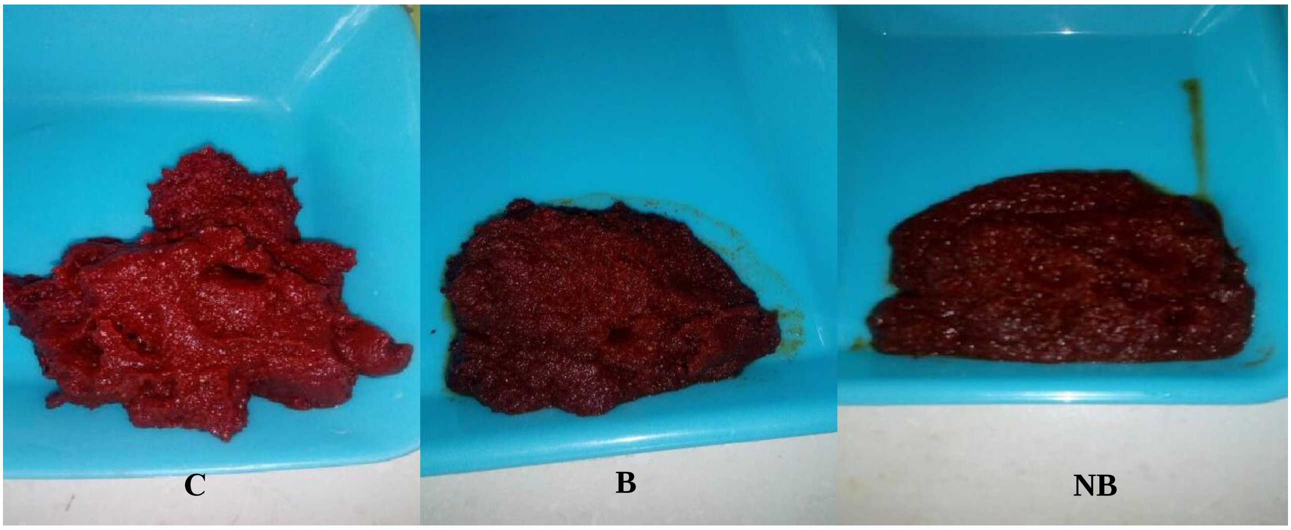

Plate 3. Commercial tomato paste (C), tomat paste with binder (B) and tomato paste with no binder (NB).

Plate 4. Reconstitution stages of tomato paste

Plate 3. Sensory evaluation of tomato paste samples

APPENDIX 5.0: Consumer Acceptability Results for the Reconstituted Tomato Paste against Commercial Tomato Paste Sample

SAMPLE CODE	COLOUR	AROMA	THICKNESS	SMOOTHNESS	BITTER AFTER TASTE	OVER ALL LIKENESS	WILLINGNESS TO USE PRODUCT
B	4.65± 1.70[a]	4.87± 1.80[a]	5.08± 1.38[a]	5.14± 1.54[a]	4.57± 1.73[a]	4.98± 1.58[a]	4.57± 1.63[a]
NB	5.10± 1.39[a]	5.10± 1.54[a]	5.06± 1.46[a]	4.73± 1.69[a]	4.43± 1.99[a]	5.05± 1.43[a]	4.44± 1.65[a]
C	6.27± 0.88[b]	6.13± 0.94[b]	6.21± 0.90[b]	5.95± 1.01[b]	5.70± 1.34[b]	6.10± 1.04[b]	5.97± 1.18[b]

Appendix 6.0: ANOVA Table for Proximate Composition of Reconstituted Tomato Paste

		Sum of Squares	df	Mean Square	F	Sig.
Moisture	Between Groups	5.422	2	2.711	3.017	.191
	Within Groups	2.695	3	.898		
	Total	8.117	5			
Fat	Between Groups	.046	2	.023	15.742	.026
	Within Groups	.004	3	.001		
	Total	.051	5			
Ash	Between Groups	3.823	2	1.912	12.126	.037
	Within Groups	.473	3	.158		
	Total	4.296	5			
CrudeFibre	Between Groups	41.710	2	20.855	27.167	.012
	Within Groups	2.303	3	.768		
	Total	44.013	5			
Protein	Between Groups	.137	2	.069	2663.095	.000
	Within Groups	.000	3	.000		
	Total	.138	5			
Carbohydrate	Between Groups	119.289	2	59.645	208.282	.001
	Within Groups	.859	3	.286		
	Total	120.148	5			

Appendix 7.0: ANOVA Table for Physicochemical Properties of Reconstituted Tomato Paste

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.019	2	.009	283.500	.000
	Within Groups	.000	3	.000		
	Total	.019	5			

Brix	Between Groups	.173	2	.087	17.333	.022
	Within Groups	.015	3	.005		
	Total	.188	5			
Redness	Between Groups	14.675	2	7.338	14.017	.030
	Within Groups	1.570	3	.523		
	Total	16.245	5			
Titratable Acidity	Between Groups	.001	2	.000	6.870	.076
	Within Groups	.000	3	.000		
	Total	.001	5			