DEHYDRATION CHARACTERISTICS, QUALITY EVALUATION AND CONSUMER ASSESSMENT OF SOLAR DRIED TOMATO.

By

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(B.Sc. Nutrition and Food Science; MPhil Food Science)

A Thesis Submitted to The Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi in partial fulfilment of the requirements for the award degree of

DOCTOR OF PHILOSOPHY FOOD SCIENCE AND TECHNOLOGY

NOVEMBER, 2018.

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

Tomato (*Lycopersicon esculentum*) is an important vegetable used in cooking most local foods in Ghana. At the peak season of harvesting, high loses are incurred because of the absence of facilities to store, process and extend the shelf life of fresh tomatoes. Solar drying has been proven to be a more efficient and low cost method of enhancing quality and adding value to tomato and other vegetables. However, there are concerns on the usage, functionality and sensory appeal of the dried products by consumers due to the methods of drying. In this study a natural mixed mode solar dryer suitable for drying tomato was adapted and used to investigate the dehydration characteristics, quality and consumer acceptability of the dried products. An initial baseline survey was conducted using semi structured questionnaires administered to 395 randomly selected respondents in the Accra Metropolis. Information was obtained on the demographics, consumption pattern, knowledge and acceptance of tomato processing technologies and assessment of quality attributes of tomato. The efficiency of a passive solar dryer was evaluated and used in the processing of fresh tomato to powder. The processing involved the pre-treatment of 6mm slices of fresh roma variety of tomato by dipping in (a) 1% potassium metabisulphite solution and (b) 1 % ascorbic acid solution (1:1) for 10 minutes. Untreated tomato slices served as control. Samples were then dried in the passive solar dryer and in the open sun, with the open sun drying serving as control. The moisture content, moisture ratio and dehydration rate of solar dried tomato was assessed. The quality of dried tomato was also assessed for their physicochemical, nutritional and microbiological characteristics. Physicochemical analysis involved the determination of pH, total titratable acidity, dry matter, ash, tristimulus colour, total soluble solids, water activity and moisture. Nutritional quality was assessed for lycopene, beta-carotene, total carotenoid acids using high performance liquid chromatography (HPLC). Flowability, smoothness and compressibility (or packing porosity), particle size and shape distribution of the tomato powder was determined using a Morphologi G3-ID. Scanning electron microscopy of pre-treated solar and sundried tomato samples were imaged with an FEI Quanta 3D FEG scanning electron microscope. Quantitative Descriptive Analysis (QDA) was carried out to compare the sensory descriptive profiles of solar dried tomato powder with existing products on the market using a trained descriptive panel of nine (9). Home Use Test (HUT) was conducted using a trained panel to assess the acceptability of solar dried tomato powder in local foods. The results showed that, most consumers (74%) preferred tomato powder that was conveniently packaged to retain the characteristic intense taste and the flavour. The 24 hr dryer efficiency of 24.2 % facilitated the drying process of tomato (final moisture content of 12-14%). The ash content was slightly higher in the sundried tomato (9.3 -10.14 %) compared with the solar dried tomato (9.4 - 9.68 %), an indication of potential contamination with extraneous materials from the environment. Water activity for solar dried tomato powder were significantly lower (0.35 - 0.38) than the sundried tomato powder (0.53 - 0.57). Generally, water activity lower than 0.6 is considered microbiologically safe for storage. Lower tristimulus colour L* values (37.81 - 40.31) observed for sundried tomato samples indicated that these samples were darker in colour than the solar dried samples with L* values (50.35 - 46.44). Aerobic mesophile counts were lower in solar dried tomato pre-treated with potassium metabisulphite (3.90 CFU/g) compared with sundried samples (4.85 CFU/g). Sulphur dioxide content of solar dried tomato pre-treated with potassium metabisulphite (740.8 ppm) was lower than the maximum legal limit (2000 ppm) recommended in fruits and vegetables. This indicates its safety for human consumption. A strong, negative correlation between sulphur dioxide concentration and microbial load was observed for solar dried tomato. QDA results indicated a strong tomato aroma intensity (scored 127 out of 150) for solar dried tomato powder, with the market samples having an extremely low intensity score of 0.7 out of 150 for tomato. Sensory profiling of the two products differed extremely in aroma, appearance and texture. Sensory characteristics of the reconstituted solar dried tomato powder was similar to that of fresh tomato and tomato paste (two products commonly used in cooking). It had a very coarse appearance and texture (as predicted by the particle size distribution and shape profile and parameters of convexity and circularity) and a strong boiled/cooked aroma compared to tomato paste which had a higher intensity of red colour, metallic and stewed tomato concentrate aroma and flavour. Most of the participants used tomato powder to prepare local dishes such as "jollof "rice, tomato stew and light soup because of the good swelling characteristics of the product. The mixed mode solar dryer developed in this study was efficient in processing tomato powder which appealed to consumers and had varied uses in food production. The dryer thus has the potential of enhancing post-harvest loses, extending the shelf life of tomato and creating an alternative processing method which is simple and convenient.

CONTRIBUTION TO KNOWLEDGE

Key findings established from the study are;

i. Established protocol for processing dried tomato using the natural mixed mode solar dryer.

ii. Application of MorphologiG3-1D in the determination of flowability, packing porosity, particle size and shape distribution of tomato powder.

iii. Sensory profiling of solar dried tomato powder for potential pilot scale production.

These finding have resulted in the following publications which form part of the body of knowledge of the processing of solar dried tomato.

i. Owureku-Asare, M., Kingsly Ambrose R.P., Oduro, I., Tortoe, C., Saalia, F.K. (2016). Consumer knowledge, preference, and perceived quality of dried tomato products in Ghana. *Food Science and Nutrition,* 1–8.

ii. Owureku-Asare, M., Oduro, I., Saalia, F.K, Tortoe, C., and Kingsly Ambrose, R.P. (2018). Physicochemical and Nutritional Assessment of sun-dried and solar dried tomato. Journal of Food Research,7, (6), 1-15.

iii. Owureku-Asare, M., Kingsly Ambrose R.P., Oduro, I., Tortoe, C., Saalia, F.K. (2016). Drying characteristics and microbiological quality assessment of solar dried tomato. (Under internal review).

DEDICATION

To my husband and kids, Elhanan, Asabea, Fiifi and Ohemaa. I love you very much and thank you for the support throughout my PhD studies. A special dedication goes to my mother Mrs Cecilia Owusu-Ahinkorah who has been an inspiration for me.

ACKNOWLEDGEMENTS

This work was facilitated by financial and logistical support from The Norman E. Borlaug Leadership Enhancement in Agriculture Program (Borlaug LEAP), Purdue University and International Institute of Tropical Agriculture (IITA), Nigeria

I wish to honestly thank my supervisors, Prof. Ibok Oduro, Provost of College of Science, KNUST; Prof. F. K. Saalia, Head of Department, Food Process Engineering, University of Ghana and Dr. Charles Tortoe, Deputy Director of CSIR- Food Research Institute for their constructive criticisms, guidance and mentorship which have brought this work to a successful completion. I wish to Thank Dr Kingsly Ambrose of Agricultural and Biological Engineering (ABE) Department, Purdue University and Dr Busie B. Maziya-Dixon of International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria for mentoring me under the Borlaug LEAP and for his input in this thesis.

My appreciation goes to the following: Mr Michael Adesokan, Yumeng Zhao and Achint Sanghi of ABE-Purdue University I am grateful to my colleagues Papa Toah-Akunnor, Dr Charlotte Oduro-Yeboah, Matilda Dzomeku, Solomon Douwona, Dr. Margaret Owusu, Desmond Mensah, Jonathan Ampah, Nelson Amey, Theophilus Annan, John Bosco, Joyce Agyei-Amponsah for their help in executing my thesis research.

Also to Mr & Mrs Alex Aseidu, Mrs Sefakor Boadu, Mrs Adwoa Nyarko, Alberta Anno, Sandra Owusu-Ahinkorah and Rita Owusu-Ahinkorah, I say a big thank you for your prayers and support.

I am most grateful to my husband Elhanan Owureku Asare for his financial support and encouragement throughout my studies. I am above all most grateful to God Almighty for giving me strength and wisdom to carry out this work.

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LIST OF ABBREVIATIONS

a* redness when positive and greenness when negative

AA ascorbic acid

a_w Water activity

b* yellowness when positive and blueness when negative

CE diameter circle-equivalent diameter

CLT Central Location Test

DA Solar-dried tomato powder pre-treated with ascorbic acid

DC Solar-dried tomato powder with no pre-treatment

DK solar dried tomato powder pre-treated with potassium metabisulphite

DR Drying rate

E.coli Escherichia coli

HPLC High Performance Liquid Chromatography

HS High sensitivity circularity

HUT Home Use Test

KMS Potassium metabisulphite

L* Lightness and varies from 100 for perfect white to zero for black

MC moisture content at time t (kg water/kg dry matter)

MR Moisture Ratio

RH Relative humidity

RSDP Reconstituted Solar Dried Tomato Powder

SA Sun-dried tomato powder pre-treated with Ascorbic acid

SC Sun-dried tomato powder with no pre-treatment

SDE Solar Dryer Efficiency

SK sun-dried tomato powder pre-treated with potassium metabisulphite

TTA Total titratable acidity

ΔE Color intensity value

AOAC Association of Official Analytical Chemists

ETHICAL APPROVAL

This research was assessed and approved by the Council for Scientific and Industrial Research (CSIR) – Institutional Review Board.

CHAPTER ONE: INTRODUCTION

Tomato (*Lycopersicon esculentum*) is an important vegetable used in cooking most local foods in Ghana (Tambo and Gbemu, 2010). Tomato production is a significant economic activity with annual production of 366,772,000 tonnes per annum (FAOSTAT, 2016a) at the height of the harvest season in Ghana. It is typically a small-holder activity and seasonal with prices of tomato fluctuating throughout the year based on weather and cropping cycles (Robinson and Kolavalli, 2010). In most parts of the country, its production is very lucrative especially in Upper East Region where its production is more profitable than yam, groundnut and maize (Yeboah, 2011). Farming methods for tomato cultivation are based on availability of water and shortfalls in the supply are as a result of poor postharvest handling, storage and distribution by farmers and retailers. Tomato glut occurs after the harvest periods (between August to October and January to March) whiles scarcity is a frequent occurrence from December to February, and April to May (Gongolee, 2014).

Attempts to solve the problem of seasonal glut and scarcity through commercial processing has not been successful (Owureku-Asare *et al.*, 2013). At the peak season of harvesting tomato, losses of between 20-50% are incurred due to the absence of tomato processing setups or facilities, which results in fluctuations in prices (Kader, 1992). In the past, some attempts were made to reduce these losses by processing tomato into paste by setting up processing factories such as Pwalugu Tomato Factory and Nsawam Cannery (Robinson and Kolavalli, 2010). None of these attempts resulted in a sustainable practice of tomato preservation due to the complexity of setting up and the high overhead costs of running tomato canning facilities. Increasing demands of tomato from traders compounded with high importation of canned tomato products makes the marketing of tomato, a daunting challenge for smallholder farmers in tomato production areas (Clottey *et al*., 2009).

Ghana consumes about 50,000 tonnes of tomato paste per annum and is currently ranked the world's second highest country in canned tomato importation (Auvillain and Liberti, 2014). The massive increase in these imports has affected livelihoods of tomato farmers.

Improving domestic tomato processing would help the extra supply, reduce the losses and strengthen the tomato value chain. It would also minimise the country's over dependence on canned tomato imports and offer employment opportunities to the youth (Owureku-Asare *et al*., 2013). Formulation and processing of tomato into convenient forms such as dehydrated tomato should be promoted using technologies that are easily adaptable to farmers (Owureku-Asare *et al.*, 2013).

Sun-drying tomatoes is a common practice in many countries and is a simple technology even though it may be a slow process (Belessiotis and Delyannis, 2010, Forson *et al.*, 2007; Hawlader, *et al.*,1991). By reducing moisture content and water activity, many microbial, enzymatic and chemical degradation mechanisms are inhibited and, in the process, unique products are created (Latapi and Barrett, 2006). Solar drying on the other hand can be employed, with minimal capital investments, even though it may be a slow process compared with conventional drying (Chua and Chou, 2003; Bena and Fuller 2002). In comparison with open sun-drying, the drying time for solar dryers can be reduced by about 65% and the hygienic quality of the dried product improved (Demir and Kamil, 2012).

Food companies that use sun-drying for processing tomatoes experience some challenges with maintaining a consistent supply of quality dried products (Andritos *et al.,* 2003). Solar dryers are more effective in preserving and enhancing the shelf life of agricultural products.

Solar dryers are better suited for areas with abundance of sunshine which can be utilized during the harvest periods (Demir and Sacilik, 2010). Solar dryers come in different types, sizes, functionalities and efficiency which enhance the quality characteristics of the dried food (Altobelli *et al.,* 2014; Esper and Miihlbauer, 1998). Dried tomato products have low moisture content and low microbial load in order to stay wholesome (Leon *et al.,* 2002). Regulation of humidity, temperature, moisture and preservation treatments will influence the drying characteristics, aesthetic value, nutritional and shelf life of the products developed (Esper and Miihlbauer, 1998. Passive solar dryers which do not require the use of electricity will offer practical processing solution to reducing post-harvest losses in urban and rural tomato producing communities.

1.2 Problem Statement and Justification

Tomato continues to be an important ingredient in the diet of man globally. It is used in different forms, both fresh and processed. However, it is highly perishable thus during the bumper season post harvest losses are very high (40-50%). In trying to address this problem, several approaches have been adopted especially canning in various forms such as tomato paste, whole tomato, dices or puree. This however has not been sustainable in several developing countries including Ghana due to several factors, including the cost of production. Drying on the other hand has been practiced in some situations using the sun and in a few instances using the solar dryer. This form has not received much attention especially in terms of efficiency and its commercial application. There is thus the need to study this technology with the prospect for commercial production of dried tomato products. In this regards, this research work which focuses on processing of fresh tomato using solar drying technique would be very relevant since the positive outcomes would contribute to the economic well-being of the Country.

1.3 Main Objective

To investigate the dehydration and quality characteristics, and consumer acceptability of solar-dried tomato using a natural convection mixed mode solar dryer.

1.4 Specific Objectives

1. To assess consumer knowledge, preference, patronage and perceptions of dried tomato in Ghana.
2. Evaluation of Natural convection solar cabinet dryer for the drying tomato and assessment of drying characteristics of dried tomato.
3. To assess drying characteristics of tomato and the efficiency of a modified passive solar dyer used for processing dried tomato powder.
4. To assess the quality characteristics of solar and sun-dried tomato powder.
5. To conduct sensory profiling of solar dried tomato powder.
6. To conduct consumer evaluation on the solar dried tomato powder using Home Use Test.

CHAPTER TWO: Literature Review

2.1 Origin and varieties of tomato

Tomato (*Lycopersicon esculentum*) is a yellow-red berry-type fruit from the family, *Solanaceae*. Wild tomato is native to South America which spread to Europe by the eighteenth century (Peralta *et al.*, 2005; Rick and Holle, 1990). Tomato can be grouped according to their colour or characteristics of their fruit (such as cherry tomato, paste tomatoes, winter storage tomatoes (MOFA, 2016). Tomato vary in size, from berries to cherry and beefsteak tomatoes (Relf *et al.*, 2009). Campari tomatoes are known for their sweetness and juiciness, whiles plum and pear tomatoes are used in tomato sauce and paste because of their high bred with higher solids content and pectomech is suitable for processing (Robinson and Kolavalli, 2010). Tomato for processing and fresh consumption include cherry, roma and plum tomatoes (Yahia and Brecht, 2012). In modern times different varieties of tomato are bred for either processing or for fresh consumption.

2.2 World production of tomato

Tomato is the world's most produced and second most consumed vegetable (FAOSTAT, 2016b). Tomato is highly perishable and requires proper handling as a requirement for maintaining quality (Osei *et al.,* 2010). It is rich in nutrients, vitamins, dietary fibre, organic acid and is processed into products such as juice, puree, sauce, paste, dried tomato, tomato powder and ketchup (Akanbi, Adeyemi and Ojo, 2006). The world tomato production reached 177,042,359 tonnes in 2013, and China, India, United States of America, Turkey and Egypt are the five highest producers, respectively (FAOSTAT, 2016b). Asia produced 60.7% of the world's tomato in 2016, with the United States (15%), Europe (12.8%), Africa (11.1%) and Oceania 0.3% with the least production. Africa produced 19792182 tonnes in 2016 with Ghana producing 366,772 tonnes per annum FAOSTAT, 2016b).

2.3 Nutritional Composition of Tomato

Tomato contributes to a healthy, well-balanced diet (Naika *et al.,* 1989) because it is a good source of vitamins and fibre, low in calories, and rich in vitamins A, B1, B2, B6 and C, and rich in Beta carotene and lycopene. (Yahia *et al.*, 2005). Tomato contains vital minerals such as, potassium, magnesium, Zinc, Manganese, phosphorus, copper, iron, sodium, calcium (Rahman *et al.*, 2010; Agarwal *et al.*, 2001). It also contains significant amount of fibre, folic acid, tartaric acid, citric acid, niacin, thiamine and folic acid making the tomato a highly nutritious vegetable (Table 2.1).

Vitamin C content (230 mg kg/1) of tomato is lower in comparison to other fruits, however because of its high usage in the diet of many, it's contribution to meeting Vitamin C requirements is significant as the adult US recommended daily intake of Vitamins A and C is about 20% and 40% respectively (Yahia and Brecht 2012).

Table 2.1. Nutritional and chemical composition of an average red ripened tomato

Nutritional content	**Wet weight basis**
Alpha carotene	124µg
Beta-carotene	552µg
Calcium	1.2mg
Carbohydrate	4.7g
Cholesterol	0.0mg
Copper	0.073mg
Dietery fibre	1.5g
Energy	22.14kcal
Fat	0.2g
Folate	18µg
Iron	0.33µg
IU vitamin A	1025µg
Lutein + zeaxanthin	151 µg
Lycopene	3165µg
Magnesium	1.4mg
Manganese	0.140mg
Moisture	116.26g
Niacin	0.73mg
Potassium	292mg
Phosphorus	3.0g
Pantothenic acid	0.11mg
Protein	1.0g
Riboflavin	0.02mg
Selenium	0.0 µg
Sodium	6mg
Thiamine	0.05 mg
Total Choline	8.2 mg
Total polyunsaturated fatty acids	0.10 g
Total Sugars	3.23 g
Vitamin C (total ascorbic acid)	16.9mg

Vitamin B-6	0.10 mg
Vitamin D2 + D	0.0 µg
Vitamin B-12	0.0µg
Vitamin E - alpha-tocopherol	0.66 mg
Vitamin K (phyloquinone)	9.7 µg
Zinc	0.21 mg

Source: USDA National Nutrient Database (2010)

In addition to the micronutrient content, tomato products contain substantial phytochemicals such as lycopene, beta carotene, anthocyanin (with some varieties containing 40 times the normal vitamin A, and four times the regular concentrations of lycopene (Vallverdú-Queralt *et al*., 2011).

2.4 Health Benefits of Tomato

Over the past two decades, there has been increased awareness and interest in the health and nutritional benefits of tomato (Giovannucci and Clinton 1998; Guester 1997). Lycopene makes up 83% of the total carotenoids in tomatoes (Gould, 1992). The exocarp of fresh tomato contains about five times more lycopene than the pulp (Papaioannou and Karabelas, 2012). Lycopene extracted from tomato products is used as a food additive to boost nutritional quality and improve storage stability of food products (Osterlie and Lerfall, 2005). It is a natural antioxidant with high oxygen-radical quenching and scavenging activity which imparts the characteristic red colour of tomato (Dumas *et al.*, 2003). Dietary source of lycopene is high in tomato based products (Table 2.2).

Tomato has been linked to lower incidence of cancer (Grieb *et al.,* 2009; Zhang *et al.,* 2009) and heart disease (Stahl and Sies, 1993; Burri, 1997; Oslon, 1999). These benefits are as a result of the antioxidant properties of vitamin C and carotenoids composition specifically with lycopene, beta-carotene and lutein that accumulate in blood plasma and organs (Dorais *et al*., 2008; Markovic´ *et al.,* 2006; Aust *et al.,* 2003;) and has the ability to mop up free radicals (Palozza and Krinsky,1992). Epidemiological studies indicate that consumption of tomato through the role of lycopene is inversely correlated to the incidence of stroke, cancer risk and cardiovascular disease (Campbell *et al.,* 2004; Gaziano, and Buring, 2003), it also protects the skins against harmful ultra violet rays (Maccrae, 2008).

Table 2.2. Dietary sources of lycopene

Source	**Wet weight (μg/g)**
Apricot	<0.1
Gac	2,000–2,300
Papaya	20–53
Pink grapefruit	3.6–34
Pink guava	54
Raw tomato	8.8–42
Tomato juice	86–100
Tomato ketchup	124
Tomato sauce	63–131
Watermelon	23–72

Source: http://en.wikipedia.org/wiki/Lycopene

2.5 Tomato Production in Ghana

Tomato is a food security crop and has significant economic value in Ghana (Horna *et al.,* 2006). It makes up 38 % of vegetables grown in Ghana and in spite of its importance; local production of tomato is low and not able to meet domestic demand (FAO, 2005). In Ghana, the annual realizable yield for tomatoes is 15 metric tonnes per hectare, however the actual yield is 7.5 metric tonnes per hectare; a gap of 50 % which can be attributed to the current use of traditional methods of farming (MOFA, 2011).

In Ghana, tomato production is dominant in the Upper East, Eastern, Ashanti, Brong Ahafo and Greater Accra regions and is highly lucrative in the Upper East region where it supersedes rice, maize, rice, groundnuts, yam and pepper in profit (Yeboah, 2011; Ochieng and Sharman, 2004). Tomato sells at a faster rate than cereals and grains in this region and about 90% of the people in this area produce them (Horna *et al.*, 2006).

Tomato cultivation is an income generation activity and generates employment for the youth. However due to non-adoption of improved husbandry practices, yields and returns on investments are quite low in Ghana compared with other tomato producing countries (Sowley and Damba 2013). Challenges farmers encounter include, unavailability of good quality certified seeds and the recycling of seeds which affects the quality of seeds and subsequent yields (Horna, 2006). Available seeds on the open market are either mixed or heavily infested with diseases (Asare-Bediako *et al.,* 2007). Seasonal yields from commercial productions of tomato using seeds of foreign origin, may be affected due to lack of proper adaptation of seeds to the Ghanaian environment (Robinson *et al.,* 2010b; Adu Dapaah and Oppong- Konadu, 2002).

There are many varieties of tomato cultivated throughout the country including Pectomech VF, Rio Grande, Tropimech, Cac J, *Wosowoso*, Roma VF, and Laurano 70 (MOFA, 2008). For many years, researchers have worked on developing varieties "local" cultivars with the quality attributes of some foreign cultivars suitable for the

Ghanaian environment. Two such cultivars are the "Owusu-Bioh" and "Wosowoso" which were developed at the Crop Science Department at the University of Ghana. Both cultivars are tall intermediate types, tolerant to nematodes and very vigorous. *Wosowoso* is not suitable for tomato paste production due to its high water content and low dry matter (Gongolee, 2014). The northern variety (roma) of tomato was introduced specifically for the tomato canning industry in northern Ghana (Robinson and Kolavalli, 2010). This variety has thick skin, desirable red colour, few seeds and high pulp content with relatively high soluble solids. Exotic varieties available in Ghana are Roma Vf, Pectomech Vf (also known as burkina), Tropimech, Rio Grande, Cac J, and Laurano 70. Pectomech is most suitable variety for processing tomato paste and is most preferred by consumers with a premium price (Robinson and Kolavalli, 2010).

2.6 Post-harvest management of tomato in Ghana

High post harvest losses up to 40% are incurred annually in the production of tomato in Ghana (Robinson and Kolavalli, 2010). Since most Ghanaians use fresh tomato in large quantities for cooking, improving the post-harvest handling and storage practices during marketing of fresh tomato is very important, that way the economic viability of the tomato industry will also be sustained.

Factors that contribute to post harvest losses (PHL) include poor and/or inadequate infrastructure from farm to market, improper harvest sanitation, poor cooling (Beecher, 2000; Kereth *et al,* 2013) and the lack of processing facilities to prolong the shelf life of tomato (Robinson and Kolavalli, 2010; Owureku-Asare, 2013). Transportation of tomato is also very important and cooling to at least 12.5°C immediately after harvest and packing is recommended to remove heat and retard ripening (Yahia and Brecht, 2012).

A common practice in Ghana is the open display of tomato during transportation and at market centers which exposes tomato to further deterioration, reducing the overall quality (Owusu-Ahinkorah and Sefa-Dedeh, 2006). A study by Johnson *et al.*, (1998) in five marketing centers in Accra, revealed that, retailer's perception on sorting, cleaning, poor packaging and lack of storage facilities for tomato correlated well with the physical defects results and post harvest loses of tomato. Previous study conducted by Owusu-Ahinkorah and Sefa -Dedeh (2006) on retailers of tomato in some local markets in Ghana, sixty percent (60%) of tomato traders indicated high rate of deterioration associated with the mode of storage of tomato at markets.

2.7 Tomato Processing in Ghana

Tomato processing is not a common practice in Ghana despite high post-harvest loses incurred annually and local processing is insignificant even with the perennial gluts in some parts of Ghana, particularly the Upper East region of Ghana. Eighty percent (80%) of respondents in a study by Aggey *et al.* (2007) indicated high patronage for tomato paste in Ghana because the end-uses of canned paste is similar to fresh tomato which is used to imparts flavour, colour and bulkiness to a wide array of local dishes.

Farmers loose up to 50% of produce in the harvesting season, because there are no processing facilities for processing tomato (Kitinoja and Gorny, 1999). The massive importation of canned tomato paste contributes to farm gate tomato price fluctuations in excess of 300%, and reduce farmers' earnings (IIR, 2003).

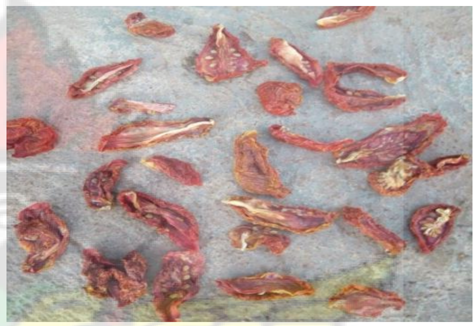
Ghana started processing tomato in 1968, with the setting up of three tomato canneries which produced tomato paste, in Pwalugu, Wenchi and Nsawam. These canneries operated on partial contract farming arrangements providing either equipment or guaranteeing market access for pre-agreed quantities produced by smallholders. Not all farmers were engaged with the factories, but the running of the factories led to reduction in the bargaining power of Tomato Queens who bought supplies from farmers not contracted to the canneries, for sale throughout the country. For example, Pwalugu tomato cannery was closed down because of competition with cheap subsidized tomato paste from Europe (Aggey *et al.*, 2007). Agreement between the Pwalugu factory and the tomato farmers broke down because the price offered for fresh tomatoes were frequently below market price and farmers sold their tomatoes elsewhere. Strong private association of Tomato Queens exploited farmers by creating a restricted market and monopolized the tomato market (Adimabuno, 2010). Regional trade agreement policy opened a market opportunity in Ghana for Burkina Faso tomato farmers, presenting further challenges for local tomato farmers. The pectomech variety commonly cultivated in Burkina Faso was of higher premium for local consumption and suitable for tomato processing compared to the local varieties. Some local tomatoes varieties such as "wosowoso" have very high water content making them less suitable for processing into tomato paste. There were difficulties in managing the high costs involved in sourcing fresh tomatoes from a large number of smallholders who rather sold their produce to market queens from Accra. Managing this cost involved sourcing fresh tomatoes from a large number of smallholders and the high cost of electricity was challenging for the State owned factories. Also productivity levels fell because work force morale was low. A case study carried out on the Wenchi Canning Factory in 1990 revealed that workers had not been paid for three years (Adimabuno, 2010). In the light of numerous challenges with tomato processing companies all three state owned factories shut down their operations. Currently there are no state owned processing facilities for processing fresh tomato to paste. The presence of a few private tomato processing companies has not resulted in sustained processing options for tomato. Bell *et al.*, (1999); Robinson and Kolavalli (2010); Owureku-Asare, (2013), have recommended tomato processing for domestic and export markets as approaches to reducing post- harvest losses by exploring alternative, convenient low cost methods such as drying to help absorb excess supply and strengthen the tomato value chain.

2.8 Traditional processing of dried tomato in Ghana.

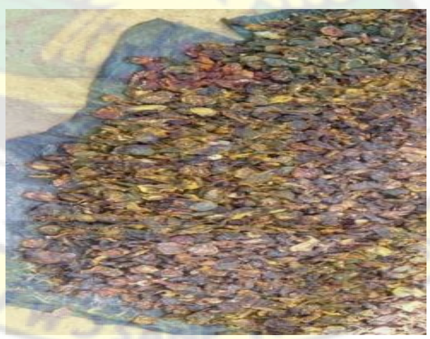
Traditionally, open sun drying is used for processing tomato in some tomato producing areas such as Navrongo, Bolgatanga and Tamale in the northern part of Ghana for household consumption and sale at local markets (Adimabuno, 2010). Sun drying is usually done during the dry season (December-February) with fresh whole tomato which is cut into halves and dried on bare cemented pavement or on polyethylene sheets (Plate 1.1). The drying process is dependent on prevailing atmospheric weather conditions. The method of drying can cause browning and discolouration of the final product.

Drying may take between 4 to 7 days and can be sold or further processed by adding corn flour, red colour, “kokonte” and salt and milled into powder. In the southern parts of the country a product processed from annatto seeds, corn flour and red colour (does not contain dried tomato) is marketed as “tomato powder”. This product is mainly patronized by street food vendors who use it in preparing street foods such as “jollof rice”, tomato stew for serving “waakye” and rice (Adimabuno, 2010).

However, in neighbouring country Burkina Faso, solar drying is used for local processing tomatoes in the glut season, yielding products with better and more consistent quality than what is produced in Ghana (Adimabuno, 2010).



Source: Field pictures



Source: Adimabuno, 2010.

Plate 1.1: Sun-dried tomato processing in Northern Ghana.

Source: Field pictures

Plate 1. 2. "Tomato powder" made from annatto seeds, corn flour and colour sold in some local markets in Accra.

2.9 Storage, processing and preservation methods for fresh tomato

Tomato, a climacteric fruit is highly perishable, and anticipating harvest before the climacteric and introducing appropriate storage methods slows down senescence and prolongs shelf life (Saltveit, 2005). Food preservation involves techniques of maintaining food at desired quality to reduce deterioration and increase shelf life. Preservation techniques inhibit microbiological or biochemical change and provides the nutrients required for health. (Fellows, 2000). Examples of processed tomato products include, concentrated tomato products, pizza sauce, dehydrated tomato, tomato ketchup.

2.9.1 Storage methods for enhancing shelf life of tomato

2.9.1.1 Controlled Atmosphere (CA) Storage

Controlled atmosphere storage is an agricultural storage method in which oxygen; carbon dioxide and nitrogen concentrations as well as temperature and humidity are regulated. Controlled atmospheres (CA), with low O_2 and high CO_2, have been used to enhance quality and extend storage life in many fruits (Saltveit, 2003). CA storage facilities are composed of airtight thermally insulated rooms, machinery, refrigeration systems, equipment for creating and maintaining the desired gas concentrations in a specific environment, with systems for measurement and control of storage factors (Hoehn *et al.*, 2009).

Because CA storage is capital intensive and expensive to operate, it is more appropriate for those foods that are agreeable to long term storage such as apples, kiwi and pears. However, Brecht (2006), Kader (2003) and Saltveit (2003) have all investigated the successful application of CA storage for other fruits and vegetables such as tomato.

2.9.1.2 Modified atmosphere Packaging (MAP)

MAP is the replacement of air in a pack with a single gas or mixture of gases. The mixture of gases in the package depends on the type of product, packaging material and storage temperature (Church and Parsons,1995). In modified atmosphere (MA) systems, unlike controlled atmosphere systems, no further control is exerted over the food after modification of the initial gas composition (Robertson, 2012; Church, 1994; Kader *et al.,* 1989). An equilibrium modified atmosphere will be established in the package so long as the permeability (for O_2 and CO_2) of the packaging film is adapted to the product's level of respiration, hence extending the shelf-life of the product (Phillips 1996; Church and Parsons, 1995). MAP storage has been widely used in combination with refrigeration to maintain the safety and extend the shelf-life of whole and minimally processed fruits and vegetables (Mir and Beaudry, 2014; Mangaraj *et al.*, 2009). MAP systems are designed for tomatoes to be held at between 5 and 10 ^oC

(Fagundes *et al.*, 2015; Bailèn *et al.*, 2006). D'Aquino *et al*., (2016), indicated that MAP with moderate levels of CO_2 (around 3 kPa), O_2 not below 12 kPa and Relative humidity not higher than 90 % could prolong overall quality and reduce decay of red-ripe cherry tomatoes at 20 ^oC.

2.9.2 Processing and preservation techniques for tomato

2.9.2.1. Canning

Tomatoes are canned whole or diced and serve as important ingredients in soup, ketchup, spaghetti sauce, sauces tomato juice and pizza sauces. Tomato paste is typically produced by cleaning/washing, macerating, removal of seed and skin, concentration, canning, sterilization and storage (Gould, 1992). Heat treatment is applied to inactivate microorganisms and reduce the water content, a process which preserves and prolong the shelf life of the produce. Although they do lose some nutrients such as Vitamin C and B, the heat process actually increases the availability of lycopene and beta-carotene (National Food Processors Association, 1992).

2.9.2.2. Drying

Drying is an energy intensive process used to preserve and prolong the shelf-life of agricultural products with significant importance in the food industries (Mohsen Ranjbaran *et al.*, 2014; Dincer, 2011; Tettey, 2008). Drying is effective for preserving tomato by reducing moisture content, water activity and inhibiting microbial and chemical degradation mechanisms. Different drying methods have been used to extend storage and minimize costs of transporting food (Ghaffari and Mehdipour, 2015; Okos *et al.*, 1992).

Dried tomato products enjoy special market and are in high demands and tomato powder is the major ingredient in soups, sauces and tomato ketchup (Liu *et al.*, 2010). Several drying methods have been applied to food systems based on economic returns, environmental concerns and resultant quality (Demir and Sacilik, 2010; Latapi and Barrett, 2007; Goula and Adamopoulos, 2005a; Okos *et al.*, 1992). However, some drying methods commonly employed to tomato include infrared, convection, spray drying, solar drying, sun drying and freeze drying.

2.9.2.2.1 Infrared (IR) drying

Infrared drying uses infrared wavelength radiation from a source to facilitate the removal of water by interacting with the cells of the sample, increasing its temperature. IR drying technique is ideal for products with significant moisture content, which is absorbed by radiation (over 3μm) facilitating the drying process (Kneule, 1982). IR drying in comparison to conventional drying is highly energy efficient, dries food faster as it reduces the air flow through the product (Togrul, 2005). Infrared has been used in drying of peaches, carrots, onions (Volonchuck and Shornikova, 1998, Wang and Sheng, 2006). In studies by Ruis-Celmaa *et al.* (2009), the drying rate of tomato was found to increase with increasing temperature, thus reducing the drying time.

2.9.2.2.2 Convection air drying

Conventional air-drying is the commonly used drying method in food industry. Hot convection air dryers are used for drying foods such as mangoes, banana, pineapple, tomato, herbs and bay leaf. Low cost convection dryers have great potential in small farming areas of less than 1 ha where electricity is available and the dried products could be stored for several months without the risk of spoilage if properly packaged. Convective type dryers such as drum dryers, belt dryers and fluidised bed dryers in which heat is transferred to the food product by hot gases can be found in commercial drying plants for processing numerous industrial agri-foods. Convection drying has been employed in drying tomato on commercial basis by Zanoni *et al.* (1999).

2.9.2.2.4 Vacuum drying

Vacuum drying is one of the efficient modes of drying food which are heat sensitive and have oxidative properties (Pap, 1995). The vacuum created in the dryer enables the products to attain similar final moisture content but at lower temperatures in comparison with other methods of drying (Rajkumar, 2004). Rajkumar *et al.* (2007) reported that the quality of tomato slices dried under vacuum-assisted solar dryer was of superior quality in terms of colour retention and rehydration ratio. Zanoni *et al.*, (1999) also reported lower oxidative heat damage of tomato halves for vacuum drying compared with convection drying.

2.9.2.2.5 Freeze drying and spray drying

These methods are for producing dehydrated food powder particularly from juices or fluids obtained from foods (Castoldi *et al.*, 2015; Pavan *et al.*, 2012; Caparino *et al.*, 2013) leading to products with better commercial value and easier handling, packaging, and transportation (Cuq *et al.,* 2011). These methods have been explored in the production of tomato powder from tomato juice (Tang *et al.,* 2003; Goula and Adamopoulos, 2003, 2005a; Bhandari, 2007). Freeze drying is an expensive drying process because unlike oven air drying, which removes water in a single phase, this takes a longer time and requires a high amount of energy (Chou and Chau, 2001; Khallouf and Ratti, 2003). Freeze drying is suitable for products sold at a premium price and for foods that are sensitive to heat such as functional foods (Sablani *et al.*, 2007). In a study by Atuobi-Yeboah (2014), freeze dried tomato powder had significantly lower moisture and better colour than solar dried tomato powder due to the porous nature of freeze dried tomato (Abascal *et al.*, 2005).

Spray dried tomato powder was lighter in colour, had a more spherical structure and a higher tendency to agglomerate than cast-tape dried tomato powder (Durigon *et al.*, 2016). Goula and Adamopoulos (2005a) observed lycopene losses between 8.1and 20.9% for spray-dried tomato powder as consequence of the high inlet air temperature (110–140^{0}C) and the presence of oxygen and light.

2.9.2.2.6 Sun drying

Sun drying is one of the oldest methods for preserving and extending the shelf life of vegetables and fruits (Demir and Sacilik 2010). Sun drying is mostly done in regions where there is abundance of sunshine over long periods of time, to preserve food and reduce losses (Chen and Huang, 2005; Sacilik, Keskin and Elicin, 2006). The use of renewable energy is on the rise worldwide, as there is renewed interest in reducing the over dependence on conventional sources of energy (Duran *et al.*, 2010). Though most drying techniques involve energy costs, sun drying requires less energy (Demir and Sacilik, 2010). Traditional sun-drying is a slow process and may cause colour degradation, poor rehydration, high microbial growth and loss of certain nutrients like ascorbic acid and lycopene (Adimabuno, 2010). Some characteristics associated with sun drying of tomato include over-drying, under drying, contamination with insects, dust and microorganisms (Esper and Miihlbauer, 1999).

2.9.2.2.7 Solar drying

The difference between solar and sun drying is that solar drying employs an equipment to trap sun radiation for subsequent drying applications. Solar drying is a more attractive technology for farmers because it requires minimal capital (Lapati and Barrett, 2006). Solar drying protects food from dust, insects, pests and minimizes case hardening which may occur from direct exposure to sunlight Sacilik Keskin and Elicin 2006), Jon and Kiang 2008). Solar drying can shorten the drying time for agricultural produce by 65% in comparison with sun drying (Demir and Sacilik 2010). Tomato has a high moisture content of 95-97% and requires a lot of heat to remove the moisture to an appreciable water activity that will impede the growth of spoilage organisms. In a study by Demir and Sacilik (2010) it took 86h to reduce the moisture content of tomato for a solar tunnel dryer and 101h for open sun drying from 11.71 to 0.01 kg [H2O]/kg. The study also emphasized that tomato samples produced using the solar dryer were superior than sundried. In a study by Gallali *et al.*, (2000) mixed mode and direct solar dryers were more effective in significantly reducing the moisture content of dried grape, figs and onions as compared with sun drying.

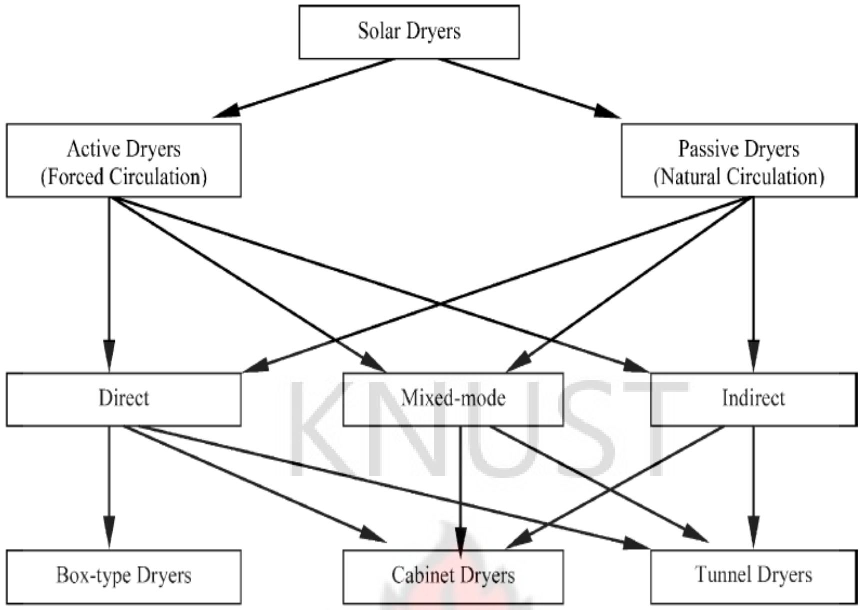
2.10 Solar Dryers

Solar dryers are effective for overcoming problems associated with open sun drying (Falade *et al.*, 2010; Doymaz and Pala 2002; Gogus and Maskan, 1999). In most solar dryer systems, air is heated by solar irradiation, the heated air passes over the products removing moisture in the process. There are a variety of dryers ranging from very primitive and small ones found in rural communities to more complex industrial solar dryers, even though the latter are still very few and under development (Belessiotis and Delyannis, 2011). Kiebling (1996) documented 66 different solar dryers in relation to their capacity, specifications, products dried and cost implications of building dryers. Fuller (1995), Ekechukwa and Norton (1999) also reviewed many solar dryers, and compared their performance and applicability in rural settings.

Though Rajkumar, (2011) and Farkas (2004) in their respective publications reviewed different types of solar dryers and evaluated their energy requirements for processing different foods, solar dryers with air flow by natural convection which requires no electric energy is mostly preferred for domestic use, in rural and remote settings (Afriyie *et al.*, 2011). Figure 2.1 represents the different categories of solar food dryers based on their mode of operation and energy utilization. Solar dryers are grouped into two based on the mode of operating as direct and indirect dryers. (Jon and Kiang, 2008; Belessiotis and Delyannis, 2010). Sun rays directly heat the air in the chamber where the products are enclosed with a clear lid which facilitates the removal of water in the food material and outlets to allow for air exchange in direct dryers (Leon, 2002). Direct solar dryers are easy to design and build and also least expensive (Afriyie *et al.*, 2011).

In the case of indirect dryers; air is heated in a chamber known as a collector and moved naturally or aided by a fan into a separate food chamber in order not expose the food to direct sunlight. This dryer type is often used for food whose nutritional properties are sensitive to direct sunlight (Lopez-Malo and Rios-Casas, 2008; Leon, Kumar and Bhattacharya 2002). They are more complex to build and more expensive than direct solar dryers. Mixed mode dryers are a combination of features of direct and indirect dryers. These dryers are more expensive but cause less damage to food from ultra violet irradiation than the direct dryers.

Hybrid dryers combine solar heating with other energy sources such as fossil fuel or biomass. In many rural areas the use of residues from crops such as maize cobs, rice husk, and rice bran are readily available and generally underutilized (Leon *et al.,* 2002). In as much as this technology is promising to ensure easy access and adoption solar dryers should incorporate features such as; easy construction, easy operation ease of maintenance and replacement of parts, efficiency and effectiveness in enhancing drying (Jon and Kiang, 2008).



Source: Leon et al., (2002).

Figure. 2.1. Categories of solar dryers and drying modes.

a) *b*

Source http://energymarketers.in/portfolio/solar-dryer/ *photo credits: Mavis Owureku-Asare*

c)

source: http://www.goodagronews.com/category/researchpossibility/

Plate 1.3 Natural passive solar dryers a) box b) cabinet c) tunnel type

2.11 Solar Cabinet Dryers

These types of dryers are ideal for drying fruits and vegetables. substantial savings can be made on these types of dryers since they employ sustainable energy for drying (Panwar, 2012). These dryers are suitable for onsite farm drying and within remote communities immediately after field harvest (Belessiotis and Delyannis, 2011). They are easy and cheaper to operate because they use natural convection. Though cabinet dryers may come in different types and shapes, they have common features consisting of three components:

i) Solar collector, which receives the sunrays and move it to the drying chamber.

ii) A drying chamber with walls made of glass, wood or plastic material containing trays on which food is dried.

iii) A chimney or exhaust located at the end of the system which increases the convective flow of the air through the dryer. (Ghaffari and Mehdipour, 2015).

There is the need to improve the design, heat exchange and drying rate of passive solar dryers to enhance dryer performance (Duran, 2015; Afriyie *et al.*, 2011; Fudholi *et al.*, 2010). Soda and Chandra (1994) indicated that technical performance must be evaluated to provide a basis to compare passive cabinet dryers with other dryers. Parameters considered in the evaluation of solar dryers are thermal performance of solar dryers and solar dryer efficiency.

2.11.1. Thermal performance of solar dryers

Thermal performance of a dryer is dependent on the drying time/drying rate, drying air temperature, airflow rate, relative humidity and efficiency (Singh and Kumar, 2012). For performance comparison of different dryer designs, the tests must take into account the influence of these climatic variables on the drying efficiency (Altobelli *et al.*, 2014).

The thermal sensitivity of most fruits and vegetables limits the operation of dryers at high temperatures. Ideally tomato should be dried between 50-60 ^{o}C (Mahapatra and Imre 1990; Prakash, 1997) as high temperature in the beginning of drying causes case hardening whiles food may scorch when temperature is high towards the end of the drying period (Hughes and Willenberg, 1993).

2.11.2. Solar Dryer Efficiency

Drying efficiency is an index of dryer performance (Leon *et al.,* 2002). This performance depends on the product being dried, the drying air characteristics, and the dimensional variables of the dryer (Mills-Gray, 2015). Passive crop dryers like box dryers, tunnel dryers and cabinet dryers have efficiencies ranging between 10-15% (Altobelli *et al*., 2014). Performance evaluation of solar food dryers is highly dependent on the time used to dry a product and this can be an index for the comparison of different dryers (Ranjbaran and Zare, 2013).

2.12. Effect of drying on food quality

The quality of the dried product gives an indication of the performance of a dryer (Chen *et al.,* 2005). Application of heat in processing tomato causes changes to its nutritional properties. Tomato goes through volumetric, physical and chemical changes during drying (Chen, *et al.,* 2005). Physical changes to shape, colour and texture as well as chemical and enzymatic reactions effecting changes in the flavour, colour and the nutrients of dried products occurs during the drying process (Lin *et* *al.*,1998). Handling practices and preparation methods prior to drying, can also cause loss of nutrients of dried tomato (Gallali, 2000).

2.12.1 Chemical Quality

Enzymatic and non-enzymatic browning are common changes that can affect tomato during drying. Non-enzymatic browning (Maillard reaction), occurs when reducing sugar react with amino acid at high temperatures; and enzymatic browning involves the activity of polyphenoloxidase and other enzymes (Lewicki and Jakubczyk, 2004; Pizzocaro, *et al.*, 1993). Both reactions are affected by temperature; however, at very high temperatures Maillard reaction takes place over enzymatic browning which is usually controlled by blanching and the use of chemical such as sodium bisulphite (Lapati and Barette, 2006).

2.12.2 Nutritional Quality

Heat destroys some types of vitamins such as thiamine but water-soluble vitamins are more stable to heat and oxidation during drying (Leon *et al.*, 2002). During preparation and the drying of tomato losses in ash, sugar, vitamin C, beta-carotene content, and acidity is incurred (Gallali *et al.*, 2000; Soponronnarit *et al.*, 1993). Higher ash content may be an indicator of contamination by dust, and decrease in sugar content and ascorbic acid may be due to higher drying temperatures and longer drying periods. Increases in acidity may be due to fermentation and quality deterioration (Leon *et al.,* 2002). Thermal treatments may cause oxidation of ascorbic acid, in tomato to dehydroascorbic acid before going through further irreversible degradation (Capanoglu, 2008; Gahler *et al.*,2003; Dewanto, *et al.*, 2002). Alteration of carotenoids during drying of tomato may be as a result of enzymatic or non-enzymatic oxidation (Rodriguez-Amaya, 1999b, 2002). Gallalia *et al.* (2000) reported that due to the relatively higher temperature inside solar dryer, loss of vitamin C and sugars were higher than open-sun drying.

2.12.3 Microbial Quality

Water activity (a_w) of dried tomato, is an indicator of microbial growth and toxin release and is of significant importance for food preservation (Mills-Gray, 2015; Belessiotis and Delyannis, 2011). Most microbial activity is inhibited below aw 0.6, fungi, yeast and bacteria are inhibited below aw 0.7, 0.8 and 0.9 respectively (Mills-Gray, 2015) Also the combination effect of certain conditions such as temperature, aw, pH, oxygen and carbon dioxide, and or chemical preservatives will alter or prevent the growth of microorganisms in dried tomato even during storage (Prabhakar and Venkateswara., 2014)**.**

2.12.4 Sensory Quality

Sensory quality is influenced by different senses of perception in one's choice of consuming a particular food (Leon *et al.,* 2002). Drying at higher temperatures causes volatile losses and chemical reactions which damage flavour profile and sensory appeal of the dehydrated product (Praveenkumar *et al.,* 2006; Prakash *et al.,* 2004).

Loss of sensory quality in tomatoes is associated with reduction of sweetness and acidic taste, flavour intensity and firmness (Grierson and Kader, 1986). In a study by Gallali *et al.* (2000), sundried tomato without any pre drying treatment had better sensory qualities than solar dried tomato. However other fruits in the same study dried in a solar dryer recorded higher scores for quality and acceptability from consumers than sundried. Pretreatment enhanced the sensory quality attributes of solar dried tomato. Flavour and colour mainly affects commercialization of tomato thus these must be enhanced (León-Sánchez, 2009). In a study by Chen *et al.* (2005) sensory characteristics such as colour, aroma, orange peel flavour of dried lemon slices was better for samples dried with solar dryer with gradual temperature changes than that of hot oven dryer set at a constant temperature at 60 ^{o}C. Thus the sensory quality of the dried products can be used to assess the performance of the designed dryer systems.

2.12.5 Physical Quality

Physical and physicochemical changes (Krokida and Maroulis, 1997) chemical changes occur that affect saccharides and proteins in food tissues (Soria *et al.,* 2010). This causes shrinkage and reduces the water holding capacity and the rehydration ability of dehydrated fruits and vegetables (Lewicki, 2006; Panyawong and

Devahastin, 2007; Rajkumar *et al.*, 2007). Due to structural changes that happens during drying, dehydrated products do not keep their visco-elastic behaviour (Krokida *et al.*, 1999).

Pre-drying treatments and drying affects the structure of plant tissues and alters rehydration properties of tomato which enhances its use in food preparation (Taiwo *et al.* 2002; Lewis, 1987). Khedkar and Roy (1990) reported a higher rehydration ratio for cabinet-dried mango than sundried mango because the cells of cabinet dried mango undergo less rupture than sun dried mango.

2.13. Methods of pre-treatment

2.13.1 Blanching

Blanching is commonly used as pre-treatment for processing dried fruits and vegetables (Severini *et al.*, 2005). Blanching with hot water or steam is applied to tomato prior to drying as a way of inactivating enzymes which may otherwise facilitate certain reactions, that result in undesirable colour, texture or flavor changes (Belessiotis and Delyannis, 2011; Falade *et al.*, 2010; Severini *et al.*, 2005)

The extent of blanching affects the texture and appearance, colour, flavour and other sensory characteristics of the dried product (Piga *et al.*, 2004). It also affects the rate of dehydration and reduces microbial contamination (Falade and Shogaolu 2010). Blanching vegetables before drying causes some losses of some water soluble vitamins such as vitamin C, B-complex and minerals (Leon *et al.*, 2002).

2.13.2 Use of Sulphur based compounds

Gaseous sulphur dioxide, sodium or potassium bisulphite and metabisulphite are commonly used for pre-treating some fruits and vegetables during processing. This process known as sulphiting, protects the product against non-enzymatic browning during drying and storage (Latapi and Barrett, 2006).

Sodium metabisulphite pre-treatment of tomato slices prior to drying significantly affected rehydration ratio, yeast count and colour because sulphites plasmolysed the cells which facilitated the drying process (Gould and Russel, 1991). The lycopene content of dried tomato was enhanced when tomato slices were pre-treated with sodium metabisulphite solution before convection drying (Owureku-Asare *et al.,* 2014). Pre-treatment of tomatoes with 6% or 8% sodium metabisulphite for 5 min before drying produced the best colour, increased rehydration ratio and reduced the microflora count of dried tomato (Latapi and Barrett, 2006). Thus concentration of the dipping solution and dipping time significantly affected the final sulphur dioxide content of sun-dried tomato (Latapi and Barrett, 2006; Pazyr *et al.,* 1996). Reducing sodium intake, increasing potassium intake, and use of potassium-containing salt substitutes in the diet significantly decrease blood pressure, particularly among those with hypertension (Sun *et al.,* 2017). Thus Potassium metabisulphite is a better substitute to sodium metasuiphite as a preservative.

Treating fruits with sulphur dioxide reduces the rate of ascorbic acid losses during processing and storage (Tharrington *et al.,* 2005). Although the limits of sulphite are generally established according to the purchasing company's specifications, Davis *et al.,* (1973) indicated that an initial sulphur dioxide content of 3,000mg/kg ensures acceptable quality of dried fruits. The safety of sulphites and their role in triggering asthmatic reactions in some sensitive people has been questioned (Taylor *et al.*, 1986). Thus the Food and Drug Agency (FDA) in 1986 modified the limits of sulphite use in fruits and vegetables by reducing GRAS (Generally Recognised as Safe) levels of sulphite. In this regard, we should minimise the use sulphites within safe limits for food preservation. Fruits have also been pre-treated with ascorbic acid solution to prevent darkening and to prevent bacteria contamination during drying (Kingsly *et al.*, 2006).

2.13.3. Osmotic pre-drying treatment

Osmotic treatment, a dewatering process involves putting the food material in a hypertonic solution of concentrated sugar or salt solution, which facilitates the migration of water from the cells of the food material into the solution (Falade, 2009; Sereno *et al.*, 2001). The moisture content of the food material is reduced by 30–50% (Falade *et al.*, 2009). Osmotic treatment prior to drying preserves flavour, odour and nutrients and prevents microbial spoilage enhancing the shelf life of the dried fruit. (Mayor *et al.*, 2006; Mandala *et al.*, 2005). In a study by Falade (2010), effective moisture diffusivity of dried pumpkin slices increased with pre-treatment osmotic solution concentration as compared to pre-treatment by blanching in hot water.

2.13.4. Dipping in chemical solutions

The effects of pre-treating various fruits and vegetables in different chemical solutions prior to drying are reported in literature (Doymaz, 2004; Doymaz and Pala, 2002; Vargas and Camacho, 1996). Tomatoes have been pre-treated with different solutions such as calcium chloride (Lewicki and Michaluk, 2004), sodium chloride (Sacilik *et al.*, 2006) based on their antimicrobial, antioxidant activities and ability to inhibit enzyme activities in foods. In a study by Lapati and Barretti (2006), pre-treating tomato with salt solutions before sun-drying resulted in significant reduction in yeast cell count and rehydration rate of sun-dried tomato.

In a study by Davoodi *et al.* (2007), combination of two pre-treatments; dipping in 1 g/100 g $CaCl_2$ in combination with 0.2 g/100 g (Potassium metabisulphite) for 10 min produced tomato powder with high quality and red colour similar to the fresh tomato powder over 6 months of storage. Tomato pre-treated with 15% Sodium chloride (NaCl) solution after three months of storage exhibited darker brown compared with sulphited products. (Latapi and Barrett, 2006). Salt can be used as an antimicrobial agent because it can inactivate enzyme systems vital to the cell. Pre-treatment with ethyl oleate facilitated the drying and rehydration of dried tomatoes (Doymaz, 2002).

2.14. Consumer knowledge, perceptions and patronage of new food products

Consumer demand for novel products is crucial for driving the needed innovations for New Product Development (NPD). Even though new technology and market opportunities can lead to NPD (Eliashberg *et al.*, 1997), consumers are the ultimate judge responsible for the successful adoption of new products (Brown and Eisenhardt,1995). Consumer research helps to assess and predict the success and performance of a product on the market (van Kleef *et al.,* 2005; Brown and Eisenhardt, 1995). Research indicate that, consumer knowledge and attitude influences their behaviour towards new products (Redmond and Griffith, 2007; Drichoutis and Lazaridis, 2005; Haapala and Probart, 2004). These research findings also show that prior knowledge and experience of a product influences this choice process (Anderson, 2008). Perner, (2010) defines consumer attitude as a response result of consumer's beliefs, feelings and response towards which can range from very negative to very positive (Tenbult, 2011). Dried tomato products may not be a new product parse, however, the product is not readily available to many consumers in Ghana. Consumer perceptions, knowledge and attitude towards solar dried tomato will influence its patronage. Consumer studies is therefore important components for the development of this product.

2.15. Sensory Evaluation

Sensory evaluation and consumer studies helps us understand the connection between food properties and purchasing power of consumers as well as generate huge amounts of data which can help with enhancing food product development (Naes *et al.*, 2010).

Sensory evaluation enables the use of scientific methods to evoke, measure, analyse and interpret product characteristics to perceived human senses (Stone and Sidel, 2004).

Different sensory test methods use participants selected using different criteria to achieve different goals.

2.15.1. *Quantitative Descriptive Analysis (QDA)*

Descriptive analysis involves the detection (discrimination) and the description of both the qualitative and quantitative sensory aspects of a product by trained panels of judges (Meilgaard *et al.,* 2007). Descriptive testing has proven to be the most comprehensive and informative sensory evaluation tool used to quantify perceived intensities of sensory characteristics of a product (Moussaoui and Varela, 2010; Lawless and Heymann, 2000). Using a panel of trained judges in a method design know as Quantitative Descriptive Analysis (QDA), it has been used to characterize changes in different products and answered research questions in food sensory (Stone and Sidel, 2004). The information gathered in QDA can be related to consumer acceptance data and instrumental measures using statistical techniques such as regression and correlation (Lawless and Heymann, 1999).

2.15.2 *Central Location Test (CLT) verses Home Use Test (HUT)*

Marketing professionals and sensory scientists have several hedonic testing methods at their disposal to assess product acceptability. CLT and HUT are two types of testing methods employed for consumer testing.

The Central Location Test (CLT) usually takes place in a standardised location such as a food sensory laboratory, school, mall under controlled conditions where subjects taste the food and rate on a Hedonic scale (Lawless and Heymann, 2010). CLT is more frequently used and provides a more controlled environment where food product preparation, service and assessment of the product is done (Ressurreccion, 1998).

Home Use Test though expensive and time consuming are more practical and realistic test as consumers take the products home to assess in a more natural uncontrolled environment (Lawless and Heymann, 2010). Given the artificial conditions of a CLT, it is assumed that a more realistic HUT yields more relevant Hedonic data in spite of the uncontrolled conditions. (Boutrolle *et al.,* 2005; Meiselman, 1992).

In a comparative study of CLT and HUT by Meiselman (1992) for two fermented milk beverages with different fat and sugar content, significant differences in the degree of likingness was recorded though, the scores for "likeness" was higher with HUT than CLT.

CHAPTER THREE: Consumer knowledge, preferences, perceptions and patronage of dried tomato in Ghana

3.1 Introduction

Industrial processing of tomatoes in Ghana remains very low due to a variety of reasons such as irregular raw material supplies, poor maintenance cycles of equipment and the lack of adequate skilled labour (Robinson and Kolavalli, 2010). Consequently, alternative processing method such as drying of fresh, ripe tomato into dried tomato products needs to be explored to extend the shelf life as well as add value to the crop.

Several methods of drying have been employed for food (Doymaz and Pala, 2002; Telis and Sobral, 2002; Kingsly *et al.*, 2007; Ekow, 2013), and among them solar drying has been effective. The technology of solar drying has been practiced for different foods for decades, and it is a promising technology for drying tomato even though it has rarely been used for that purpose. Drying using electric (convention) ovens is more commonly practiced but it is also much more expensive due to the high moisture content in fresh tomatoes and the associated energy costs. There are several types of solar dryers, but the passive type, whose operation does not depend on electric energy, will be more suited for tropical communities (Afriyie *et al.*, 2011).

While drying tomatoes in a solar dryer may appear easy and inexpensive, the same might not be said for consumer acceptability of the dried products for food applications. Dried tomatoes will have functional and quality characteristics that are very different from the fresh ones, and product quality characteristics are very important in consumer choices. Moreover, fresh tomatoes are generally more accepted in both traditional and cultural food applications. Also improved tomato varieties (such as Pectomech, roma and pecktofeck) which are suitable for processing are mostly preferred by consumers and achieve a premium price over the local varieties (Robinson and Kolavalli, 2010). Cultural factors influence food choices (Rozin and Vollmecke, 1986) because of differences in both perception and preference (Prescott and Bell, 1995). However, consumers' perceptions are quite dynamic and the usage and demand of a product may depend more on the consumer's perception about the product (Koster and Mojet, 2007). For traditional or local food products, consumers rarely make food choices in the absence of extrinsic factors of personal, social and cultural significance (Trubek, 2008; Sutton, 2010; Paxson, 2013). Alphonce *et al.* (2015) showed that consumer preferences for dried fruit are affected significantly by its typical aroma intensity.

Several studies have also examined the relationship between consumer perceptions or preference and how that is incorporated into the quality characteristics of the product through the production process (Korzen and Lassen, 2010; Mueller and Szolnoki, 2010; Cerjak *et al.*, 2011; Chrea *et al.*, 2011). These are important prerequisites for market success of a new product, especially at an early stage of their transformation into marketable products (Siegrist, 2008). The quality of dried tomato when assessed by consumers may or may not be as expected to influence the purchase of the product. Consumer surveys provide information needed to manage and shift consumer expectations on products. It is inherent to assess factors that influence consumers interest in a new product. These factors; knowledge, perception, attitude, concerns, and assessment of the products will influence consumption. This study thus sought to assess the knowledge, preference, likely patronage, and perceived quality of solar dried tomato products by consumers.

3.1.1 Specific Objective

To assess consumer knowledge, preferences, perceptions and patronage of dried tomato.

3.2 Materials and methods

3.2.1 Methodology

A survey was carried out by administering semi-structured questionnaires to randomly selected and willing respondents in the Accra Metropolis. Preliminary survey was conducted to pre-test the questionnaires using 25 subjects. Response gathered was used to validate and modify questionnaires used in the survey. A sample size of 395 was obtained using the method described by Moore and McCabe, (1993). Respondents were randomly sampled to participate in the survey. Although self-administration of questionnaire was encouraged, in situations where respondents could not fill out the questionnaire independently, field assistants were available to help them write out their responses (in a language of mutual understanding) as accurately as possible. Questions were designed to assess among other things, consumer's preference, ranking, and scoring of desirable quality attributes of dried tomatoes. Information on product preference, production quality and packaging preference for dried tomatoes were provided by consumers. Information gathered on product quality attributes will serve as baseline and guide in the production of dried tomato using solar drying technique.

3.2.2. Study Location

The locations for sampling in the survey included all five residential classes based on socio-economic classification of Accra, according to the Accra Metropolitan Development Classification of Accra. The locations for sampling of respondents in the survey included parts of central, northern, southern, eastern and western parts of Accra in order to make the sample population representative of Accra. First class residential areas respondent were sampled from included Airport residential area, Dzorwulu and East Legon. Second class areas included Korle-bu, Haatso, Adabraka and Tudu. Third class residential areas included Ashongman and Dome and fourth class area included Ashaiman, Teshie and La. Fifth class areas included Nima, Mamobi and Madina Zongo. The survey was conducted in Accra because, Accra is a cosmopolitan city with residents representing different ethnic groups from all the regions of Ghana.

3.2.3. Data Analysis

Data entry and analysis was done using Statistical Package for Social Sciences (SPSS version 16.0). Frequencies were generated for variables and significant associations were tested at $p \leq 0.05$ using Chi-square test. Information including preference of tomato products, ranking of quality attributes, production quality and packaging preference for dried tomato were gathered from potential consumers.

3.3. Results and Discussion

3.3.1. Demographics of respondents

Table 3.1 presents the factors that influence food choices of consumers, demographic information including gender, age, level of education, and marital status of the respondents.

Table 3.1: Demographics of respondents in a consumer survey of dried tomato products in Accra metropolis, Ghana.

Demographic variable	Number of respondents	Percentage (%)
A. Gender		
Male	169	42.8
Female	226	57.2
Total	395	100.0
B. Age		
< 25	183	46.3
26-35	107	27.1
36-45	62	15.7
46-55	32	8.1
56+	11	2.8
Total	395	100
C. Respondents region of birth		
Greater Accra	82	21.0
Central	63	16.2
Western	20	5.1
Eastern	68	17.4
Brong Ahafo	10	2.6
Volta	68	17.4
Northern	15	3.8
Upper East	5	1.3
Upper West		1.0
Ashanti	55	14.1
Total	390	100.0
D. Marital status		
Married	114	28.9
Single	259	65.6
Divorced / Separated	12	3.0
Widowed	10	2.5
Total	395	100
E. Highest educational status		
None	18	4.6
Primary	8	2.0
Junior high school	62	15.7

/ O level		
Senior high school / A level	101	25.6
Tertiary	206	52.2
Total	395	100.0
F. Main occupation		
Unemployed	26	6.6
Self employed	134	33.9
Private sector	89	22.5
Civil / public servant	26	6.6
Student	110	27.8
Apprentice	10	2.5
Total	395	100

Females mostly decide on the products used for cooking in the home, as such women (57.2 %) were therefore more willing to take part in this survey compared to males. The majority of respondents were aged below 35 years (Table 3.1). This indicates that the younger generation is more curious or "adventurous" and willing to participate in a survey, the findings could potentially have some influence on their food choices. The age of the respondents also aligns with the marital status of the respondents with majority of them being single. Of the 395 respondents, 390 were Ghanaians and an overwhelming majority of the respondents (95.4 %) had some form of formal education. Aside from students (27.8 %) and a few (6.6 %) who were not engaged in any gainful employment, most respondents (65.6 %) were engaged in one form of income generating activity and had purchasing power for buying commercial and/or novel food products.

3.3.2. Consumer preference and patronage patterns of tomato products

The respondents had fairly uniform and near unanimous perceptions and opinions on their choice of tomato products. Majority of them (93 %) like tomato products either extremely or moderately, (Table 3.2). While students generally showed moderate preference for tomato products, most other respondents, irrespective of occupation showed extreme preference for them. Almost half (47.6 %) of the respondents would buy dried tomato products from the open market rather than from a shop or supermarket because the prices of food ingredients are usually less expensive on the open market than in supermarkets. Occupation or socio-economic standing did not significantly ($p \leq 0.05$) influence the respondents' choice for the open market purchase over supermarkets (Table 2). The quality of dried tomato on the local market should be monitored and improved because it was the most preferred choice for consumers

Consumer rankings for tomato products are presented in Table 3.3. The data show that tomato products may be divided into two significantly different groups based on preference rankings: familiar tomato products and non-familiar products. Fresh tomatoes and canned tomato products are quite familiar to most consumers and were ranked very high, with no significant differences between them. On the other hand, cut dried tomatoes and powdered tomatoes, which are less common among consumers, were ranked extremely low, with no significant ($p \leq 0.05$) differences between them. Tomato paste and fresh tomato are used in a wide variety of soups, sauces, stews mainly to impart flavours and colour (Latapi and Barette, 2006; Yahia and Brecht, 2012). Canned tomatoes are readily available and convenient products on the Ghanaian market. Aggey *et al.* (2007) reported that at least 7 in 10 households use tomato paste in preparing their meals during the lean season.

Description	Occupation						X^2	df	p-value
How much do you like tomato or tomato products?	Unemployed	Self employed	private sector	civil/ public servant	Student	Apprentice			
Extremely	53.8	70.9	62.9	64.0	40.0	100	38.712	12	0.01
Moderately	34.6	21.6	29.2	32.0	53.6	0			
Slightly	11.5	7.5	7.9	4.0	6.4	0			
How would you prefer to obtain dried tomato?									
Prepare yourself	11.8	23.2	14.1	6.2	15.2	25.0	15.314	18	0.64
Open market	52.9	49.5	43.8	43.8	48.5	37.5			
Shop	23.5	12.6	15.6	6.2	13.6	12.5			
Supermarket	11.8	14.7	26.6	43.8	22.7	25.0			

Table 3.2: Association between occupation of respondents and their preference for tomato products.

***X^2* - chi-square, df-degree of freedom, and significance at p≤ 0.05**

Table 3.3. Consumer preference ranking of tomato products in Accra, Ghana

Tomato Product	Rank mean ± SD
Fresh tomato	$3.89^{a} \pm 0.810$
Canned tomato	$2.77^{ab} \pm 0.669$
Cut dried tomato	$1.05^{c} \pm 0.588$
Tomato powder	$1.02^{c} \pm 0.718$

****Maximum rank mean is 4, where 1 is least preferred and 4 is most preferred, at p≤ 0.05***

On the other hand, consumption of dried tomato and tomato powder appears to be very low. Adimabuno (2010) observed that because the processing of sun or solar drying of tomato is tedious and laborious farmers prefer to sell tomatoes fresh than in the dried form. The development of a solar dryer that is easy to use, with improved yield and good quality products may appeal to farmers to process dried tomato products. Traditionally dried tomatoes are not commonly used in the preparation of meals, and therefore their consumption is very low although, the concept of dried tomatoes is not entirely new among food processors. There is a product made using milled annatto seeds, corn, cola nuts and colours from the E colour series for red, and sold as "tomato powder" in some markets in Accra. The product is highly patronized by cottage food processors and street food vendors as an inexpensive substitute for tomato paste. The patronage of this product suggests that hygienically processed solar dried tomatoes of good quality and the right colour will be acceptable to food processors.

Table 3.4. Assessment of consumer desirable attributes for fresh and dried tomatoes

Fresh tomato attributes	Rank mean ± SD	Dried tomato attributes	Rank mean ± SD
Colour	$3.17^{a} \pm 1.27$	Colour	$1.05^{cd} \pm 1.44$
Functionality	$3.1^{a} \pm 1.24$	Functionality	$2.5^{b} \pm 2.01$
Taste	$3.04^{b} \pm 1.38$	taste	$4.3^{a} \pm 1.62$
Texture	$2.94^{b} \pm 1.36$	texture	$1.9^{bc} \pm 1.02$
Flavour	$2.64^{c} \pm 1.41$	flavour	$2.74^{ab} \pm 1.33$

Values with the different alphabets as superscript along the column are significantly different at $p \leq 0.05$. the rank scale is 1-5, where 1 is the lowest and 5 the highest rank for desirable product attribute.

Fresh tomato of high quality is red in colour, with a firm but juicy texture, good taste and flavour. Though the fruit comes in different colours such as red, pink, yellow, and orange, the characteristic red colour is the most desired (Latapi and Barett, 2006; Yahia and Brecht, 2012). Table 3.4 shows that consumers buy fresh tomato based on the colour (rank mean = 3.17 out of 5) and not flavour (rank mean = 2.64 out of 5). The data suggest that colour, functionality and taste were the most critical attributes of fresh tomato that consumers seek. Attributes of dried tomato are also very important to consumers as revealed by the significant differences observed in their rank means ($p \leq 0.05$). Even though the characteristic red colour was the most desirable quality attribute associated with fresh tomato, taste and flavour were ranked as the most desirable attributes for dried tomato products. Flavour and colour mainly affects commercialization of tomato (León-Sánchez *et al*., 2009) thus these quality attributes must be enhanced.

Taste and aroma constituents, influence the flavour of tomato and is mainly affected by interactions between sugars and acids (citric and malic) and is also responsible for sweetness, sourness and overall flavour intensity in tomatoes (Malundo *et al.*, 1995).

Table 3.5. Consumption pattern of tomato products

Variable	Number of respondents	Percentage (%)
A. How often do you consume foods containing tomato? Products (in a week)?		
B. Very often (every day)	275	69.6
Often (at least 3 - 6 days in a week)	104	26.3
Not that often (at least 1 day in a week)	16	4.1
Total	395	100.0
C. What alternative ingredients do you use when fresh tomato is not available or in season?		
D. No alternative ingredients	330	83.5
Alternative ingredients	65	16.5
Total	395	100
E. Have you patronised dried tomato products before?		
Yes	13	3.3
No	382	96.7
Total	395	100

Consumers patronage of tomato products presented in Table 3.5 indicate that majority of the respondents (69.6%) consumed tomato at least once daily while only 4.1% consumed at least once a week. Thus most individuals consume tomatoes every week and all year round, irrespective of season. With high post-harvest losses during harvest season, it is imperative from this result that the development of solar dried products could make dried products available for consumers. The study also revealed that most of the respondents (83.5 %) do not use alternative ingredients as substitute to tomato products during the lean season for tomato production.

3.3.3. Consumer patronage of fresh and processed tomato products

Figure 3.1. shows high consumer patronage for fresh tomato (95.9 %) because of its utilization in most Ghanaian sauces (Tambo and Gbemu, 2010), stews and salad. Canned tomato is the second most patronised (74.9%) tomato product with the least being dried tomato (2.3%) and tomato juice (2.8%). The seemingly low availability of good-quality dried tomato products on the market could be one reason for the low patronage of dried tomato. The introduction of improved solar drying technologies that could retain the nutrient content of fresh tomato with improved re-constitution characteristics similar to tomato paste could change consumer patronage of dried tomato products.

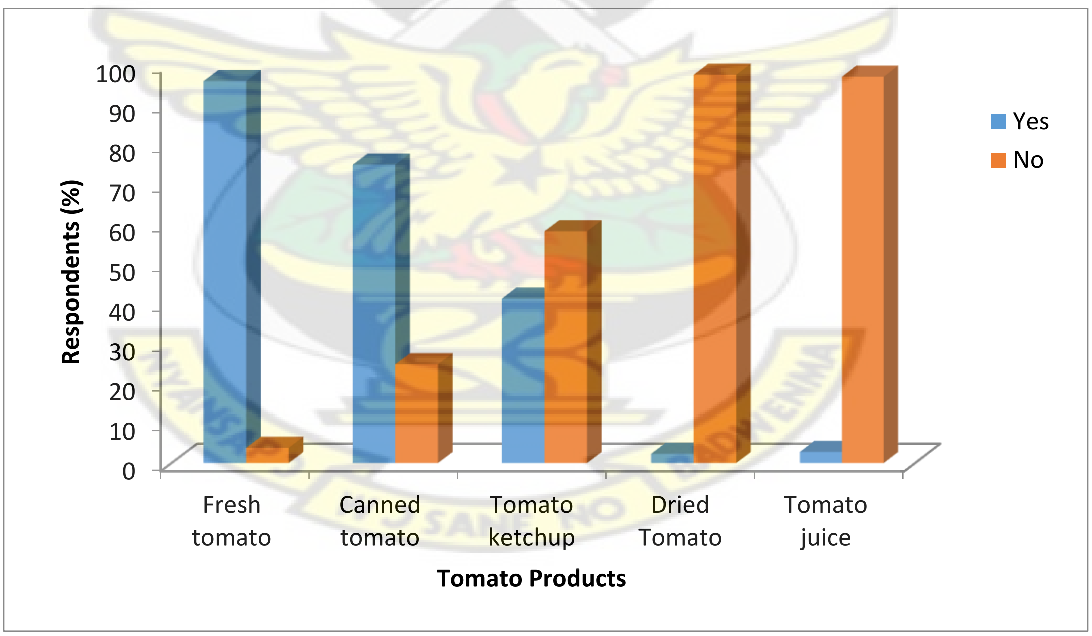


Figure 3.1. Consumer patronage of fresh and processed tomato products

Table 3.6. Consumer preference for dried tomato products

Variable	Respondents (%) Yes	No
Will you consume dried tomato products?	32	68
What is your preference for dried tomato products?		
Half dried	8	92
Diced dried	18	82
Tomato powder	74	26
What is your reason for patronising dried tomato?		
convenience	65.6	34.4
availability	48.6	51.4
suitability	35.1	64.9
cost	33.3	66.7
Other	6.3	93.7
What mode of drying would you use for tomato?		
Sun drying	46	54
Solar drying	26	74
Oven drying	28	72

Although dried tomato products are not highly patronized by consumers more than half of them (68 %), are willing to patronize dried tomato products if they are readily available on the market (Table 3.6). Majority (74 %) of the respondents will prefer dried tomato products to be in the powdered form, compared with cut dried tomato. The least preferred dried tomato products (8 %) are those that are halved and dried. The low patronage of tomato powder among Ghanaian consumer could be due to the lack of knowledge on the potential uses and functionality of dried tomato for preparing local dishes. Consumers would patronize dried tomato because of convenience (65.6 %) and if it is readily available for purchase (48.6 %). Consumers preferred to explore sun-drying for processing dried tomato over solar-drying because sun-drying is simple and requires no capital input to set up.

3.3.4 Knowledge and understanding of the economics of the tomato distribution system.

Consumer knowledge can be identified in two main components: familiarity of the product and its functionality or performance as an ingredient in a related product (Alba *et al.,* 1991). About 91% of consumers are not aware of the availability of dried tomato products (Table 3.7). An alternative “dried tomato powder” is made of annatto seeds.

Tomato growers lose more than 40 % of their produce before it reaches the final consumer due to poor postharvest handling (Gustavsson *et al.*, 2011). In Ghana, at the height of the harvest season, farmers may lose about 20-50 % of produce due to the lack of adequate processing facilities which results in severe price fluctuations during the year (Kader, 1992). Majority of the consumers (82.8 %) are aware of price fluctuations in tomatoes and 75.2 % are also aware of the post-harvest losses of tomato (Table 7). About half the numbers of respondents (50.8 %) believe that post-harvest losses (PHL) highly contribute to fluctuations in the price of tomato and there is the need to reducing PHL in order to stabilize tomato prices.

Table 3.7. Consumer knowledge of tomato economics in Accra Metropolis

Description	Number of respondents	Percentage (%)
Are you aware of the fluctuations in the price of tomato?		
Yes	327	82.8
No	68	17.2
Total	395	100
Are you aware of the postharvest? losses of tomato?		
Yes	297	75.2
No	98	24.8
Total	395	100
To what extent do postharvest losses contribute to price fluctuations of tomato?		
High	151	50.8
Moderate	114	38.4
Low	32	10.8
None	98	24.81
Total	395	100.0
Are you aware of the production and sale of tomato powder in some markets in Ghana?		
Yes	36	9.2
No	359	90.8
Total	395	100

3.3.5. Consumer perceptions of dried tomato quality

Although there was no significant association between educational background and mode of drying tomato ($X^2 = 10.434$, df = 8, $p < 0.236$) (Table 3.8), solar drying was embraced mainly by respondents with tertiary (26.0 %) and secondary (21.3 %) education. The mode of drying, rate of drying and reactions occurring during drying can affect the quality of the dried products (Sabarez, 2008). As such when tomato is dried in a controlled environment there is a low likelihood of contamination by pests and other extraneous material such as dust. In comparison with open sun drying, the drying time for solar dryers can be reduced by about 65% improving the hygienic quality, facilitating the removal of moisture and preventing the products from contact with environmental factors such as rain, dust and insects (Mechlouch *et al.*, 2012). The proposed improved cabinet solar dryer is portable and can be used at the household level by the consumers.

Table 3.8. Association between Education and processing quality of dried tomato

Description	Highest Educational level achieved (%)					X^2	df	p-value
What method will you use to prepare dried tomato?	None	Primary	Junior High School	Senior high School	Tertiary			
Open sun drying	54.5	50.0	41.3	52.1	44.1	10.434	8	0.236
Solar drying	27.3	50.0	32.6	26.0	21.3			
Oven drying	18.2	0	26.1	21.9	34.6			
Do you have concerns about the quality of dried tomato products?								
Yes	50.0	50.0	41.9	52.5	49	1.733	4	0.785
No	50.0	50.0	58.1	47.5	51			

X^2 chi-square, df-degree of freedom, and significance at $p \leq .05$.

3.3.6. Consumer concerns of dried tomato quality.

Consumers' concerns about the quality of dried tomato were categorized into two groups: concerns about the quality during production (Figure 3.2) and attribute quality (Figure 3.3).

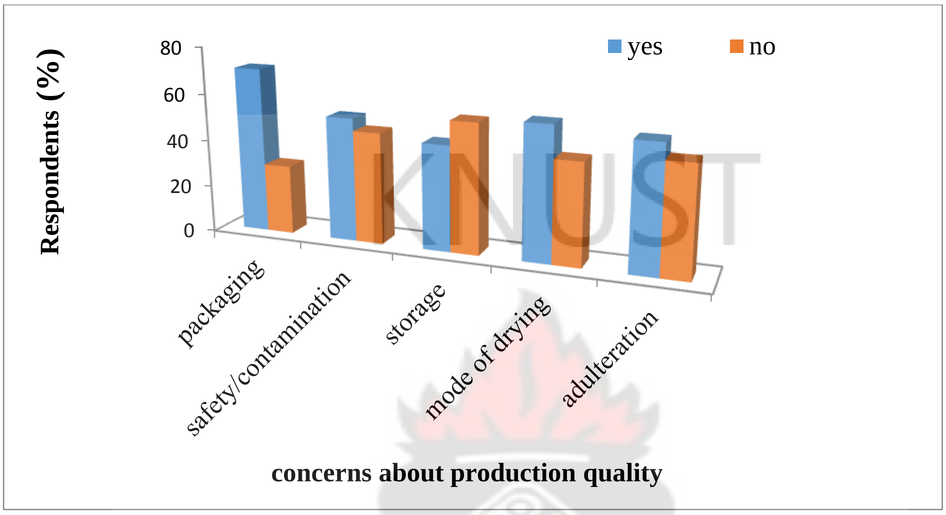


Figure 3.2. Consumer concerns about production quality of dried tomato (n = 154)

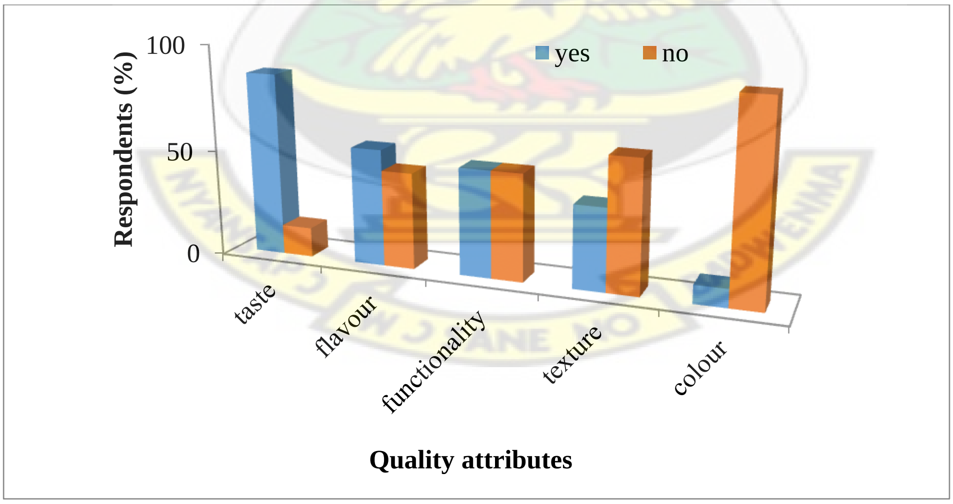


Figure 3.3. Consumer concerns about attribute quality of dried tomato (n = 84).

Concerns of respondents were more about the production quality of dried tomato products. The quality of fresh tomatoes was assessed based on appearance, with colour being the most important quality attribute (Latapi and Barett, 2006), but repeated purchase depended on other quality attributes such as taste, texture and nutritional value. (Yahia and Brecht 2012). Fresh tomato are important sources of lycopene, vitamin C and are valued for their colour and flavour (Kingsly *et al.*, 2007). Majority of the respondents (86.1 %) were more concerned about changes in the characteristic flavour and taste of dried tomato (Figure 3.3) which must be preserved to a greater extent by the choice of the drying process. Most of the respondents (70.5%) indicated that they have concerns about packaging of products (Figure 3.2). They indicated appropriate packaging such as metalized polyethylene bags, low and high density polyethylene bags and polyethylene terephthalate (PET), that will preserve and extend the shelf life of dried tomato. The mode of drying tomato and issues of adulteration of the products were of major concerns to consumers.

3.4. Conclusion

Findings of the survey indicated that consumers mostly preferred tomato powder compared to other forms of dried tomato products. Taste was the most important quality attribute of tomato powder to consumers, majority of whom would patronize the product if conveniently packaged to retain the characteristic intense tomato flavour. Therefore, there seems to be a promising market for the commercial production and sale of tomato powder.

CHAPTER FOUR: Evaluation of Natural convection solar cabinet dryer for the drying of tomato and assessment of drying characteristics of dried tomato

4.1. Introduction

Drying is among the most common processes used to assure food stability, since it considerably decreases the water activity, reduces microbiological activity and minimizes physical and chemical changes during storage. Open sun-drying is a widely practiced method of processing operation for agricultural products. In many cases this has been improved into more sophisticated solar drying method in which solar energy is collected to heat air. The heated air is then used for drying the food. The application of solar dryers for food has led to a reduction in the utilization of conventional sources, such as gas and wood, (Condorı´ *et al.,* 2001; Duran *et al.*, 2010) that used to be the source of energy in heating air for drying. Different solar dryer designs have been proposed to overcome the shortcomings of open sun drying. However, two designs; viz cabinet and tunnel type dryers have been proposed for domestic applications, as they require no electric power and can be used in rural areas (Bena and Fuller, 2002; Hossain and Bala, 2005).

Comparative studies by Forson (1999) and Mohamad (1997) on natural convection solar crop dryer designs revealed that the mixed mode natural convection solar crop dryer (MNCSCD) is the most promising and effective dryer suited for tropical humid areas.

The MNCSCD is a cabinet-type of solar dryer. It consists of a transparent cover, and a solar air heater. It allows for natural airflow and utilises direct solar energy and the convective energy of heated air to dry food in a drying area or chamber.

The efficiency and performance of dryers is influenced by environmental variables such as the solar radiation, ambient temperature and the ambient relative humidity. These factors must be considered in solar dryer design (Sokhansanj Jayas, 1995; Leon *et al.,* 2002). Another design factor that enhances the efficiency and drying speed in natural convection solar dryers is airflow (Afriyie *et al.*, 2011; Ekechukwu and Norton, 1999; Fudholi *et al.,* 2010; Pangavhane and Sawhney, 2002). These parameters influence the quality (sensory and nutritional parameters, and rehydration capacity) of dried tomato products. Thus comparison between solar dryers is necessary to assess the efficiency of the dryer (Rachmat *et al.*, 1984; Gallali, 1999).

The lack of appropriate evaluation procedures for solar dryers has sometimes resulted in selecting the wrong dryer type and operating conditions for certain food products (Brakel, 1978). Various studies have been conducted on the thermal efficiency of solar dryers (Lawrence, 1990; Leon *et al.*, 2002; Holman, 2004, Singh 2005; Altobelli *et al.,* 2014). However, there is no general agreement on methodology to compare their performance (Singh and Kumar, 2012). This is partly because food products have different drying rates which are dependent on prevailing environmental conditions. Solar energy varies with time and geographic location, which makes it difficult to compare results obtained from solar dryers even if they are of the same type. In rural Ghana, and in many tropical rural communities around the world where there is poor access to the national electric grid, solar dryers can be used to dry tomatoes, and save considerably on electric energy (Ekechukwu and Norton, 1997; Belessiotis and Delyannis, 2011; Afriyie *et al.*, 2011).

Solar dryers have lower load capacity, because product dimensions and conditions in the dryer cause air pressure fluctuations that are not conducive to the airflow rate with natural convection (Duran *et al.*, 2015). Hence, adapting and enhancing dryer design to improve airflow by natural convection may be effective in drying agricultural produce such as tomato. The most important parameter to consider in the evaluation of a solar dryer is the drying rate and the moisture loss (Leon *et al.,* 2002). Rupp *et al.,* (1995) presented a method of evaluating and comparing different solar dryers based on user's assessment.

Dryer efficiency, weight of moisture evaporated and energy input to the dryer during drying should be estimated for all the dryers to establish performance. The overall drying efficiencies of solar dryers have been shown to vary widely depending on the loading densities and weather conditions (Altobelli *et al.*, 2014). Dryer efficiency reported for natural convection solar crop dryers range from 10 % to 15 % (Forson *et al.,* 2007). Leon *et al.*, 2002, also reported an efficiency of 12.5 % for the optimization for the design of a passive solar dryer for drying vegetables (Leon *et al.,* 2002).

Considering this range assessing the efficiency of the natural convection dryer for tomato will be useful in evaluating the performance and quality of the dried products. This will also form the basis for selection of an appropriate dryer for processing tomato and other vegetables.

4.1.1. Specific objective

Evaluation of the efficiency of a natural convection solar dryer and assessment of the drying characteristics of pre-treated dried tomato.

4.2. Materials and methods

4.2.1 Samples

Roma variety of tomato purchased from a farmer in Bolgatanga was used in this study.

4.2.2. Drying

The study evaluated the performance of a mixed-mode natural convection solar dryer (MNCSD) (Figure. 4.1) designed for drying tomatoes. Open -sun drying method (Figure 4.2) was used as a control for comparison purposes.

Plate 4.1. Mixed mode natural convection solar dryer

Plate 4.2. Cut tomato on drying racks in open sun drying.

4.2.3 Drying equipment

Drying experiments were performed in a prototype solar cabinet dryer, constructed by the Engineering Unit, Food Processing and Engineering Division of Food Research Institute of the Council for Scientific and Industrial Research, CSIR, Accra). The dimensions of the dryer chamber were length; 1m, width; 0.6 m and height; 1m. Solar dryer with collector tilt angle of 15.6 ^{o} facing South North position for optimum solar radiation in Accra, Ghana located at 49 m above sea level at 5.6301 N 0.1801 W (accuracy: 3 m radius, device info: Garmin eTrex 30).

4.2.4 Description of Dryer

The three main components of the dryer are; primary and secondary collector; a drying chamber, in which the crop to be dried is placed; and a chimney (plate 4.3) designed using Autodesk® Inventor® 2016 (Build 200138000, 138). The dryer was constructed from 1inch thick plywood, 1.5 mm thick metal sheet, 1inch spaced wire mesh, sieving material and 5 mm thick glass sheet. The collector was constructed using local materials of wood, aluminum sheets, metals, fibre glass, stones and glass sheet. The collector was insulated by placing 10 mm thick glass wool insulation between the wooden base and metal sheet. Wooden battens were then positioned at intervals of 25 cm from the opening of collector. These battens served as restrictions for stones which were placed in the primary collector to facilitate heat absorption and release into the drying chamber. To enable flow of convective heat and prevent insects going into the drying chamber, pieces of wire mesh and sieving material was used to close up the opening of collector. Heated air goes through a (primary collector), into the drying chamber which has four racks with total dimensions 87 cm x 53 cm from edge to edge including the battings) and 79 cm x 45 cm (without the battings) and positioned horizontally at 150 mm intervals from the base. This was constructed using wooden battings, wire mesh and sieving material. The latter was introduced to forestall food samples falling through and also from sticking directly to the mesh. The drying chamber has drying capacity of 4 kg for thin layer drying of tomato slices. An access door to the drying chamber is located at the rear. An exit air vent on top of the secondary collector to facilitate the removal of moist air from the chamber. To reduce the effect of corrosion, the chimney was constructed by moulding 1.5 mm thick aluminum sheet painted black into a cylindrical shape and a conical shape, riveting them together. The interior of the dryer was painted with black paint for maximum absorption of solar radiation

Table 4.1. Physical properties of materials for construction of solar dryer

No	Item	Dimension	Thermal diffusivity (m^2/s)	Thermal conductivity W/ (m K)
1	Chimney	0.1 m diameter 0.4 m height	8.418×10^{-5}	205
2	Plywood	1 m x 1 m x 0.6 m	8.2×10^{-8}	0.12
3	Glass wool	0.01 m	-	0.04
4	Metal sheet	2 m x 1 m	8.418×10^{-5}	205
5	Glass sheet	2.02 m x 1.02 m x 1 m	$3.4 \times 10{-}7$	0.96

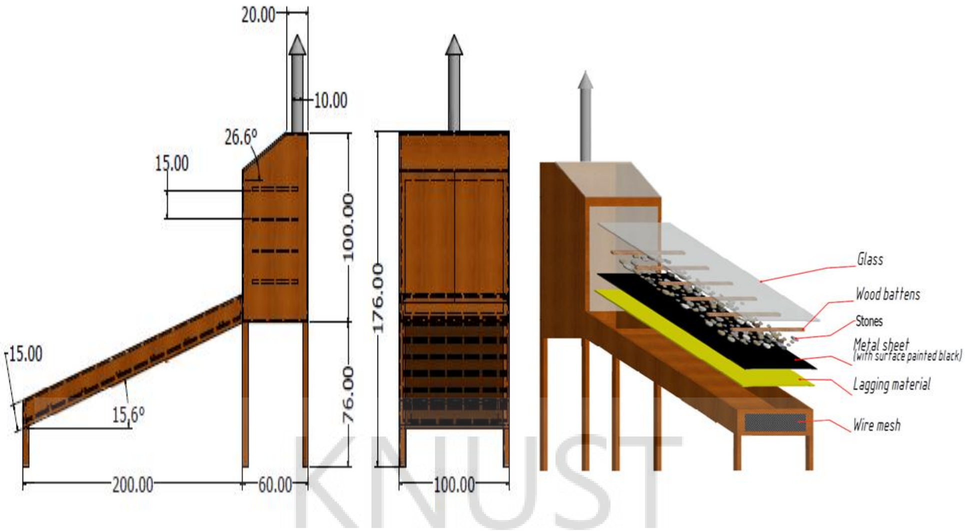


Plate 4.3. Schematic representation of mixed mode solar cabinet dryer for tomato

4.2.5 Sample preparation

Fresh tomato (Roma variety) was purchased from a farmer in Bolgatanga and transported in wooden crates to the laboratory in Accra. Tomato was stored in a cool room. Ripe but firm tomato was selected, washed under running tap water and with 1 % sodium metabisulphite solution. Tomato was cut into slices of 5 mm, using tomato slicer (Jaccard stainless steel mandolin, USA). This size was selected based on results from preliminary studies. The initial moisture content of tomato was measured using the air-oven method (AOAC, 2000).

4.2.6 Pre-treatments prior to dehydration process

Sliced tomato was divided into three batches, and assigned to three treatments as follows: dipping in (a) 1 % Potassium metabisulphite (KMS) solution for 10 minutes, (b) 1 % Ascorbic acid (1:1) and (c) untreated was be kept as control. The selection of pre-treatment was based on preliminary work that was carried out using different pre-treatments.

4.2.7 Dehydration processes

Pre-treated tomato slices (4 kg) was uniformly spread on rectangular mesh trays (87 cm x 53 cm) and placed in the drying chamber of the solar dryer. The weight of samples for moisture content analysis was recorded every two hours by a digital balance of 0.001g accuracy (Scaltec Instruments, Gottingen, Germany). Samples were taken from the solar dryer, weighed and placed in a hot air oven set at 105 ^{o}C for 10 h. Drying progressed till moisture content of samples reached 13 -15 % moisture content for solar dried samples. Experiments were replicated three times.

4.2.8 Experimental Design

Tomato slices pre-treated with potassium metabisulphite solution, ascorbic acid solution and control (no pretreatment) were dried under two drying conditions; solar and sun drying over a period of three days. Data on humidity, solar radiation and temperature of the dryer were recorded. The moisture content of samples assessed at two hours' interval throughout the drying period. Three replicated drying experiments were carried out between 9:30 and 16:30 h on sunny days (using British Broadcasting Corporation weather forecast for Ghana) during December 2015 to March 2016.

4.2.9 Monitoring of process variables: humidity, wind speed and temperature

4.2.9.1 Solar dryer

Probes connected to a data logger (Hobo U23 Pro V2, USA) were placed at five different locations in the solar dryer chamber (4 placed on the drying racks and 1 in the solar collector). Data for temperature and relative humidity were recorded at one-minute interval using a Lab VIEW signal express program and exported to Microsoft Office Excel for further analysis. Thermocouple (ALMEMO 2890-9, Gottingen, Germany) measuring Software WinControl and stored data on SD card was used to measure the temperature of the outlet and inlet air of the dryer. Inlet wind speed was recorded by Almemo digital vane anemometer (FVAD 15S220, Gottingen, Germany). Airflow outlet was measured by thermos-anemometer probe (FVAD 35 TH5K2, Gottingen,Germany). Solar radiation was measured at 10min interval using a silicon pyranometer sensor (S-LIB-M003, Bourne, MA).

4.2.9.2. Sun-drying

In order to compare the performance of the cabinet dryer with that of open sun drying, 4kg of sliced tomato were placed on drying trays (similar to that used in the solar dryer) as seen in figure 4.4. Ambient air temperature was measured using Thermocouple sensor (NiCR-Ni, Germany) and wind velocity using ALMEMO (2890-9, Germany). Solar insolation was measured at 10 min. interval using a solar radiation sensor (Silicon pyranometer sensor S-LIB-M003, Germany). Triplicate sun drying experiments were carried out simultaneously with cabinet solar dryer. Sun drying progressed till moisture content of 19-23 % was reached.

4.2.10. Moisture Content

Moisture content of tomato samples was determined by using the method described by AOAC (2000). Three grams of tomato samples was placed in a metal dish (pre-weighed) and placed in the air-oven (Gallenkamp, United Kingdom) for 8 h at 105

°C. The dish with dried sample was cooled in a desiccator and the average moisture content from triplicate samples determined.

4.2.11. Moisture ratio (MR)

In thin-layer drying, the moisture ratio during drying was calculated as follows:

MR was calculated using the equation:

$$\mathrm{MR} = \frac{M - M_e}{M_0 - M_e}$$

Where MR is the dimensionless moisture ratio, M the moisture content at time t, and Mo and Me the initial and equilibrium moisture contents, respectively, on dry basis. During thin-layer drying of tomato slices in the cabinet dryer, the samples were not exposed to uniform relative humidity and temperature continuously. So the moisture ratio was simplified according to Pala *et al.*, 1996 and Doymaz 2004 to:

$$\text{Moisture Ratio} = \frac{M}{M_0} \qquad (Eqn\ 1)$$

4.2.12. Dryer efficiency

$$\text{Dryer Efficiency (DF)} = \frac{M\ x\ L}{I\ x\ A\ x\ t} \qquad (Eqn\ 2)$$

M = Mass of moisture removed (kg)

L = Latent heat of vaporization of water

I = Average Solar radiation over the drying period (W/ m^2)

A = Area of collector (m^2)

t = drying time (s)

4.2.13. Drying rate

Weight of samples in the dehydrator was recorded every two hours and drying rate calculated using the equation 3 and curves plotted with the values obtained.

$$Drying\ Rate = \left(\frac{Difference\ in\ weight\ \ for\ time\ between\ reading\ (g)}{Time\ interval\ \ (min.)}\right)\ (eqn\ 3\ )$$

4.3. Results and Discussion

4.3.1 Drying performance of solar dryer

The contribution of environmental variables such as the solar radiation, ambient temperature and the ambient relative humidity are considered important in solar dryer design. During the experiment period from December to March, 2015, the average daily variation of solar radiation ranged from 116.85 to 955.6 W/m^2 over the drying hours for sun drying and solar drying of tomato (Figure 4.1).

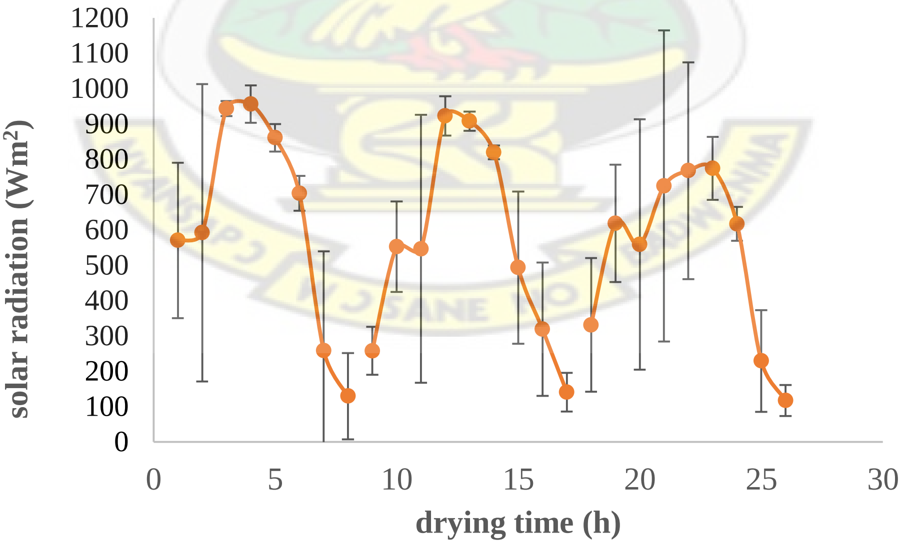
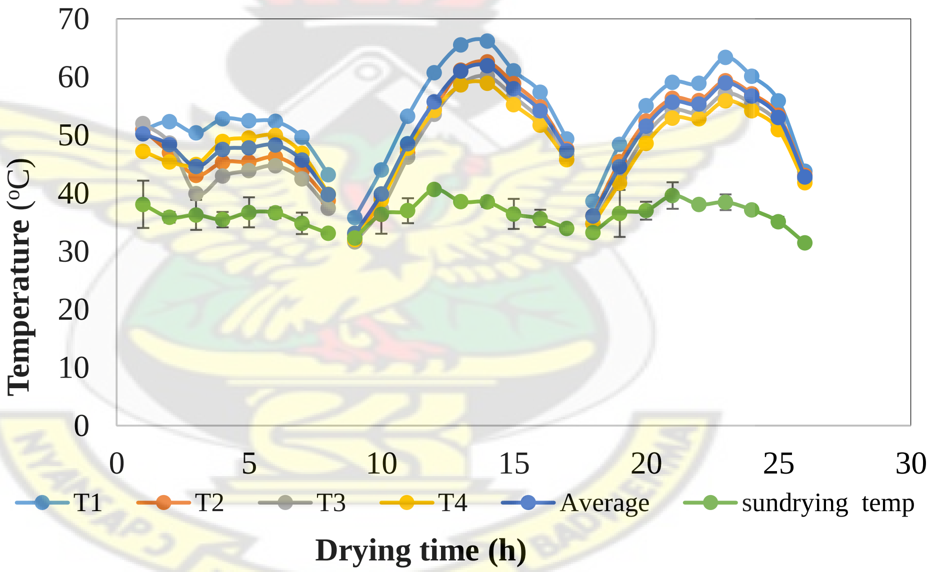
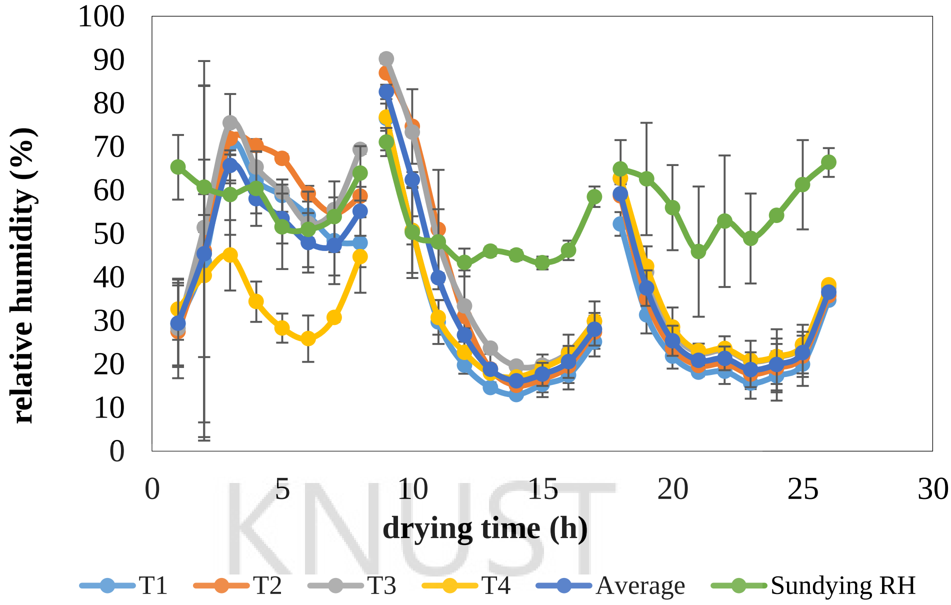


Figure 4.1. Variation in solar irradiation during the drying of tomato slices.

The drying temperature reached a maximum average of 62 °C for solar dryer whiles the maximum ambient temperature was 41 °C for sun drying, with the top tray of the solar dryer recording a maximum temperature of 66°C (Figure 4.2a). The mean temperature range recorded was 30 - 41°C for sun drying and 36-66 °C for solar drying. It is ideal to dry tomato between 55-60 °C in order to reduce case hardening (Zogzas, 1995). Tomato slices with initial moisture content of 95-96 % was reduced to 14-15 % final moisture content for solar dried tomato and 19 - 22 % for sundried tomato over 23 – 25 h. Relative humidity was lower in the solar dryer compared to that of the ambient air which facilitated the drying of tomato slices in the solar dryer (Figure 4.2b).



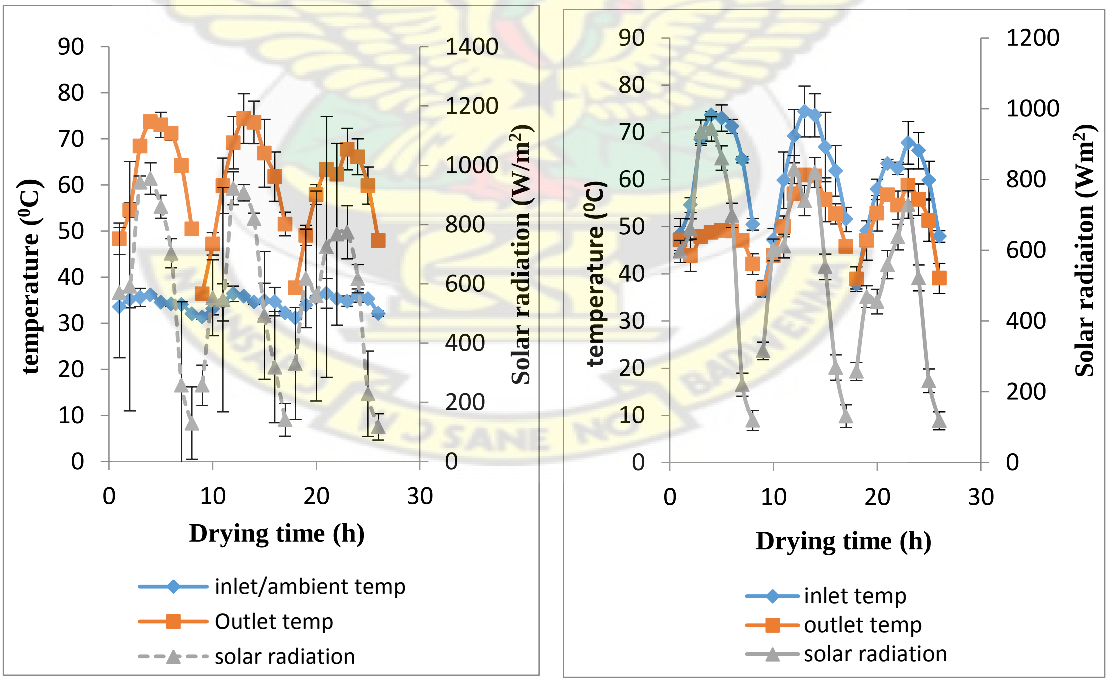
(a)



(b)

T1 - top tray T2-second tray, T3-third tray and T4 -bottom tray in the drying chamber

Figure 4.2. Variation in temperature (a) and relative humidity (b) of sun and solar during the drying of tomato slices.



a) Solar dryer collector *b) Solar drying chamber*

Figure 4.3. Variation in temperature of collector (a) solar dryer collector and (b) drying chamber.

The area of the collector receiving solar radiation is an important consideration in the estimation of drying efficiency for the mixed-mode dryer as tomato slices received solar radiation indirectly from the primary collector and directly from the secondary collector. The primary and secondary collectors indicate the total solar radiation collection area. The average inlet (ambient) temperature of air entering the collector was 31- 37 ^{o}C and outlet temperature leaving the collector and entering the drying chamber of the solar dryer ranged from 47 – 74 ^{o}C during the drying period (Figure 4.3).

An elevation in temperature of at least 10–15 °C from the ambient is required for effective drying to take place and this is a useful indication of the collector/dryer performance (Leon *et al.*,2004; El-Beltagy, 2007). The drying temperature (outlet air from collector, inlet air into the drying chamber) reached a maximum of 74 ^{o}C whiles the maximum ambient temperature was 36 ^{o}C a difference of 38 ^{o}C which is significantly high and gives an indication of the relatively high efficiency of the dryer. Temperature of outlet air leaving the drying chamber ranged between 37-61 ^{0}C, also significantly high and could be channeled and recycled as an alternative heat source.

Temperatures in the range of 50 - 60 °C are recommended for drying temperature-sensitive products like fruits and vegetables (Leon *et al.*, 2004). However, temperatures up to 65 °C may be used at the beginning, but should be lowered as food begins to dry and should not exceed 55 °C in the last hour of drying as this may affect the quality of tomato and cause case hardening or browning of tomato (Hughes & Willenberg, 1994). The maximum temperature entering the drying chamber was 74 ^{o}C however, the maximum temperature recorded in the drying chamber of the dryer was 66 ^{o}C at 1pm in the afternoon on the top drying rack (directly under the secondary collector). The temperature of air entering the chamber varied with the intensity of sun radiation and the time of the day, however the highest temperature of 66 ^{o}C recorded was over a short period of time and not long enough to cause heat damage such as case hardening of tomato. It is important not to expose tomato samples to very high temperatures over a longer period time.

.3.2. Solar Dryer Efficiency

Efficiency of the solar cabinet dryer markedly varied with the moisture content of the product and the incident solar irradiation over the drying period. The first-day efficiency is important for the drying process since the moisture content of tomato is highest on the first day and an inefficient drying system during this period compromises the quality of dried tomato (Altobelli *et al.*, 2014). The high moisture of the tomato at this phase promotes the growth of microorganism which makes tomato susceptible to spoilage.

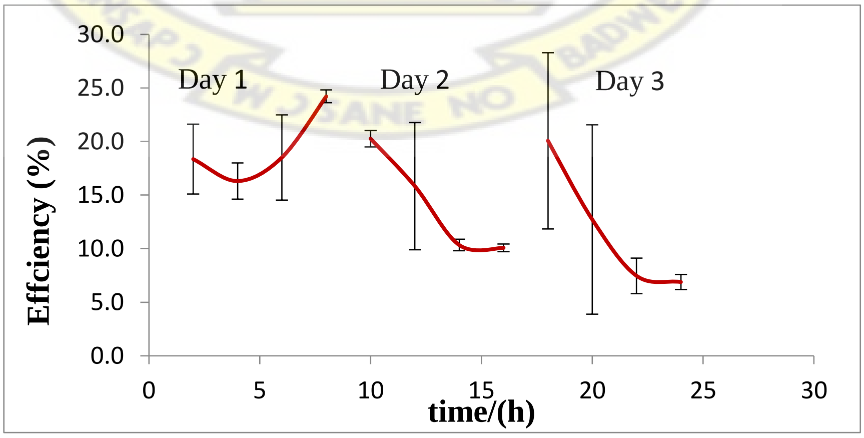


Figure 4.4. Changes in Solar dryer efficiency during drying period

Leon *et al.* (2002) noted that for the same energy input, drying efficiency decreases when process shifts from the constant phase to falling phase. When food is placed into a dryer, there is an initial settling down period referred to as the constant phase when the surface of the food material heats up to a temperature closer to that of the surrounding temperature (Fellows, 2000). A falling phase begins when the surface of the food materials heats up as water leaves the interior of the food at the same rate as it evaporates from the surface. The rate of water movement becomes the controlling factor and when the moisture content of the food falls below the critical moisture content, it reaches an equilibrium moisture content and the food dries slowly. The efficiency of the drying process gradually decreases till it reaches a stationary phase where there is no further loss of moisture (mass transfer) or change in weight of the food material. This is because unbound water is no longer available for removal in the drying process and bound water which formed an integral part of the tomato cannot move from the inner tissues of tomato.

From figure 4.5, the first day dryer efficiency of 24.2 % was higher than the overall efficiency value of 12.5 % reported for an optimized mixed-mode natural convection solar dryer by Forson *et al.,* (2007), an indication that the dryer used in this study had a better performance because of to its design. In some studies, the drying period of 5.5h has been used in assessing the dryer efficiency (Altobelli, 2014). However, the drying efficiency of solar dryers vary widely depending on the loading capacity and ambient weather conditions. A sharp reduction in efficiency is observed on the first day of drying because unbound water is readily available for removal by the drying system.

4.3.3. Drying characteristics of tomato slices

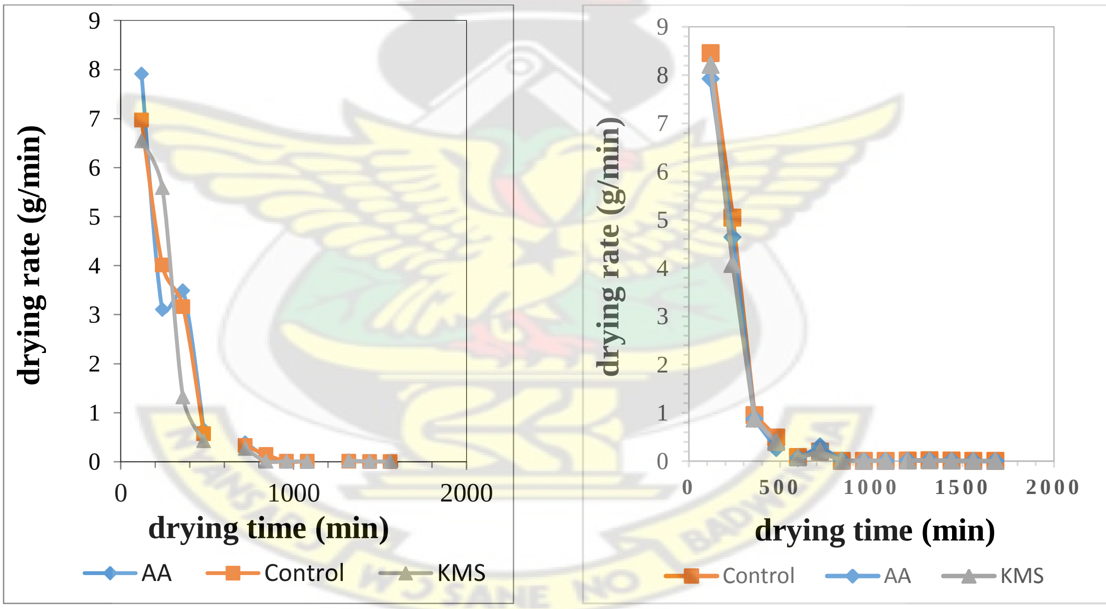
Figure 4.6 shows the drying rate of solar and sun-dried tomato over drying period. The constant phase was not observed in both solar and sun-drying of tomato, while three falling rate periods were observed for solar dried tomato. The falling-rate period is usually the longest part of drying and in some foods the falling-rate period is the only part of the drying curve to be observed (Fellows, 2000).

Three falling phases were observed in all pre-treated solar dried samples. The first falling phase ended at 240 min of dehydration at a drying rate of 5.59 g/min for KMS pre-treated tomato, whiles the second falling rate period ended at 480 min at a drying rate of 0.43 g/min. The last falling phase period lasted up to 840 min of dehydration. A first, second and third falling phases were observed at dehydration times of 360, 480 and 720 min respectively for tomato pretreated with ascorbic acid.

The first falling phase ended at 360 min of dehydration at a drying rate of 3.16 g/min and the second falling phase occurred at 480min at a drying rate if 480g/min and a third around 840 min at a drying rate of 0.15 g/min similar to the of ascorbic acid pre-treated tomato.

Two falling phases for pretreated tomato samples were observed for sundried tomato. The drying rate of solar dried pre-treated with potassium metabisulphite was faster at the first falling phase (occurred till 240 minutes of dehydration) compared to 360 min for control and ascorbic acid pretreated samples. The overall drying rate on the first day of drying was faster and steeper (depicted in the drying curve figure 4.5b). This observation was similar to that of Tunde-Akintunde *et al.*, 2005 and Doymaz, 2004b, where the drying rate of peach and carrot was improved by chemical pre-treatments and blanching.

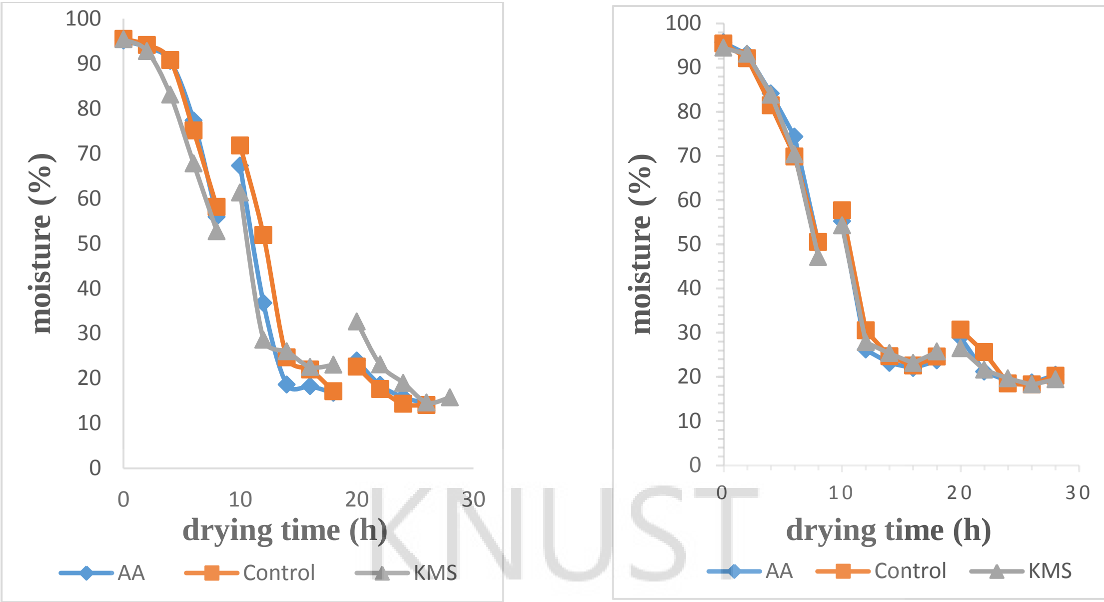
Drying rate at the falling phase was facilitated by the easy removal of unbound water from the surface of tomato slices on the first day of drying. The drying rate curves indicates that both sun and solar drying mainly occurred during the falling phase, similar to drying of pre-treated and fresh, pre-osmosed, blanched and sulphited pumpkin slices in studies by Falade and Shogaolu (2010), red chilli by Gupta *et al*., (2002) and carrots by Doymaz (2004) where no constant rate was observed during drying. An indication of diffusion as the main mechanism for moisture movement in dried tomato (Uddin and Howlader 1990; Karanthanos *et al*., 1995; Kaymay-Ertekin 2002).



a) Solar drying ***b) Sun drying***

AA-pre-treated tomato with 1% ascorbic acid solution; KMS-pre-treated tomato slices with 1% Potassium metabisulphite; Control-no pre-treatment

Figure 4.5. Drying rate of solar (a) and sun (b) dried tomato slices during drying

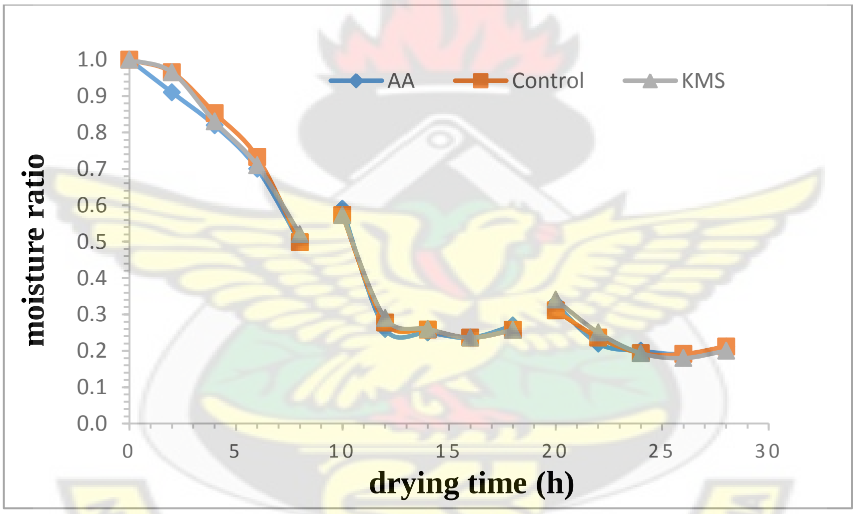


a) Solar drying ***b) Sun drying***

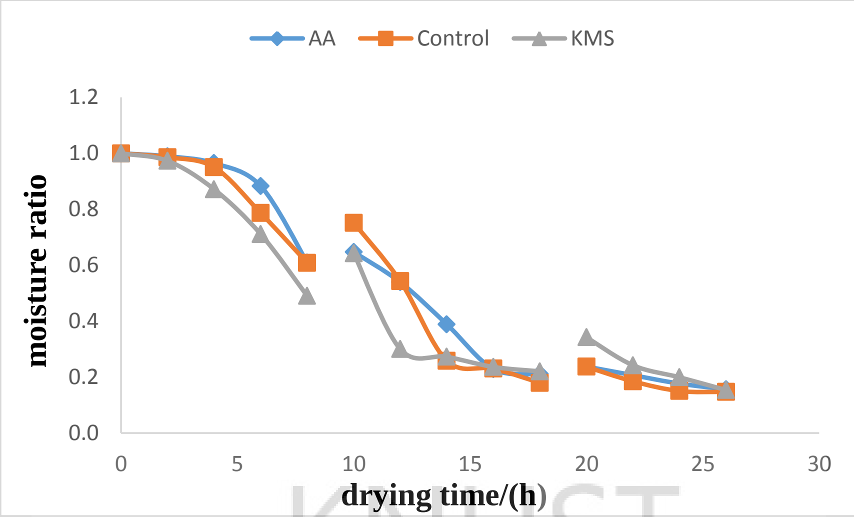
AA-pretreated tomato with 1% ascorbic acid solution; KMS-pretreated tomato slices with 1% Potassium metabisulphite; Control-no pretreatment.

Figure 4.6. Variations in moisture content of solar (a) and sun (b) dried tomato slices.

The moisture content of tomato expresses the total amount of water (free water, adsorbed water and water of hydration) present (Bradley, 2010). It is difficult to monitor drying operation of solar dryers closely till the product final moisture content reaches exactly the same value in solar dryers because the rate of removal of water in the drying process is highly dependent on ambient conditions such as temperature and relative humidity (Altobelli *et al.*, 2014). However, for comparative evaluation of dryers the final moisture content of dried tomato at a specific given time can be used to evaluate and compare the performance of dryers under evaluation (Leon *et al.*, 2002). The moisture content of solar dried tomato decreased from 95 % to 14-15 % for pre-treated samples. Samples pre-treated with KMS lost water faster than the control and samples pre-treated with ascorbic acid. The moisture content of sundried tomato at 26 hours ranged between 19-20 %. It was difficult to attain lower final moisture content for sundried tomato because of erractic changes in relative humidity of ambient air it was exposed to which directly affected the moisture content. Since dried tomato is hygrosopic in nature, it tends to absorbs water from the ambient air when humidity increases as temperature of the drying medium fall. In a similar experiment by Rajkumar *et al.*, (2007), the drying methods and the time taken to dry tomato slices was lower in a vacuum solar dryer than in open sun drying. The decrease in drying time was mainly due to the higher vapour pressure gradient created in the vacuum, which facilitated the removal of moisture from the sample.



a) Solar-drying



b) Sun-drying

AA-pretreated tomato with 1% ascorbic acid solution; KMS-pretreated tomato slices with 1% Potassium metabisulphite; Control-no pretreatment

Figure 4.7. Variations in moisture ratio of solar and sundried tomato slices over drying period

Curves of moisture ratio verses drying time for solar and sun tomato slices are shown in Figure 4.7. The moisture ratio decreased continuously with drying time for solar and sun dried tomato. Moisture ratio also decreased with increasing drying air temperature and time in the fresh and pre-treated pumpkin (Falade & Shogaolu, 2008). The continuous decrease in moisture ratio during the falling phase period is an indication of the internal mass transfer which occurred by diffusion of moisture from the internal tissues of tomato.

4.4. Conclusion

The dryer efficiency of 24.2 % achieved on the first day of drying was high and this enhanced the performance of the dryer in attaining a lower moisture content of 14 - 15 % for solar-dried tomato compared to 19 - 20 % for sun-dried tomato.

Most of the drying process of tomato occurred in the falling phase as no constant phase was observed for both solar and sun-dried tomato. Pre-treatment did not seem to influence the drying rate of sun-dried tomato because a similar trend in the dehydration curve was observed for all sun-dried samples. However, pre-treatment with potassium meatabisulphite seemed to have fewer falling phases than the other pre-treated solar dried tomato samples. However, moisture ratio showed no differences in the pre-treated solar- dried tomato.

CHAPTER 5: Assessment of quality characteristics of solar and sun-dried tomato powder

5.1 Introduction

Sun drying is an effective method of preserving and maintaining the quality of fresh produce through the reduction of water activity to lower microbial activity. However, problems such as contamination with dust and other extraneous materials, colour degradation, poor rehydration and, high microbial load associated with sun drying of agricultural materials are well documented in literature (Doymaz, 2004, 2005b). It has been established that the use of solar and hot-air dryers can significantly improve the quality issues associated with sundried food products (Doymaz and Pala 2002; Gogus and Maskan, 1999; Adom *et al.*, 1997). An important criterion for these drying operations is that they should maintain the quality and functionality of dehydrated food materials (Prabhakar, 2014). Thus, the quality of the dried products is often used to assess the performance and efficiency of the dryer system used (Chen *et al.*, 2005).

Quality assessment of dried tomato involves assessment of sensory, microbial, physical, nutritional parameters, microstructural and rehydration capacity (Gallali, Abujnah and Bannani, 1999; Ranganna, 1986). During the drying process, agricultural fresh produce undergoes continuous physical and biochemical changes. Typical physical changes of dried food product may result in changes in size, shape, colour and texture whereas the biochemical reactions cause changes in the flavour, colour and nutrients of perishable produce like tomato (Lin *et al.*, 1998; Lenart, 1996).

The heated air used in the drying process initiates changes in the nutritional and chemical properties of tomato by causing oxidation of carotenoid and chlorophyll pigments. Post-harvest handling and processing methods also cause substantial variation in nutrient losses (Gallali *et al.*, 2000). Since there is increasing awareness and interest in the health benefits of fruits and vegetables and phytochemicals such as lycopene and carotene, it is important that processing methods are able to preserve them (Tonucci *et al.*, 1995). Pre-treatment with potassium metabisulphite before drying has been reported to preserve certain vitamins, maintain colour, reduce microbial contamination and prevent storage changes of tomato and other fruits and vegetables (Prabhakar, 2014).

5.1.1. Main Objective

The main objective of this work was to assess the physicochemical, nutritional and microbiological properties of pre-treated solar dried tomato powder.

5.2. Materials and methods

5.2.1. Sample preparation

Fresh tomatoes (Roma variety) were purchased from a local farmer. Ripe (over 90% of redness in colour) but firm (using hand-feel) tomato were selected and washed under running tap water. Tomatoes were cut into slices (thickness of 5mm), using a slicer (Jaccard stainless steel mandolin, USA). The thickness of tomato slice (0.5mm) was selected based on results from preliminary studies.

5.2.2 Experimental Design

A 3 x 2 full factorial design for pretreatment (1 % ascorbic acid solution, 1 % metabisulphite solution and no pretreatment) and drying methods (solar and sun-drying) was used in the study.

5.2.3 Pre-treatments prior to dehydration process

Tomato slices were randomly divided for three treatments as follows: dipping in (a) a solution of 1 % Potassium metabisulphite (KMS) for 10 min, (b) 1 % ascorbic acid solution for 10 min and (c) untreated as control. The choice of these selected pre-treatment was based on preliminary studies carried out prior to this study.

5.2.4 Dehydration processes

Drying experiments were performed in a prototype solar cabinet dryer (Figure 4.3) constructed by the Engineering Unit, Food Technology Research Division of CSIR-Food Research Institute, Accra). The dimensions of the dryer chamber were length; 1 m, width; 0.6 m and height; 1 m with a collector tilt angle of 15.6 ^{o} placed in a South North position for optimum solar radiation in Accra, Ghana which is located at 49 m above sea above sea level at 5.6301N 0.1801W (accuracy: 3 m radius, device info: Garmin eTrex 30). Pre-treated tomato slices (4 kg) were uniformly spread on rectangular mesh trays (87 cm x 53 cm) and placed in the drying chamber of the solar dryer over three-day period till moisture content of 13-14 %. In order to compare the performance of the cabinet dryer with that of open sun drying, 4 kg of sliced tomatoes were placed on drying trays and sun-dried (Figure 4.4). Triplicate sun drying experiments were carried out alongside the solar dryer. After drying, both sundried and solar dried tomato samples were milled into powder using Kenwood dry mill blender (BL335, Manchester, United Kingdom) at 450 W speed for three (3) minutes.

5.2.5 Analytical methods for dried tomato.

5.2.5.1 Moisture and total solids

Moisture content of the tomato powder was determined using the air-oven method at 105 ^{o}C as described in the AACC Method 44-15, (2000). The moisture content was determined as loss in moisture using the following equation: % Moisture= Ax100/B

In which A= loss in sample weight in grams, B= original weight of sample. Total solids were estimated by subtracting moisture content from 100%. Moisture content and total solids of fresh and dried tomato samples were determined in triplicates.

5.2.5.2 Water activity (a_w)

Water activity was determined using a water activity meter (Paw kit, Model Series 3 TE, Decagon Devices, Inc., Pullman, WA, USA) for tomato powder according to (AACC Method 44-35, 2000).

5.2.5.3 Colour

Tristimulus colour dried tomato powder were measured using chroma meter (LABSCAN XE Hunterlab, Virginia, USA) which was calibrated with a white tile (L=97.51, a=5.45, b=-3.50) according to (AACC method 14-22.01, 2000). The colour was expressed in terms of lightness (L) and colour difference (ΔE). (ΔE) was calculated as (ΔL^2 + Δa2 + Δb2)1/2 where L = lightness; a (+) = red a (-) = green; b (+) = yellow, b (-) = blue colour value. The colour of each sample was measured five times and the mean calculated.The total colour difference ΔE was calculated as: $\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$ *Eqn 1*

Where ΔL^{*2}- difference in L*, Δa^*- difference in a*, Δb^*difference in b*

5.2.5.4 Total Soluble Solids (TSS)

Total Soluble Solids of tomato juice was measured in triplicate using a digital Refractometer (AR 200, Reichert Analytical instrument, NewYork, USA) at 20 ^oC. TSS of tomato powder was determined by reconstituting tomato powder into 10%

solution before placing a drop of the juice on the lens of the refractometer after which subsequent reading were taken according to (AACC method 02-57, 2000).

5.2.5.5 pH

The pH was measured directly using a pH meter (Research pH meter, 3330, Jenway, UK) equipped with a glass electrode (Orion 9102, Orion Research, Boston, MA, USA), after calibration using standard buffer solutions (Merck) at pH 4.0 and 7.0 at ambient temperature. The pH of tomato powder was measured from 10% tomato powder solution made from tomato powder. The pH was determined for tomato powder samples. Ten grams of sample was blended in 90 g of distilled water in a stomacher (AACC method 02-52, 2000).

5.2.5.6 Total Titrable Acidity (TTA)

Ten grams (10g) of sample was dispersed into 20 ml of distilled water and homogenized for 2 min using a magnetic agitator. The electrode of the pH meter was placed into the sample solution and the pH was read. 70 ml of distilled water was added to the sample solution and 0.1N sodium hydroxide was added whiles agitating to continue neutralization until a pH of 8.5 was reached and the amount of sodium hydroxide used was read (AACC method 02-53, 2000). The TTA was expressed as citric acid equivalent.

$$\% \text{ TTA } \frac{Titre\ value\ x\ Normality\ x\ M.eq.wt\ of\ acid x100}{volume\ of\ sample} x\ 100 \qquad \textit{Eqn 2}$$

Milli-equivalent weight of citric acid=0.06404

5.2.5.7. Ash

Approximately 4 grams of sample was weighed accurately into a silica ashing crucible which had previously been ignited, cooled in a desiccator and weighed. The samples were incinerated in a muffle furnace until a light grey ash was obtained, cooled in a desiccator and weighed (AACC Method 08-01, 2000). Ash was calculated as follows:

$$\% \text{ Ash} = \frac{weight\ of\ crucible + ash) - weight\ of\ empty\ crucible\ x\ 100}{weight\ of\ sample}$$

5.2.5.8. Sulphur Dioxide

Total sulphur dioxide content (ppm dry weight basis) was determined using the modified Reith Williams Method (FAO, 1986). Sulphur dioxide was determined by dispersing 25 grams of tomato powder in 20 ml of water and diluted with 25 ml of dilute sodium hydroxide. It was allowed to stand for 5 min and diluted with 10 ml sulphuric acid and allowed to stand for another 5 min, and 1ml of starch indicator added. It was titrated with standard iodine solution to a permanent purple colour. The estimation of sulphur dioxide concentration (in mg L-1) was calculated as:

SO_2 concentration = titre value x 12.8 *Eqn 3*

5.2.6. Phytochemical Analysis

5.2.6.1. Extraction of carotenoids

Tomato powder (0.5 g) was crushed in a crucible mortar with 1.0 g sodium bicarbonate and celite to neutralize organic acid release. Twenty (20) ml of extraction solution (acetone: petroleum ether (0.1% BHT) 1:1) was added to each sample through a vacuum filter into a flask. The filtrate was quantitatively collected and the process repeated three times until the residue was devoid of colour. Forty (40) ml of 40 % potassium hydroxide in methanol (w/w) was added and placed on magnetic stirrer for 10 minat room temperature. Combined extract was transferred into a 250 ml separating funnel and washed with distilled water. Ten (10) ml of saturated NaCl was added to break emulsions. Aqueous layer was drained, and the petroleum ether layer was quantitatively collected into a 25 ml volumetric flask with a funnel plug made of glass cotton wool. The extract was dried under nitrogen and dissolved in 1ml of methanol: Ethyl Acetate (1:1) for HPLC analysis (Rodriguez-Amaya and Kimura, 2004).

5.2.6.2. HPLC Conditions

A Waters HPLC Model 626 Pump, 717 plus auto sampler and column heater (Waters Corp, Milford, MA) equipped with a YMC C_{30} (5µ 250 x 4.6mm) reverse phase column and a Model 2996 photodiode array detector was used. Operation and data processing were performed by Empower software. Separation of carotenoids was performed using a gradient elution of (A) Ethyl Acetate, (B) Methyl tertiary butyl ether and (C) methanol, in which elution started with 20 % A and 80 % C, which changed to 40 % A and 60 % B in 2 min then to 100 % A in 12 min and then 20% A and 80 % C in 13 min and stayed isocratic for 7 min. The flow rate was 1ml/min for 20 min. PAD spectrum of carotenoids was displayed between 200 and 700 nm. Peak identification was based on comparison of retention time and spectral characteristics of carotenoids standards (Rodriguez-Amaya and Kimura, 2004).

5.2.7. Microbiology analyses of tomato powder

5.2.7.1. Homogenization and Serial Dilution

For all solid samples, ten (10) grams were added to 90.0ml sterile salt peptone Solution (SPS) containing 0.1% peptone and 0.8 % NaCl, with pH adjusted to 7.2 and homogenized in a stomacher (Lad Blender, Model 4001, Hampshire, UK), for 30 seconds at normal speed. From appropriate ten-fold dilutions 1 ml aliquots of each dilution was directly inoculated into sterile Petri dish plates and the appropriate media added for enumeration and isolation in accordance with (NMKL. No. 82, 2006). All analyses were done in duplicate.

5.2.7.2. Enumeration of aerobic mesophiles

Aerobic mesophiles were enumerated by the pour plate method using plate count agar medium (Oxiod CM325; Oxoid Ltd., Basingstoke, Hampshire, UK). Plates were incubated at 30 °C for 72 hours in accordance with (NMKL. No. 86, 2013).

5.2.7.3. Enumeration of yeasts and moulds

Yeasts and moulds were enumerated by the pour plate method using Oxytetracycline-Glucose Yeast Extract Agar (OGYEA), (Oxoid CM545; Oxoid Ltd., Basingstoke, Hampshire, UK) to which OGYEA supplement was added to suppress bacteria growth. The pH was adjusted to 7.0 and incubated at 25°C for 3-5 d in accordance with ISO 21527-1, 2008.

5.2.7.4. Enumeration and isolation of total coliform

Coliform bacteria were counted by the pour plate method using tryptone soya Agar medium (OXOID CM131) and adjusted to pH 7.3 and overlaid with Violet Red Bile agar (OXOID CM 107) with pH adjusted to 7.4 and incubated at 37°C for 24 hours. Colonies were confirmed using Brilliant Green Bile Broth (OXOID CM 31) at pH of 7.4 and incubated at 37 °C for 24 hours in accordance with NMKL no.44, 2013. Positive reaction was indicated by the production of gas at the entire bent portion of the Durham tube.

5.2.7.5. Enumeration of Escherichia coli

E. coli bacteria were enumerated by the pour plate method using Tryptone Soya Agar medium (OXOID CM131) adjusted to the pH 7.3 and overlaid with Violet Red Bile agar (OXOID CM 107) with pH adjusted to 7.4 and incubated at 44 °C for 24 hours. Suspected colonies were confirmed using E.C. broth (OXOID CM 853) with pH adjusted to 6.9. Colonies that produced gas that has filled the entire concave part of the Durham tube were taken as thermos-tolerant coliform bacteria. To determine E. coli thermo-tolerant bacteria were confirmed for Indole production. This was done by sub- culturing into positive tubes into tryptone broth and incubated at 44 °C for 24 hours. Indole test was done by adding 0.3-0.5 ml of Kovac's reagent into the culture. Red ring colouration at the surface of tryptone broth indicated Indole positive in accordance with NMLK no.125, 2013.

5.2.8. Microstructural evaluation

Dried tomato slices were fixed in 2.5 % glutaraldehyde for one hour and rinsed in buffer for 5 min. It was immersed in 2 % aqueous osmium tetroxide for 90 minutes.

Osmium was rinsed out with deionized water for 5 minutes. This was repeated three times. Samples were then dehydrated in ethanol (ETOH) series of 50 %, 70 % and 95 % for 10 minutes each repeated three times. Specimen samples were placed in metal baskets, coded and processed in a critical point dryer and then mounted on carbon tape for sputter coating with platinum for 120 seconds. The samples were imaged with a scanning electron microscope (FEI Quanta 3D FEG, Florida, USA) using the Everhart-Thornley (ET) detector at high vacuum. Parameters for imaging, 5 kV, spot 5, 50 µm aperture and working distance of ~10 mm.

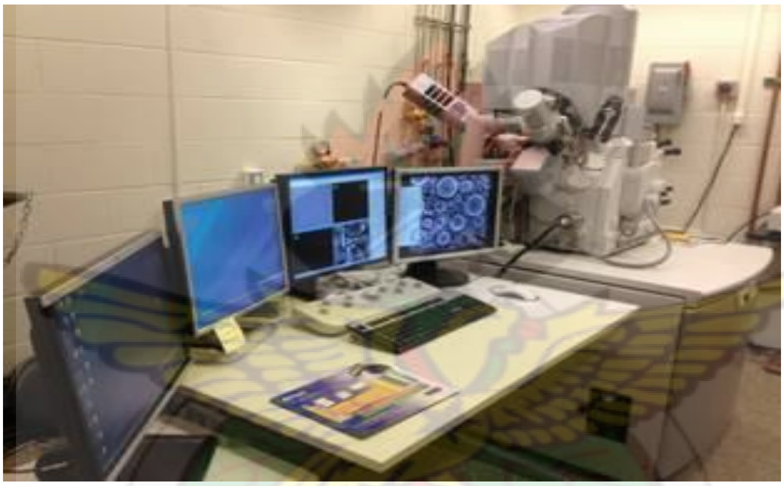


Plate 5.1 FEI Quanta 3D FEG scanning electron microscope (FEI)

5.2.9 Particle size and shape Analysis of tomato powder

Tomato particle size and shape distribution was determined using a Morphologi G3-ID (Malvern Instrument, London, United Kingdom). A total of 10,000 particles were analysed to obtain the number distribution of circle equivalent (CE) diameter, convexity, and high sensitivity (HS) circularity. CE-diameter is the measurement of particle size, expressed as the diameter of a circle with the same area as the particle image. Convexity is the measurement of the surface roughness of a particle and it is calculated by dividing the convex hull perimeter by the actual particle perimeter. The value of convexity ranges from 0 to 1. HS-circularity quantifies how close the shape is to a perfect circle by the ratio of the particle area to the square of the perimeter of the object.

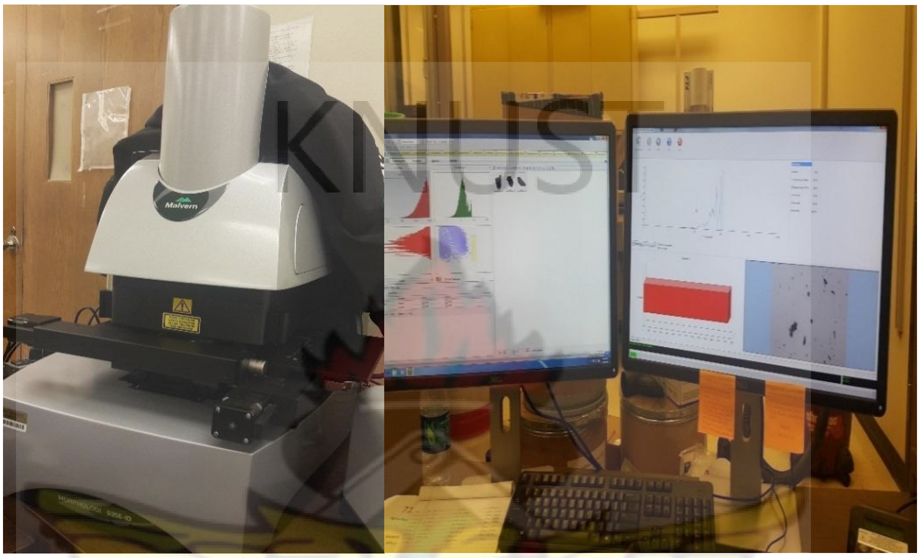


Plate 5.2. Morphologi G3-ID for particle size analysis of tomato powder

5.3. Data Analysis

All data were analysed using Minitab version 7. Means and standard deviations of the data were presented. ANOVA and Duncan's multiple range test carried out to determine differences among treatments at the significant level of $p \leq 0.05$.

5.4. Results and Discussion

5.4.1 Physicochemical assessment of tomato powder

5.4.1.1 Moisture content and water activity (a_w)

The moisture content of sundried samples fluctuated in response to the relative humidity of the ambient air. As a result, it was challenging reaching desirable low moisture content (10 - 12 %) compared to samples in a solar dryer which had elevated temperatures for drying tomato to attain low moisture content (13.95 ± 0.75%) during the drying period.

Table 5.2 Physicochemical quality characteristics of solar and sundried pre-treated tomato powder.

Drying Method	Pre treatment	Moisture (%)	Dry matter (%)	a_w	TTA (g/100g)	pH	TSS dwb	Ash (g/100g) dwb	L*	a*	b*	ΔE
Solar	**Control**	13.99^{xA} (0.40)	86.01^{yB} (0.40)	0.37^{xA} (0.01)	1.70^{xA} (0.56)	4.16^{xA} (0.6)	7.0^{yB}	9.68^{xA} (0.99)	48.63^{xyB} (2.82)	20.41^{yB} (2.16)	30.26^{xB} (1.37)	-
	KMS	13.94^{xA} (0.75)	86.06^{yB} (0.75)	0.38^{xA} (0.05)	2.87^{yB} (0.03)	4.09^{xA} (0.08)	6.0^{xA} (0.0)	9.40^{xA} (0.91)	50.35^{yB} (2.9)	20.26^{yB} (1.39)	31.76^{xB} (1.88)	3.52^{xB} (0.32)
	AA	14.57^{yA} (0.21)	85.43^{xB} (0.21)	0.35^{xA} (0.01)	1.71^{xA} (0.56)	4.07^{xA} (0.02)	7.0^{yB} (0.0)	9.55^{xA} (0.9)	46.44^{xB} (1.2)	20.38^{xAB} (1.53)	28.87^{xB} (2.33)	3.00^{yB} (2.82)
Sun	**Control**	19.38^{xB} (0.36)	80.63y^{A} (0.36)	0.53^{xB} (0.02)	1.75^{xA} (0.76)	4.13^{xA} (0.01)	6.0^{xA} (0.0)	9.30^{xA} (0.15)	37.81^{xA} (0.89)	20.91^{yB} (0.72)	23.37^{xA} (0.96)	-
	KMS	21.36^{xyB} (2.07)	78.64^{xyA} (2.07)	0.56^{xB} (0.04)	3.10^{yB} (0.02)	4.05^{xA} (0.09)	6.0^{xA} (0.0)	10.03^{yB} (2.02)	40.31^{yA} (1.67)	17.13^{xA} (2.00)	22.76^{xA} (1.65)	2.93^{xA} (0.14)
	AA	21.63^{yB} (2.26)	78.3^{xA} (2.26)	0.57^{xB} (0.03)	1.79^{xA} (0.07)	4.03^{xA} (0.07)	6.0^{xA} (0.0)	10.18^{yAB} (0.44)	41.48^{yA} (2.56)	18.06^{xAB} (3.12)	23.25^{xA} (1.52)	2.55^{xA} (0.27)

Values are means of triplicate readings with a standard deviation in brackets.
Mean values in a column for pre-treatments with the same superscript (x, y, z) are not significantly different ($p<0.05$) from each other.
Mean values in a column for drying method with the same superscript (A, B,) are not significantly different ($p<0.05$) from each other.
Dwb-dry weight basis.
TTA-Total titratable acidity
TTS-Total Soluble Solids
ΔE-total colour difference

Water activity (a_w) is a measure of how much of the water in a product is free and not physically bound, but which is available for food enzyme activity and microbial growth (Prabhakar *et al.*, 2014). Water activity (aw) for solar-dried tomato powder were significantly lower (0.35 ± 0.01 to 0.38 ± 0.05) than sun-dried tomato powder (0.53 ± 0.002 to 0.57 ± 0.03) (Table 5.2). In a similar study by Rajkumar *et al.* (2007), significant differences were observed for a_w of tomato slices dried in vacuum assisted solar dryers and open sun drying with corresponding moisture content of 11.5 ± 0.01 % (w.b). Pre-treatment of solar and sun-dried tomato powder did not have significant ($p > 0.05$) effect on water activity (Table 5.2). In general, foods have a_w levels in the range of 0.2 for very dry foods to 0.99 for moist fresh foods. Microorganisms can keep their viability regardless of the water activity, but growth of bacteria require $a_w >$ 0.8 whiles yeasts and moulds grow in $a_w >0.6$ (ECOM, 1997). Since dry fruits have a_w of 0.4; thus the a_w of solar dried tomato will enhance a stable storage shelf life for the product. In a similar study, water activity lower than 0.6 was considered microbiologically safe for storage (Wang and Brennen, 1991).

5.4.1.2 Total soluble solids, pH and ash content

Total soluble solids of reconstituted solar dried tomato were significantly ($p \leq 0.05$) lower (6.0) for all sun-dried samples (7.0), with the exception of KMS pre-treated solar dried tomato powder which was also 7.0 (Table 5.2). Generally sun-dried tomato had lower brix than solar dried tomato. This is a direct reflection of the differences in moisture content between the solar dried and sun dried samples. Solar dried samples had lower moisture content and therefore the soluble solids were more concentrated than the sundried samples.

The pH for sun-dried tomato powder was higher than that of solar-dried tomato, but the differences observed was not significant ($p > 0.05$). Total titratable acidity (citric acid) was higher for sun-dried (3.10 ± 0.02) compared with solar-dried (2.87 ± 0.03) pre-treated with KMS than sample with other pre-treatments, however the differences observed was not significant ($p > 0.05$). The higher acidity recorded for sun-dried samples could be an indication of fermentation of sun-dried tomato.

The ash content was slightly higher in the sundried samples (9.30-10.18%) compared to the solar dried tomato samples (9.4-9.68 %) (Table 5.2). Higher ash content is indicative of contamination by dust and other extraneous materials. In a study by Gallali *et al.* (2000) on dried grapes, the ash content for solar dried (2.95 %) and sun-dried grapes (12.1 %) differed significantly ($p \leq 0.05$) indicating higher microbial load with sun drying. The presence of microbes, dust and other contaminates increase the overall ash content

5.4.1.3. Tristimulus colour

Tristimus colour for lightness L* value for sun-dried tomato was significantly ($p \leq 0.05$) affected by the different pre-treatments. L*for dried tomato pre-treated with ascorbic acid and KMS was higher than the control samples which had no pre-treatment. The use of KMS and ascorbic acid which are both acidic in nature had a bleaching effect on the redness of tomato. Lower L* (37.81 ± 0.89 - 40.31 ±1.67) observed for sun-dried tomato indicated that these samples were darker in colour than all the solar dried samples with higher L* values (50.35 ±2.9 - 46.44 ± 1.2). The results are similar to findings in a study by Falade and Shogaolu (2010) where higher L* value was observed for sulphited pumpkin due to the bleaching effect of the sulphite treatment prior to air oven drying.

The presence of pigments susceptible to degradation by non-enzymatic and enzymatic reactions affects the colour of fruits, and vegetables. A low a_w in dry products leads to an increase in the half-life of the pigments (Pizzocaro *et al.*, 1993). It was also observed that the colour change in sun drying was mainly due to the non-enzymatic browning /Maillard reaction and it was in the solar dried samples compared to sun drying (Pizzocaro *et al.*,1993). The colour change (ΔE) of solar dried tomato pre-treated with KMS (3.52 ± 0.32) and ascorbic acid (3.00 ± 2.82) significantly differed from the control and was higher than pre-treated sundried tomato (2.93 ± 0.14 - 2.55 ± 0.27). There was higher degradation of the red tomato colour characterised by darker red colour (brownish) in sundried tomato than solar dried. In a similar study by Latapi and Barrett (2006), significant ($p \leq 0.05$) differences were observed in the colour of sundried tomato pre-treated with different concentrations of sodium metabisulphite. In that study colour values (hue°) decreased with increasing concentration of sodium metabisulphite and a more desirable redder colour was observed with increasing sodium metabisulphite concentration (6% - 8%). Also sun-dried tomatoes that were dipped in an 8 % sodium metabisulphite solution had the highest sulphur dioxide content, and thus the best red colour (32.2 hue°) compared with control sun-dried tomatoes with the highest hue angles before (36.9 hue°) and after storage (42.0 hue°) with darker brown colour. During drying, pre-treatment with sulphur dioxide preserves colour and reduces colour degradation.

5.4.2. Microbiological quality of tomato powder

Table 5.3 shows the microbiological quality of tomato powder. The yeast (2.48 log CFU/g) and mould (2.30 log CFU/g) counts were below the allowable limit of 3.0 log CFU/g for yeast and 4.0 log CFU/g for moulds; set by the International Commission for Microbiological Specifications for foods (ICMS). Pre-treatment aids in the inhibition of enzymatic browning, reduces water activity and microbial growth (Augustus, Kumar and Bhattacharya, 2002; Mandala *et al.,* 2005; Falade and Omojola, 2008) which results in minimal quality degradation. Yeast and mould counts were significantly ($p \leq 0.05$) lower for solar dried tomato pre-treated with KMS than for samples pre-treated with ascorbic acid and the control. Osmophilic yeasts are of no public health significance, but they are responsible for spoilage and development of off or fermented odours, which limit shelf life (Vanderzant and Splittstoesser, 1992). Significant differences in yeast count were observed between the control and pre-treated tomatoes ($p \leq 0 .05$). In a study by Lapati and Barretti (2006), sun dried tomatoes pre-treated with sodium metabisulphite did not show signs of spoilage or off-odours and had lower yeast counts than those not treated with sodium metabisulphite which had reduced yeast growth. Lapati and Barretti (2006) thus recommended pre-treatment of 6% or 8% sodium metabisulphite concentrations for 5 minutes to control yeast growth for tomato. Untreated sun-dried tomatoes, yeast counts were 4.9 log CFU/g exceeding allowable limits (103/g), resulting fermented odours with physical signs of spoilage in the same study by Lapati and Barretti (2006) and yeast

growth was reduced significantly (3.5 log CFU/g) when tomatoes were dipped in a 10% salt solution for 5 min before sun drying. *E. coli* was not detected in any of the pre-treated dried samples. Aerobic mesophile counts were also lower in solar dried tomato pre-treated with KMS compared to sundried samples. Yeast (4.20 log CFU/g) counts recorded for sundried tomato pre-treated with KMS was higher than the set limits. Sundried samples pre-treated with ascorbic acid also recorded yeast and moulds within the acceptable allowable limits ICMS set limits counts were the same for both control and treated samples (10 CFU/g).

Drying method	**Pre-treatment**	**Aerobic mesophiles**	**Moulds**	**Yeasts**	**Coliform**	**E. coli**	**Sulphur dioxide/ ppm**

Table 5.3. Microbial log CFU/g counts for pre-treated solar and sun-dried tomato

Solar	Control	5.73	3.60	3.60	3.2	ND	533.32
	KMS	3.90	2.30	2.48	ND	ND	740.99
	AA	5.15	4.78	5.11	ND	ND	538.54
Sun	Control	5.00	3.48	5.02	ND	ND	474.47
	KMS	4.85	3.60	4.20	2.95	ND	480.55
	AA	4.08	2.90	2.85	ND	ND	567.47

Microbial Counts were expressed as base-10 logarithms of colony forming units per gram (log CFU/g) for solar and sun-dried tomato.

ND - Not detected

5.4.3. Effect of sulphur dioxide on microbial load of tomato

The residual sulphur dioxide content of both solar and sundried tomato samples with Potassium metabisulphite pre-treatment was within safe limit of < 2000 ppm (Table 5.3). Pre-treating tomato with 1 % KMS implies an initial concentration of 3400 ppm of sulphur dioxide before drying, but this was significantly reduced to 740.8 ppm for solar dried tomato and 480.55 ppm for sundried tomato. The heating process removes sulphites by decomposing the sulphites and subsequent removal of the resulting free sulphur dioxide gas (Latapi and Barrett, 2006). A strong, negative correlation between sulphur dioxide 740.9 ppm concentration and microbial load was observed for solar dried tomato. Davis *et al.* (1973) recommended an initial sulphur dioxide content of 3000 mg/kg for dried fruits to enhance the microbial safety. The safety of sulphites in foods and its alleged roles in causing certain allergic reactions and asthma has been questioned. This led to the revocation of the generally recognised as safe (GRAS) levels of sulphites for use in fresh fruits and vegetables by the FDA in 1986. Thus most countries accept a maximum legal limit of 2000 ppm of sulphur dioxide in fruits

(Okan and Cemeroglu, 2002). During three months of storage of sundried tomato significant losses of about 70% sulphur dioxide content, was observed in sun-dried tomato, lowering the levels of sun-dried tomato. Similar results were also observed by Babalyk and Pazyr (1997), whereby higher losses of sulphur dioxide occurred in sun-dried tomatoes with initial high concentration of 4000 ppm.

5.4.4 Lycopene, beta carotene and total carotenoid assessment of tomato powder

5.4.4.1 Effect of pre-treatment and drying method on beta carotene, lycopene and total carotenoid quality of tomato powder

Table 5.4 shows some antioxidant composition of tomato powder. Tomato contains different kinds of micronutrients such as carotenoids, folate, vitamins (C and E), and phenolic compounds (Periago and Garcia-Alonso, 2009; Beecher, 1998). Tomato is a rich source of lycopene, an important carotenoid which has enormous health benefits. Fresh tomato fruit contains about 7.2 to 200 mg of lycopene per kg of fresh weight, which accounts for about 30 % of the total carotenoids in plasma (Stahl and Sies 1996). In this study, fresh tomato contained 14.9 mg/of lycopene per kg of fresh weight, however, it has been reported that exocarp of fresh tomato contains about five times more lycopene than the pulp (Papaioannou and Karabelas, 2012).

Solar-dried tomato pre-treated with KMS had significantly ($p \leq 0.05$) high carotenoids (43.13 ± 1.43 mg/100g), lycopene (50.35 ± 2 .01 mg/100g) and beta carotene (29.16 ± 0.78) compared with the other solar dried samples. Sun-dried tomato pre-treated with

KMS also recorded significantly high β-carotene (10.46 ± 1.78 mg/100g), lycopene (23.01 ± 2.04 mg/100g) and total carotenoid concentrations (33.21 ± 0.76 mg/100g) compared with ascorbic acid pre-treated and control sun-dried samples (Table 5.4). Drying method significantly ($p \leq 0.05$) affected the lycopene, β -carotene and total carotenoid levels in dried tomato samples. There was significant ($p \leq 0.05$) interaction of pre-treatment and drying method on the lycopene, β-carotene concentration which led to high values recorded for KMS pre-treated tomato. USDA database records lycopene of 45.90 mg/100g and β-carotene of 0.524 mg/100 g on dry weight basis for sundried tomato (<http://www.nal.usda.gov/fnic/foodcomp>).

Processing such as drying can affect isomerization, bio-accessibility and concentration of lycopene (Knockaert *et al.*, 2012). In a study carried out by Georgé *et al*. (2010), the thermal processing of tomato juice into tomato puree, (at 92 ^{o}C for 10min) significantly ($p \leq 0.05$) reduced total polyphenolic and vitamin C content in both yellow and red varieties, but did not significantly ($p \leq 0.05$) lower the carotenoid content of red tomato. Freeze drying of tomato juice also reduced the carotenoid content but did not affect total polyphenol content of tomato. In a related study by Owureku-Asare *et al.* (2014), the lycopene content of conventional oven dried tomato pre-treated with sodium metabisulphite was 93.0 ± 1.68 mg/100g showing a lowering in degradation compared to samples pre-treated with ascorbic acid. This could be as a result of the protective effect of the metabisulphite. Sun-drying, causes considerable carotenoid destruction whiles drying in a solar dryer reduces the exposure to direct sunlight and consequent destruction of carotenoids in tomato pre-treated with antioxidant. Sulphating agents reduce carotenoid degradation and inhibiting the enzyme polyphenol oxidase by binding its sulphydryl groups to the active site of the enzyme, demobilizing it (Pizzocaro *et al.*,1999). In a study by Davoodi *et al.* (2007), the retarding effect of $CaCl_2$ for browning and protective effect of KMS on lycopene was observed in tomato powders. All the carotenoids assessed were highest in KMS treated sun and solar dried tomato samples (Figure 5.1 and 5.2).

Drying Method	**Pre-treatment**	**β -carotene mg/100g (dwb)**	**Lycopene mg/100g (dwb)**	**Total carotenoid /mg/100g (dwb)**
Solar	Control	28.34^{zB} (0.23)	15.32^{yB} (1.53)	31.80^{zB} (2.01)
	KMS	29.16^{zB} (0.78)	50.35^{zB} (2.01)	43.13^{zB} (1.43)
	AA	8.753^{xyA} (0.94)	2.69^{xA} (1.82)	9.02^{xA} (0.92)
Sun	Control	9.86^{yA} (1.09)	13.86^{yA} (0.24)	28.54^{yzA} (1.72)
	KMS	10.46^{yA} (1.78)	23.01^{yA} (2.04)	33.21^{zB} (0.76)
	AA	6.39^{xA} (1.39)	11.25^{xA} (0.34)	15.21^{xA} (0.78)

Table 5.4. Beta carotene, Lycopene and total carotenoid quality of tomato powder

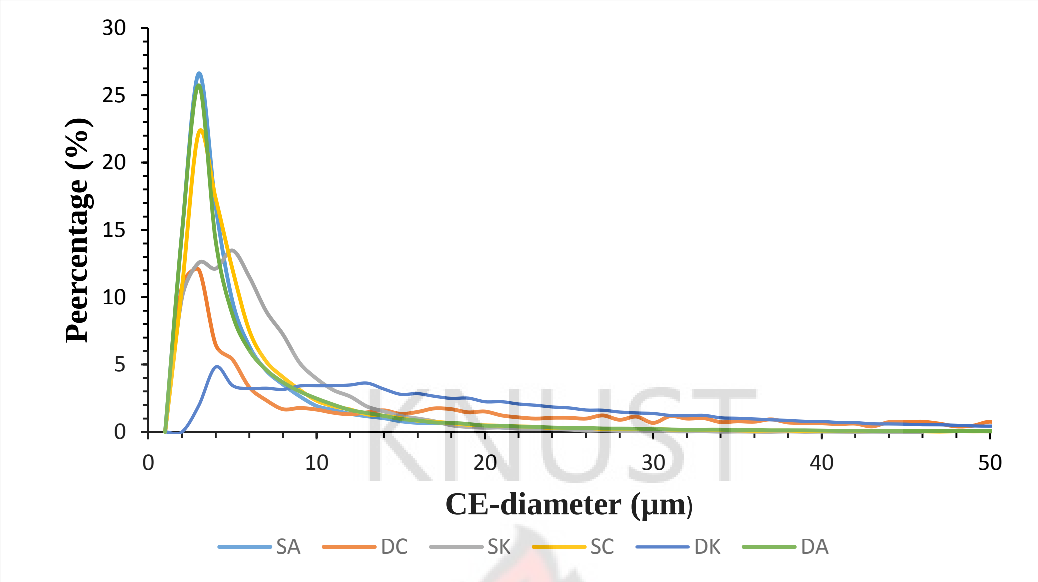
Values are means of triplicate readings with a standard deviation in brackets. Mean values in a column for pre-treatments with the same superscript (x, y, z) are not significantly different ($p \leq .05$) from each other. Mean values in a column for drying method with the same superscript (A,B) are not significantly different ($p \leq .05$) from each other. dwb-dry weight.

5.4.5 Particle size and shape distribution of tomato powder

5.4.5.1 Size diameter of tomato powders

Many food products exist in particulate form (as powders, emulsions, suspensions and pellets) and their behaviour is often dominated by the physical properties of the constituent particles. The particle size and their distribution as well as their shapes have direct influence on particulate food properties such as: texture and feel, appearance, taste, flowability and handling, viscosity (of the suspensions), packing density and porosity. Consequently, some of the most important physical properties to measure for particulate foods are the particle size, particle shape, mechanical properties and microstructure (Sign *et al.*, 2005). Particle shapes are described in terms of the shape of the particle (i.e aspect ratio), outlines (convexity or solidity) and shape parameters (HS circularity). Particles with very smooth outlines will have a convexity/solidity value close to 1, whereas particles with rough outlines, or agglomerated primary particles, will have consequently lower convexity/solidity values. Tomato powder particle circle equivalent (CE) diameter and high sensitivity (HS) circularity and convexity distributions are presented in Figure 5.1. HS-circularity quantified how close the shape is to a perfect circle and convexity is the measurement of the surface roughness of a particle and it is calculated by dividing the convex hull perimeter by the actual particle perimeter.

The physical properties including moisture content and milling methods affect particle size distribution of flours and powders (Dexter *et al.*, 1994; Gaines, 1985). Sun-dried and solar dried tomato samples pre-treated with ascorbic acid and sundried control recorded higher percentage of particles between 2-10 µm. KMS pre-treated dried tomato powder had highest proportions of small particles between 2-5 µm, there were also high proportions of the particles ranging from 2-31µm making the particles larger than the rest of the powders. Sun dried tomato powder pre-treated with potassium metabisulphite and solar dried control samples also had relatively higher particle size between 2-14 µm.

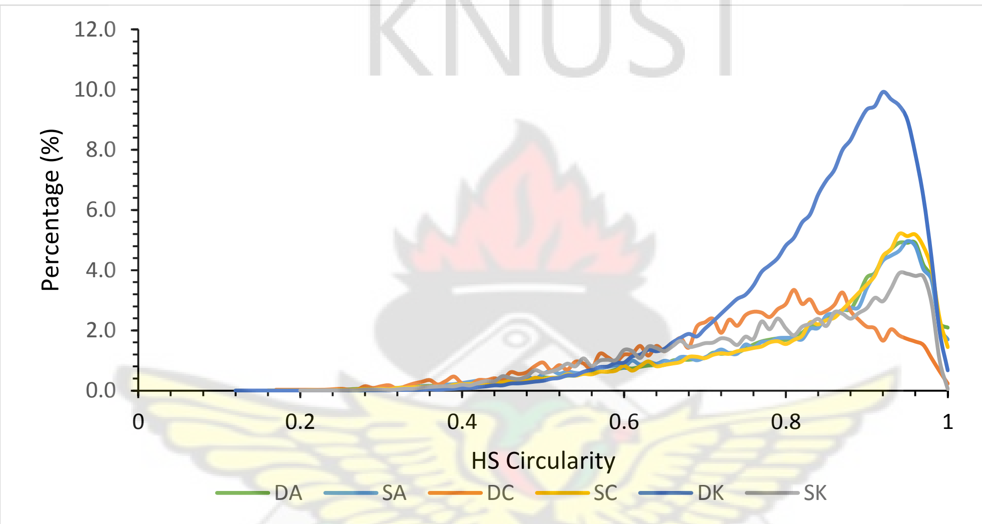


SA- sundried tomato powder pre-treated with ascorbic acid; SK- sundried tomato powder pre-treated with potassium metabisulphite; SC-sundried tomato powder with no pre-treatment; DA- solar dried tomato powder pre-treated with Ascorbic acid; DK- solar dried tomato powder pre-treated with potassium metabisulphite; DC- solar dried tomato powder with no pre-treatment

Figure 5.1 Number distribution of tomato powder particle circle-equivalent (CE) diameter.

In a study by Sign *et al.* (2005) the particles of blanched tomato powder were finer compared with un-blanched tomato powder. Blanched tomato had a narrow range of particle sizes depicting more stable particles which is desirable in processing into other tomato products. Solar dried tomato powder pre-treated with KMS (DK) had CE-diameter which was widely distributed compared to the other samples. SC, DA, SA, SK and DC had higher proportions (peak) of particles with size of up to 3µ while DK was 4µ. Tomato powder mainly composed of sugars, minerals, organic acids, lycopene and total phenols (Verma *et al.*, 2016). Compared to flours/ from starchy foods, the dried skin/exocarp of the tomato gave the powder a chaffy and coarse texture with the mesocarp of tomato producing a finer matrix to the powder. The narrow peaks for almost all the samples shows a larger proportion of smaller particles

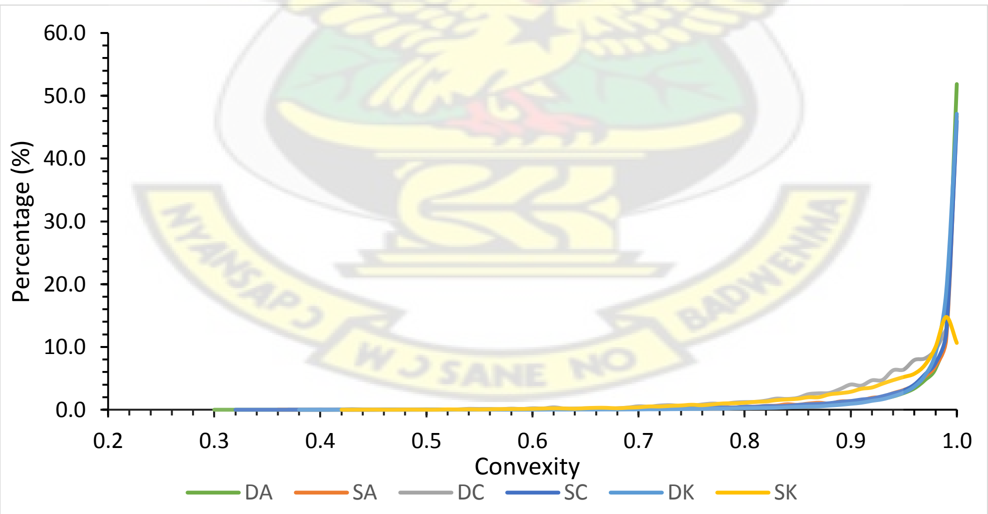
(5–10µm), an indication that the milling intensity produced smaller particle sizes (Verma *et al.*, 2016). In a study of Sorghum flour, the particles had diameters that ranged between 5 and 30µm (Choi *et al.*, 2008), which suggests starch damage enhanced by the grinding process.



SA- sundried tomato powder pre-treated with Ascorbic acid; SK- sundried tomato powder pre-treated with potassium metabisulphite; SC-sundried tomato powder with no pre-treatment; DA- solar dried tomato powder pre-treated with Ascorbic acid; DK- solar dried tomato powder pre-treated with potassium metabisulphite; DC- solar dried tomato powder with no pre-treatment

Figure 5.2 Number distribution of tomato powder particle High-Sensitivity (HS) circularity.

Even with the same milling process, the HS-circularity (Figure 5.4) and convexity (Figure 5.3) of tomato powder were highly different. The circularity of 10 % of the particles of solar dried tomato powder pre-treated with KMS were 0.92 % making up the highest proportion of the shape of the samples. The convexity of tomato powder granules was higher (0.98-1.0) because most of the powder particles were separate and less shape-distorted. On the other hand, exocarp of tomato fractions had less uniform shapes, with low convexity and circularity similar to the bran of cereal flours (Saad *et al.*, 2011). KMS pre-treated solar dried tomato powder resulted in powder particles with more convex and circular shape compared to the other samples. The treatments with KMS could have weakened the bond between exocarp and mesocarp of tomato as well as between sugars, acids and protein, resulting in a better separation of powder particles. Figure 5.4 shows some particles of tomato powder. Different particle sizes had varied convexity and circularity and particles fractions that were mostly irregular, elongated and fibrous in shape seem to come from the exocarp of the tomato whiles others mostly rounded were produced from the mesocarp matrix. From the results, it can be deduced that solar dried tomato pre-treated with KMS would give a smoother texture compared to the other samples when reconstituted into other tomato products.



SA- sundried tomato powder pre-treated with Ascorbic acid; SK- sundried tomato powder pre-treated with potassium metabisulphite; SC-sundried tomato powder with no pre-treatment; DA- solar dried tomato powder pre-treated with Ascorbic acid; DK- solar dried tomato powder pre-treated with potassium metabisulphite; DC- solar dried tomato powder with no pre-treatment.

Figure 5.3 Number distribution of convexity of tomato powder particles

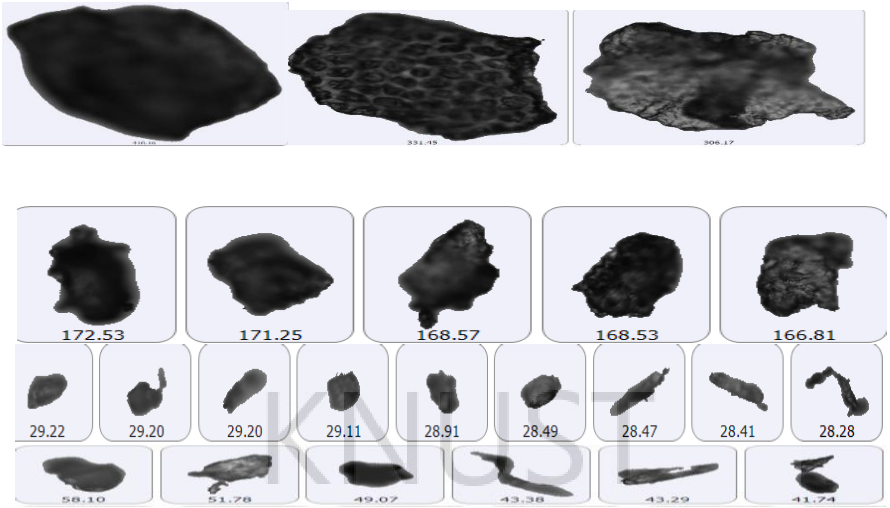


Figure 5.4. Some selected particles of tomato powder

5.4.6. Microstructural evaluation of dried tomato

Scanning electron microscopy uses microscopic techniques to examine the changes in the size and shape of the intercellular and cellular spaces and structural changes that occur when food is processed (Alzamora *et al.*, 1996; Aguilera and Lillford, 1996,). The cellular structure of tomato influences the mode of transfer of nutrients and water during drying and this has an impact on the quality of dried tomato (Gekas, 1992).

The physical characteristics of dried banana and apple correlated well with their microscopic structure. (Tortoe and Orchard, 2006). SEM of fresh tomato has shown rigid cell walls with firm edges and that of dried tomato looks depressed, distorted and deformed. Differences in the distortion, shape and appearance of cell walls could be observed for sun and solar dried samples (Figure 5.5 and 5.6). The depressions are a sign of water loss and it can be observed that the depressions for the solar dried tomato are more pronounced at the cellular level compared to the sun dried (final moisture content 19-20%); an indication of higher water loss in solar dried tomato (final moisture content 14-15%).

Zogzas *et al.* (1994) explained the extent of collapse of the cell wall during drying as being proportional to the quantity of water lost during the drying process. This is similar to what was observed in a study by Owureku-Asare *et al.* (2014), about the structure of oven dried tomato. From this observation, pre-treatment did not seem to affect the cell structure of solar and sun-dried tomato as there were no visual differences observed in the cellular structures for the different pretreated samples. In similar studies by Tortoe and Orchard (2006) and Sargent (1998) for apple and banana respectively, osmotic dehydration caused the movement of water and deformation of the pectin, hemi-cellulose and cellulose of the cell structure, plasma membrane and middle lamella resulting in the collapse of the cell and plasmolysed cells.

Dried tomato is considered to be hygroscopic (Hawlader *et al.*, 1991) and reconstitute well when water is added to it. The water moves freely across the gradient and is absorbed by the cellular membranes of tomato.

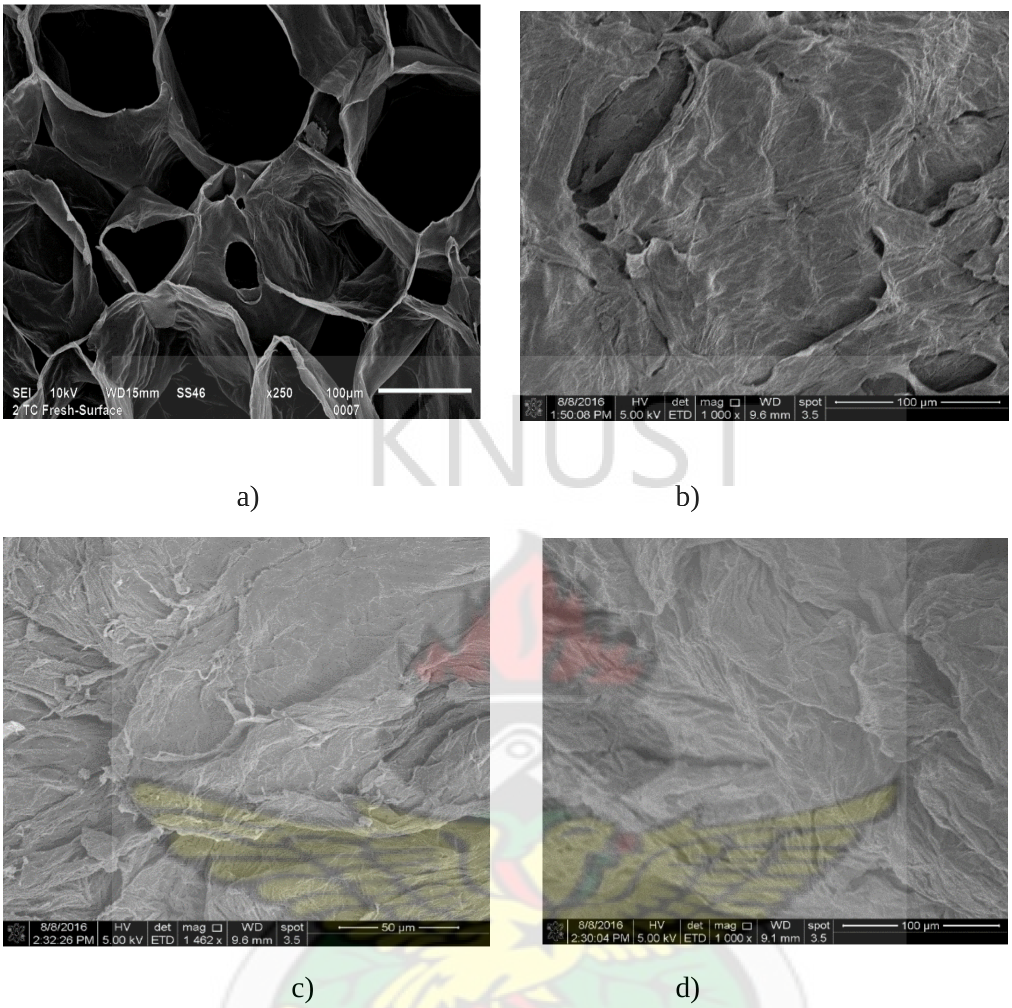
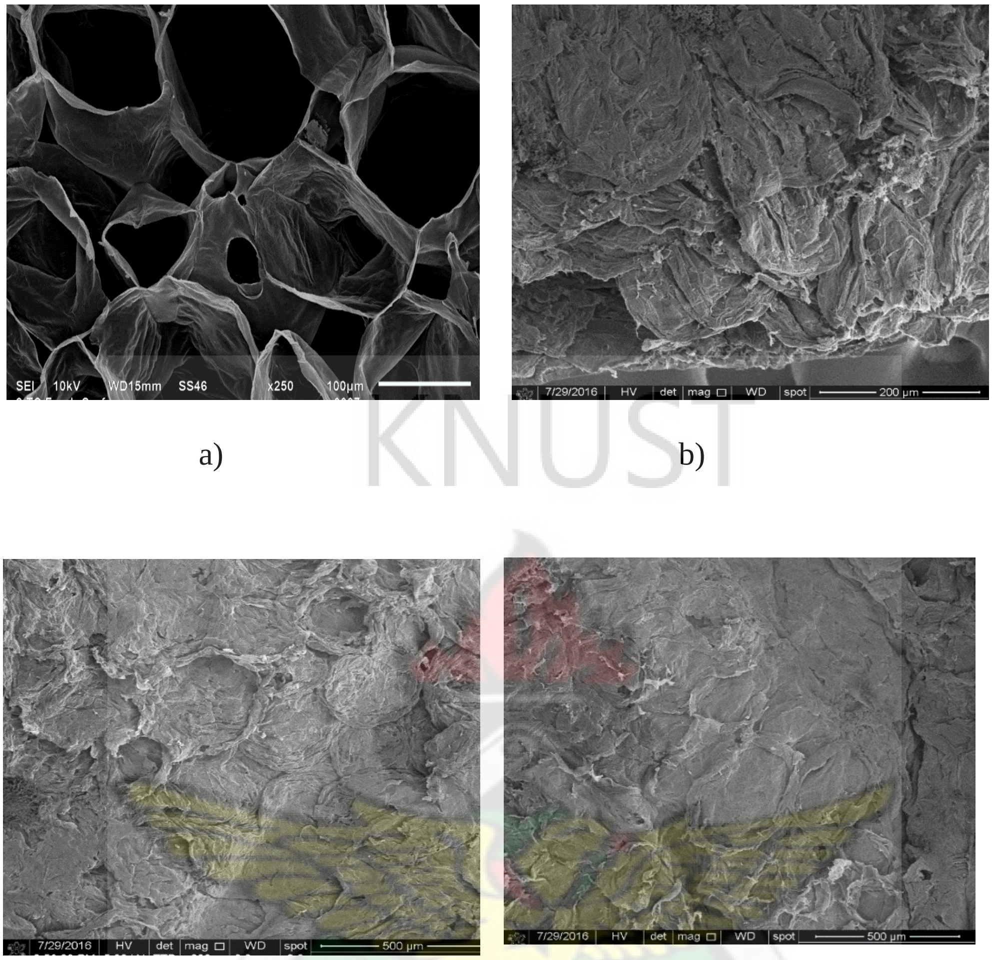


Figure 5.5. The microstructure of the surface of (a) fresh tomato (b) sun-dried tomato slices with no pre-treatment (c) sun-dried tomato slice pre-treated with ascorbic acid (d) sun-dried tomato pre-treated with KMS at SEM magnification of 500x.



a) b)

c) d)

Figure 5.6. The microstructure of the surface of (a) fresh tomato (b) solar-dried tomato slices with no pre-treatment (c) solar-dried tomato slice pretreated with ascorbic acid (d) solar-dried tomato pre-treated with KMS at SEM magnification of 500x

5.5 Conclusion

The ash content was higher in the sun-dried samples compared to the solar dried tomato samples, an indication of contamination with extraneous materials from the environment. Sulphur dioxide content of 740.8 ppm recorded for solar dried tomato pre-treated with potassium metabisulphite was much lower than the maximum legal limit of 2000 ppm of sulphur dioxide recommended in fruits, suggesting that pretreatment of tomato with metabisulphite should not pose a health hazard to consumers. Solar-dried tomato powder pre-treated with potassium metabisulphite had the best colour and microbiological quality (which was within internationally acceptable range of 3.0 log CFU/g of aerobic mesophiles count). Tomato pre-treated with potassium metabisulphite had its lycopene, beta carotene and total carotenoids better preserved than the other pre-treatments. Potassium metabisulphite pre-treated solar dried tomato powder particles were finer, had good flowability (ie more convex and circular in shape). Consequently, tomato powder obtained from metabisulphite pre-treatments will have better reconstitution characteristics, an ideal quality for further processing into other products such as sauce or paste.

CHAPTER SIX: Sensory profiling of tomato powder.

6.1. Introduction

Consumer demand for novel products is crucial for driving the needed innovations for new product development. Product development may originate from new technology or new market opportunities (Eliashberg *et al.*, 1997). However, the successful adoption of improved or new products depends largely on consumers (Brown and Eisenhardt, 1995). The role of sensory evaluation in food product development and for quality assessment has been widely documented (Stone, 1999; Klosse *et al.*, 2004; Barbosa and Vaz-Pires, 2004; Vaz-Pires and Seixas, 2006; Karoui *et al*., 2006; Etaio *et al.*, 2010).

Sensory evaluation using consumers may include the use of focus groups, surveys and the study of demographic characteristics. Information generated from such studies are important in determining and directing the objectives for new-product development, product improvement and optimization (Choi *et al*., 2007). Wind and Mahajan (1997) and Garber and Boya (2005) recommends that researchers combine these methods complementarily to provide the best possible picture for developing market oriented products with high rate of success. An example is to combine focus groups to identify product performance attributes that are important to consumer needs, and influence choice decisions for a given product category.

With consumer acceptability studies, the perceived sensory characteristics of food, and the extent of variation in sensory characteristics by the consumer is critical (Villegas, 2008). Consumer acceptability test measures the extent of consumer's likeness or otherwise towards a product (Stone and Sidel, 2004, Lawless and Heymann, 1999b), thus, an important component for predicting their food choice (Hein *et al.*, 2008).

Sensory descriptive analysis is one of the most powerful, useful and extensively utilised methods in sensory science. Its application has grown steadily from the 20th century to the 21st century and the generic descriptive analysis technique includes basic elements of Quantitative Descriptive Analysis (QDA) and Spectrum (Lawless and Heymann, 2010). Descriptive analysis serves as a link between product characteristics and consumer reaction. Sensory descriptive analysis requires as a first step the selection, training and maintenance of a panel of 8 - 20 assessors (Varela and Ares, 2012).

Sensory Profiling uses these trained panelists to assess products against important attributes that characterizes a product. It focusses on the objectives measurement of key product attributes instead of the 'liking' out of the test analysis (Meilgard *et al.*, 2006). In sensory profiling of products, subjects describe the product attributes and rate their level of intensity to capture their description of the product characteristic as perceived. Different methods can be employed to achieving this. Data from sensory profiling using a trained panel gives quantitative description of sensory attributes of the food product as perceived by the subjects and that been used in product development allowing correlations to other parameters (Lawless and Heymann, 2010; Moussaoui and Varela, 2010; Murray, Stone and Sidel, 2004).

Quantitative Descriptive Analysis of the solar dried tomato will help with preference mapping of the product; a vital tool which is used to establish how consumer preferences and likeness are explored in relation to sensory stimulus. (Hein, 2008). The monitoring of sensory parameters such as appearance, texture, mouth-feel, flavour, aroma and after effect of tomato powder is therefore paramount to assessing the quality of the product. Comparative sensory profiling of tomato powder in relation to other tomato products such as tomato paste and fresh tomato will help provide useful information to better understand the product characteristics.

Even though sensory measurements are often subjective and reflect the opinions of the assessor, physicochemical methods when validated by sensory tests, are efficient and save cost (Piggottt, 1995). Many studies have been conducted that validate instrumental data using sensory panel (Villegas, 2009; Prinyawiwatkul *et al.,* 2007; Choi *et al.,* 2007). Sensory and consumer science is also helpful in collecting quality data of the descriptors of the food samples presented and this helps us to know the constraints as well as help assess the choice of optimum responses of the participants in the study (Piggott, 1995).

6.2. Main Objective:

The main objective was to conduct sensory profiling of solar dried tomato powder and to compare it to existing tomato products.

6.3. Materials and Methods

6.3.1. Sample preparation

6.3.1.1. Preparation of tomato powder

Fresh tomato was cut into slices (5 mm) and pre-treated in 1% sodium metabisulphite solution for 10 minutes and uniformly spread on rectangular mesh trays (87 cm x 53 cm). They were dried in a mixed mode natural convection solar dryer to a moisture content of 13-14 % over a 3-day period. Samples were milled into powder using Kenwood dry mill blender (BL335, Manchester, United Kingdom) at 450W speed for three (3) minutes and packaged in 25 g aluminum foil pouches (Code A). Samples were stored at ambient temperature (approximately 26 ± 2 ^{o}C) prior to use. The market samples of tomato powder were obtained from Domi market in Accra, already packaged in 25 g clear low density polythene bags and stored at ambient temperature (Code B). Reconstituted solar dried tomato powder was compared with two other forms of tomato products; fresh blended tomatoes and reconstituted tomato paste (Plate 6.2). Fresh tomato and tomato paste are the two most common tomato products consumed in Ghana.

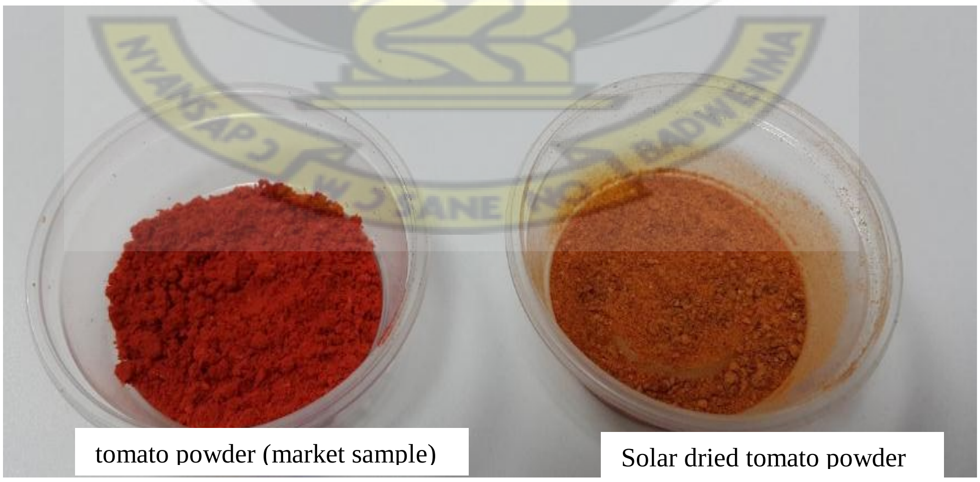


Plate 6.1 Tomato powder samples

6.3.1.2 Reconstituted powder test

A pouch (25g), of the solar dried powder was reconstituted in 100 mL of tepid water (30 ± 2°C) to produce a slurry.

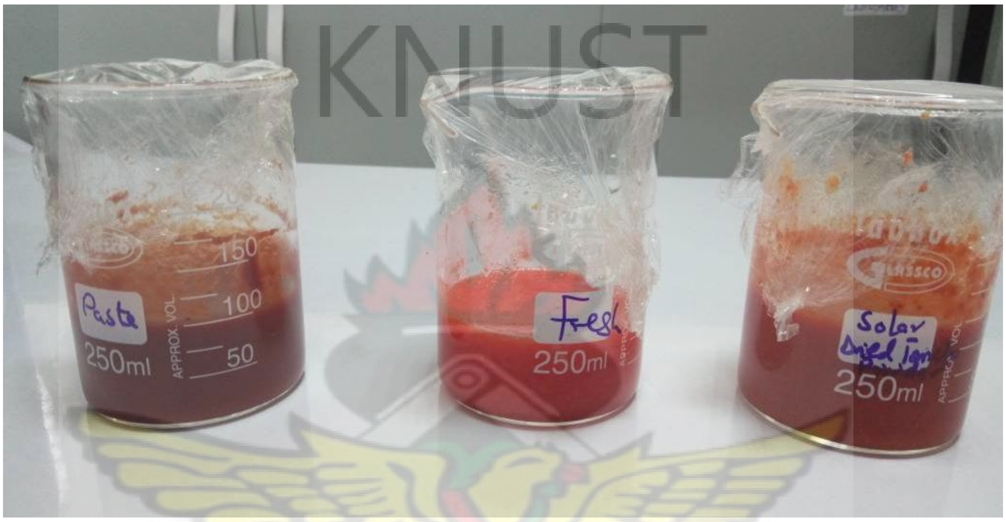


Plate 6.2 Tomato products used in the sensory analysis

6.3.1.3 Blended tomato sample preparation

Fresh tomato samples were stored in a refrigerator at 3-5 °C. Hundred grams (100 g) of fresh tomato were washed, diced and blended with a high-speed blender for 2 minutes with the Philips Blender (Avance HR 2096 SS Body, London, UK).

6.3.1.4. Reconstituted canned tomato paste preparation

To prepare samples for assessment, 50 g of the tomato paste was reconstituted in 50 ml tepid water to produce a slurry to get mixture of similar consistency to solar dried tomato powder slurry. The same batch of tomato paste was used for all assessments.

Table 6.1: Sample details for Dried powder test

SAMPLE	DETAILS	CODE
1	Solar dried tomato powder (Test sample)	A
2	Tomato powder on the market made of milled annatto seeds, corn flour, cola nuts and E. Colour series	B

Table 6.2: Sample details for reconstituted powder test

SAMPLE	DETAILS	CODE
1	Reconstituted Solar Dried Tomato Powder (RSDP)	C
2	Blended fresh tomato with seeds	D
3	Tomato paste (Gino Tomato paste double concentrate made in China for Watanmal group. Net weight= 800 g. Batch:15GE198/6, Production date: 17/07/2015, Expiry date:16/07/2017)	E

6.3.2 Quantitative Descriptive Analysis

Quantitative Descriptive Analysis (QDA®) were carried out to compare the sensory descriptive profiles of solar dried tomato powder and existing tomato products on the market with their reconstituted forms. Tables 6.1 and 6.2 summarises the samples analysed.

6.3.2.2 Training of sensory panel

Nine (9) panelists from Department of Nutrition and Food Science, University of Ghana who had previous experience in descriptive sensory analysis of different foods were selected for the study. Further training and group discussions were conducted for two (2) days for 6 hours each to generate descriptors for dried tomato. The panel was also trained to quantify the intensity of sensory attributes using line scales. All the panelists were over 18 years old, had no known food allergy and had expressed the willingness to participate in the study. The training was carried out at the Food Science Sensory Evaluation laboratory of the Department of Nutrition and Food Science, University of Ghana. The descriptors agreed on by the panel and their definitions are shown in Tables 6.3 and 6.5.

6.3.2.3. Test protocol

Sensory analysis of the samples was carried out separately by 9 panelists in purposed booths at the sensory laboratory under controlled white fluorescent lights at ambient temperature. Each panelist was served 5 mL (1 teaspoon full) of each sample (dry and reconstituted tomato) for all assessments. Samples were served at 25 ± 3°C in 20 mL transparent disposable plastic cups with lids. Each panelist was provided with crackers a cup of water at room temperature for rinsing the mouth in-between sample tasting.

(a) **(b)**

Plate 6.3. Training of sensory panel (a) and product assessment (b)

6.3.2.4. Sensory Evaluation

Two separate QDA® tests were carried out for the dried powder and the reconstituted powder samples, respectively. Assessors developed a unified list of attributes that described the different tomato samples using terms that also showed how the samples differed to each other. Food reference materials suggested by the panel were used to contextualise the descriptive list of attributes to ensure that all descriptors were used in the same way. Term generation was completed in two sessions for each test before the actual assessment was done. A verbal consensus list of all descriptors was compiled for all sensory modalities of the tomato samples (i.e. appearance, aroma, flavour, mouthfeel and aftereffect). To build a stronger consensus, the Check-all-that-apply (CATA) method was used to establish the relevance of individual attributes where assessors individually evaluated the samples using the verbally agreed consensus list. Attributes that were used consistently by half or more of the panel was included in the final list, and the remaining attributes discarded. A final verbal agreement of the consensus list was obtained. The panelists described the attributes (appearance, aroma, flavour, mouthfeel and after effects) for all samples (Appendix 19). However, the tomato powder bought from the market were not tasted due to insect infestation and unwholesomeness. Assessors completed individual scoring of intensities of the different attributes in triplicates using Compusense Cloud® or Compusense 5® (Compusense 5, Guelph, Ontario, Canada). Evaluations were done on a 150 mm line-marking scale anchored at the low end with 'not' and at the high end with 'very'. Replication was done using a true replicate design in Compusense. Samples were evaluated in triplicate in a random presentation order and served in a monadic sequential order.

Twenty-two (22) descriptive attributes were used to describe as well as differentiate between the two dried tomato powder (solar dried tomato powder and tomato powder bought from the market (Table 6.3).

6.3.2.5. Environmental controls during assessment

All assessments were carried out in individually partitioned booths in the Sensory Evaluation Laboratory at the Oraca Tetteh/ Larwey Building at the Department of

Nutrition and Food Science, University of Ghana. The laboratory has full environmental controls with ambient temperature ranging between 24 ^{o}C and 26 ^{o}C. There was minimal noise and distractions and an extractor fan removed unwanted odours from the environment. Samples were served from behind a closed partition through hatches in the partition to minimise interaction and possible bias from research staff. A discussion room was available for panel discussion and this was separated from the tasting and preparation areas. The environmental controls in the discussion area is the same as the tasting area.

6.4. Ethical clearance and consumer consent

This research was assessed and approved by the CSIR (Council for Scientific and Industrial Research - Institutional Review Board (Appendix 18). Consent was sought from consumers participating in this study and they were told that their participation was entirely voluntary and that they could withdraw from the panel at any time.

6.5. Statistical Analysis

Assessors scoring of intensities of attributes generated for appearance, taste, aroma, flavour and after taste was analysed using Compusense Cloud® or Compusense 5® (Compusense 5, Guelph, Ontario, Canada). Product characterisation tool based on two-way ANOVA in XL-Stats (Addinsoft, France) was used to analyse the data. Two-way ANOVA followed by LSD post hoc analysis was further carried out to explain sample differences in the products at 95 % and 99 % confidence interval. Correlation analysis was done using Genstat version 9.2. Graphical representation of the sensory profiles including aroma, taste and flavour characteristics were reported as spider-web diagrams by plotting the mean values for the sensory descriptors. A product map was generated using Principal Component Analyses (PCA) was used to relate solar dried tomato powder and the market sample with their sensory attributes.

6.6. Results and Discussion

6.6.1. Quantitative Descriptive Analysis (QDA) of dried tomato powder

A generic QDA session would usually have between 8-12 trained panelists using a quantitative scale and a reference standard to generate meanings to attributes used to describe a product under assessment (Lawless and Heymann, 2010). In a similar study, nine assessors were used for descriptive analysis of tomato products. In a study by Cardoso and Bolini (2008), eleven panelists were used in descriptive analysis of peach nectar. Five (5) trained panelists were also used for conducting qualitative descriptive analysis of seventeen commercial white wines from 5 grape varieties (Elmaci *et al.*, 2007). Analysis of variance (Table 6.4) showed that the two samples (market sample and solar dried tomato powder) differed significantly for most attributes in those modalities.

Table 6.3: List of sensory descriptors generated for dried tomato powder used for Quantitative Descriptive Analysis

Modality	Descriptor	Definition	Anchor

Appearance	Gritty	Coarse appearance like sand	Smooth to rough
	Orange	Burnt orange colour of pumpkin fruit	Not to Very
	Red	Characteristic colour of fresh red chilli pepper fruit	Not to Very
	Caking	Tendency of powder to form lumps/masses rather than flowing.	Not to Very
	Artificial colour	Having the appearance of artificial food colouring/ looking like powder is stained with artificial food dye	Not to Very
Aroma	Tomato	Characteristic aroma of canned tomato paste	Not to Very
	Nutty	Characteristic aroma of roasted groundnut	Not to Very
	Savoury	Savoury aroma of seasoning cubes like *Maggi* or *Royco* cubes	Not to Very
	Corn Flour	Aroma reminiscent of uncooked corn flour (cereal nature)	Not to Very
Texture in Hand	Gritty	Having a coarse texture in hand	Not to Very
	Dry	Dry feeling between fingers	Not to Very
Flavour	Corn flour	Characteristic taste of uncooked corn flour	Not to Very
	Tomato	Characteristic flavour of canned tomato paste	Not to Very
	Woody	Reminiscent flavour of saw dust	Not to Very
	Salty	Basic taste	Not to Very
	Acidic	Sharp sour taste	Not to Very
	Sweet	Basic taste	Not to Very
	Umami	Basic taste	Not to Very
Mouthfeel	Gritty	How rough or smooth particles feel in the mouth	Smooth to Rough
Aftertaste	Tomato	Lingering flavour of canned tomato paste	Not to Very
	Residual particles	Presence of particles in the mouth	Not to Very
	Salivation	Causing production of saliva	Not to Very

Table 6.4: ANOVA summary table for appearance, aroma, flavour and texture in hand attributes

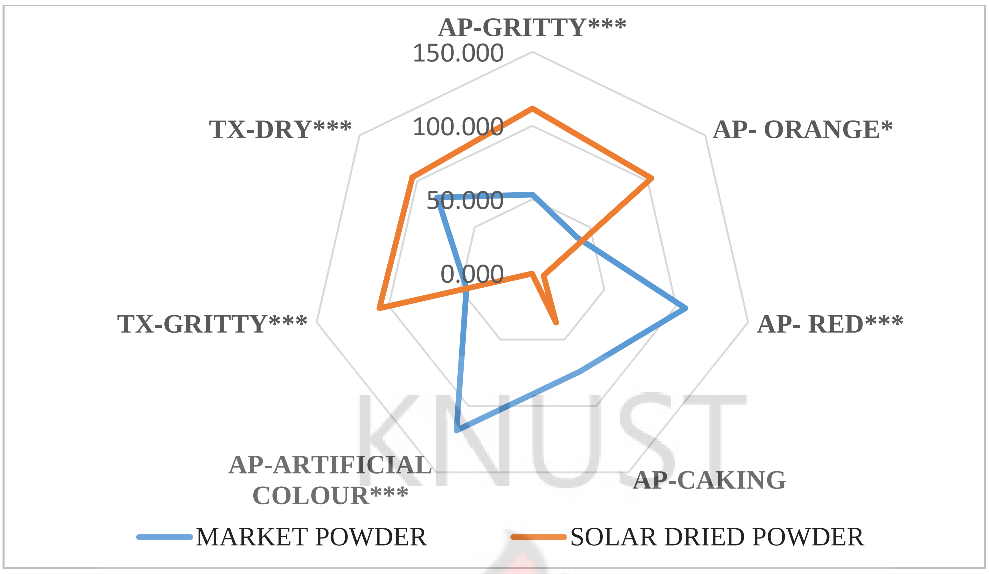
Test Statistic	AP-Gritty	AP-Orange	AP-Red	AP-Caking	AP-Artificial Colour	AR-Tomato	AR-Nutty	AR-Savory	AR-Corn Flour	TX-Gritty	TX-Dry
R^2	0.867	0.875	0.864	0.827	0.958	0.898	0.863	0.759	0.750	0.878	0.783
F	31.622	16.895	30.979	11.547	110.716	21.273	15.258	7.631	14.544	17.422	17.505
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Assessor effect	17.216	9.534	1.518	10.086	4.596	9.176	9.909	7.320	3.181	6.782	18.053
	< 0.0001	< 0.0001	0.202	< 0.0001	0.002	< 0.0001	< 0.0001	< 0.0001	0.014	0.000	<0.0001
Product	118.060		207.742		747.432				82.722		14.220
	< 0.0001		<0.0001		< 0.0001				< 0.0001		<0.001
Assessor* Product		24.255		13.008		33.371	20.607	7.941		28.063	
		< 0.0001		< 0.0001		< 0.0001	< 0.0001	< 0.0001		< 0.0001	

AP- Appearance; TX- Texture in hand, AR- Aroma

6.6.2. Relationship between QDA and Physicochemical tests

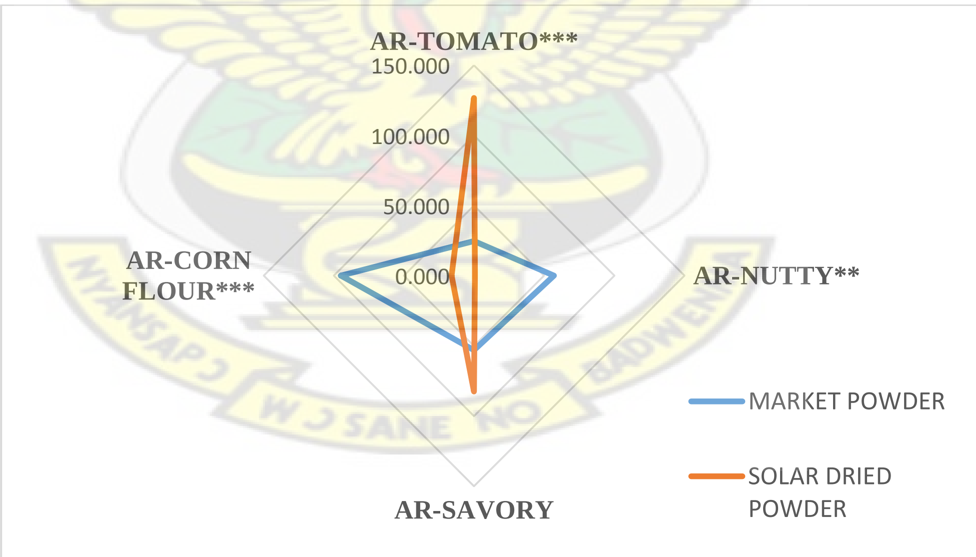
6.6.2.1. Appearance, texture and aroma

The market sample was described as more red with reference to addition of colour whiles the solar dried sample was less red (L*=50.35, a*=20.26, b*=31.76) (Table 5.2) in appearance and texture, and much drier than the market sample (Figure 6.1). There was a distinct trend suggesting that the solar dried sample was more orange in colour than the market sample. This could be as a result of the differences in the moisture content of the market sample (18.6%) which was more moist than the solar dried (moisture, 14.9 %) sample. The aroma of the two samples also differed (Figure 6.2). There was significant ($p < 0.0001$) difference between the samples for corn flour aroma with the market sample being higher in intensity (95 out of 150) for this attribute. The solar dried sample had a stronger intensity tomato aroma while the market sample had a higher intensity nutty aroma (Figure 6.2). “Tomato powder” bought from the market is reportedly made from annatto seeds, corn flour and red colour (and does not contain dried tomato). The annatto seeds and corn flour seem to have imparted the nutty and corn flour aroma respectively scored by the sensory panel.



AP- Appearance; TX- Texture in hand
**Significant difference at 90% CI*
***Significant difference at 95% CI*
****Significant difference at 99% CI*

Figure 6.1 Appearance and texture in hand profiles of solar dried and market tomato powders



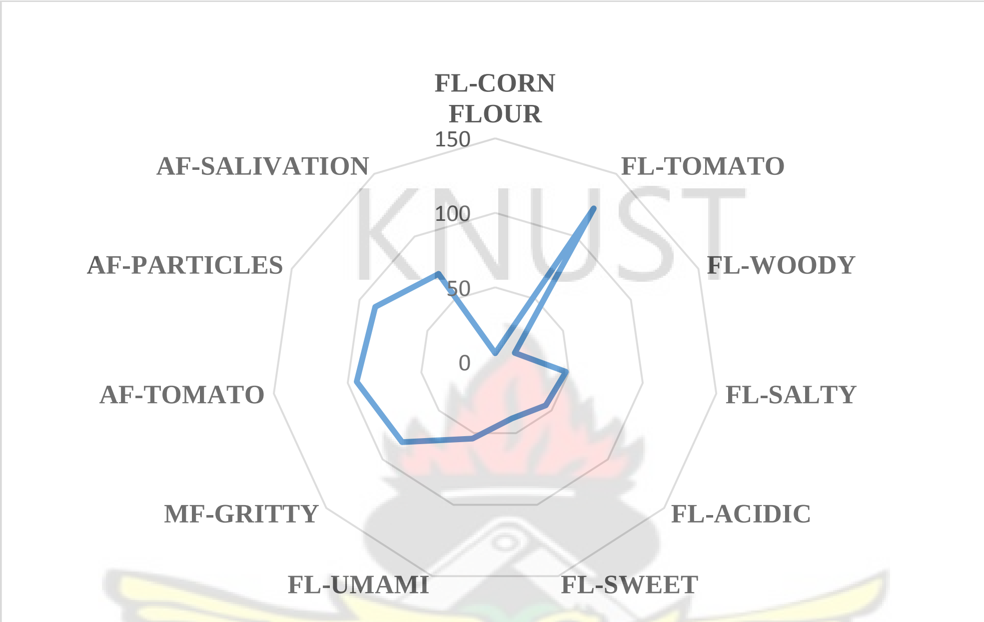
AR- Aroma
*Significant difference at 90% CI
**Significant difference at 95% CI
***Significant difference at 99% CI

Figure 6.2 Aroma profiles of solar dried and market tomato powders

6.6.2.2. *Flavour and after effect*

The flavour profile (Figure 6.5) for the solar dried tomato powder was described as tomato flavour (FL-tomato). The solar dried tomato powder also tasted *salty* and *umami* but only very slightly. The total soluble solids is an indicator of the amount of soluble solids present in a sample. These include polysaccharides that are hydrolysed into reducing sugars (Bradley, 2010).

High acid and sugar content of tomato imparts good flavour, whiles low sugar content and low acids resulting in poor flavour (Malundo *et al.*, 1995; Stevens *et al.*, 1979). Acidity (citric acid) of 2.87 ± 0.03 %, and total soluble solids of 6.0 was recorded for solar dried tomato. The market sample had low brix (1.0 ± 0.0) and acidity (0.34 ± 0.54) mainly because it is made from corn flour, annatto seeds and red colour. These do not enhance flavour of the samples. Sugars and acids in tomato are concentrated when dried due to the removal of water even though some sugar breakdown when exposed to heat. This increases the sugar content imparting sweeter taste to the tomato powder. Acidity recorded in the solar-dried tomato powder pre-treated with potassium metabisulphite was also fairly higher than sun-dried samples (Table 5.2). The market sample on the other hand had very low brix and acidity mainly because it is made from corn flour, annatto seeds and red colour. However, a high score of 122.5 out of 150 was rated by the sensory panel for characteristic tomato flavour (FL-tomato) of solar dried tomato powder samples (Figure 6.3). The sweetness index of solar-dried tomato powder was 0.48 which was not significantly ($p \leq 0.05$) rated by the sensory panel. The dominant attribute for aftereffects of the solar-dried powder perceived were; gritty and lingering tomato taste (Figure 6.3). Some assessors explained that the products sample caused them to salivate although this was not intense.



FL- Flavour; MF Mouth feel; AF- Aftereffects
**Significant difference at 90% CI*
***Significant difference at 95% CI ***Significant difference at 99%CI*

Figure 6.3 Flavour, mouthfeel and aftereffects profile of solar dried tomato powder.

6.6.4 Quantitative Descriptive Analysis (QDA) of Reconstituted tomato products

A total of 30 attributes were used to describe the product set in the five modalities; appearance, aroma, flavour, mouthfeel and after effect as shown in Table 6.5 below.

Table 6.5: Attributes of QDA describing fresh and reconstituted tomato products

Modality	Descriptor	Definition	Anchor
Appearance	Red	Red colour of tomato	Light to dark
	Froth	Presence of clustered bubbles on the surface	Not to Very
	Particles	Presence of tiny particles resembling tomato seeds in the product	None to Many
	Peels	Presence of tiny bits of tomato peels	None to Many
	Smooth	Having an even surface	Smooth to Rough
	Viscous	Product's resistant to flow	Runny to Thick
	Tomato juice	Characteristic appearance of tomato juice	Not to Very
Aroma	Stewed tomato concentrate	Aroma reminiscent of tinned tomato paste	Not to Very
	Fresh Tomato	Characteristic aroma of blended fresh tomatoes	Not to Very
	Boiled Tomato	Characteristic aroma of boiled blended fresh tomatoes	Not to Very
	Tangy	Having a sharp spicy, tart or acidic smell	Not to Very
	Metallic	Characteristic metal smell	Not to Very
Texture in hand *Protocol: Pinch and rub between thumb and index finger*	Coarse	Having a rough texture due to presence of roughage	Not to Very
	Sticky	Degree of product's adhesiveness between thumb and finger	Not to Very
Flavour	Stewed tomato concentrate	Characteristic flavour of tin tomato paste	Not to Very
	Fresh Tomato	Characteristic flavour of fresh tomato	Not to Very
	Cooked note	Characteristic flavour of boiled tomato	Not to Very
	Sour	Basic taste	Not to Very
	Salty	Basic taste	Not to Very
	Sweet	Basic taste	Not to Very

	Umami	Basic taste	Not to Very
Mouthfeel	Particulate	Presence of particles in the mouth	None to Many
	Runny	Ability to flow	Thick to Thin
Aftertaste	Stewed tomato	Lingering flavour of tinned tomato paste	Not to Very
	Particles	Presence of residual particles in the mouth	Not to Very
	Umami	Savoury	
	Sour	sharp biting taste in the mouth	Not to Very
	Salivation	Causing production of saliva mouth	Not to Very

6.6.5. Relation between QDA and physicochemical tests

6.6.5.1. Appearance

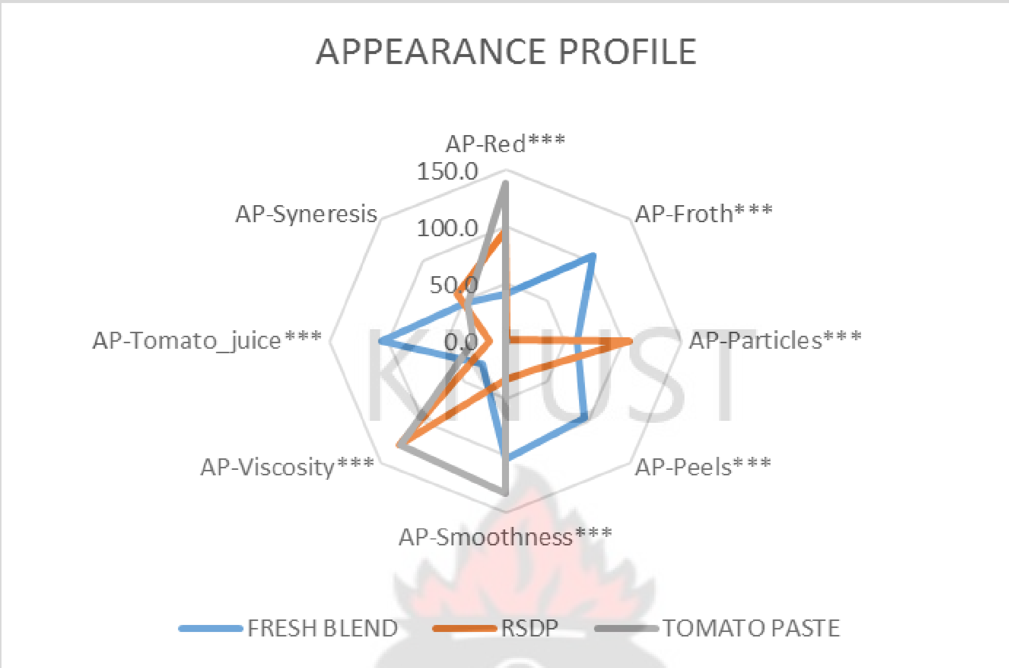
Analysis of variance showed that the samples differed significantly from each other in the different modalities. The differences observed are described for each modality as below. The products differed significantly from each other in appearance. Although statistical interaction effects were observed for some attributes, most attributes showed statistical significant product differences except for the attribute tomato juice.

Table 6.6: ANOVA table showing statistical differences for attributes of appearance for the reconstituted tomato products

	Red	Froth	Particles	Peels	Smooth -ness	Viscosity	Tomato juice	Syneresis
R^2	0.976	0.996	0.948	0.971	0.871	0.893	0.846	0.810

F	141.779	891.091	62.779	115.859	23.308	58.501	12.841	9.936
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Product	1038.449	6882.408	443.923	682.340	157.609	268.813		
	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001		
Assessor						5.923	3.364	15.603
						< 0.0001	0.003	< 0.0001

Reconstituted solar dried tomato powder (RSDP) was not smooth in texture compared to tomato paste. The smoothness of RSDP can be improved upon by using a more efficient milling process compared to what was used in the study. The viscosity of RSDP did not significantly differ from reconstituted tomato paste but was significantly more viscous than fresh blend tomato. The reconstituted solar-dried tomato powder was more red followed by the RSDP and the fresh blend tomato was the least red. Fresh blended tomato had highest degree of froth and peels and was the only sample described as looking like tomato juice. Figure 6.8 shows the appearance sensory profile of the three samples.



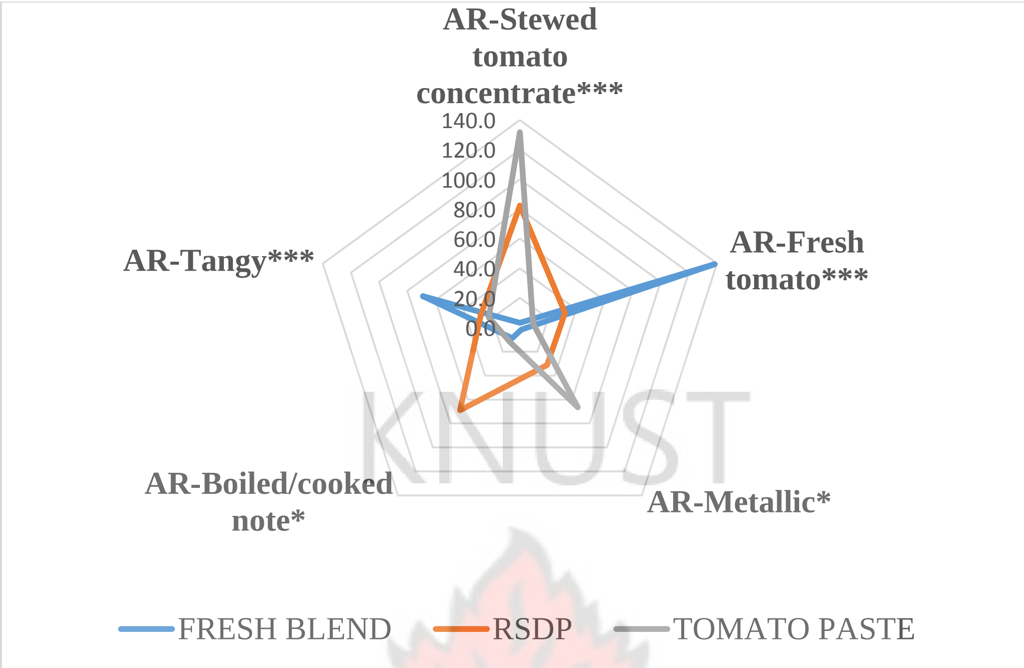
AP- Appearance
**Significant difference at 90% CI*
***Significant difference at 95% CI*
****Significant difference at 99% CI*

Figure 6.5: Profile of the appearance of the RSDP, fresh blend and tomato paste

6.6.5.2 Aroma

Most of the attributes showed statistical significant product differences except for metallic and boiled/ cooked note. The reconstituted tomato paste had the highest degree for stewed tomato concentrate followed by the RSDP and fresh blend tomato. The aroma of RSDP was the only sample described as having a boiled/cooked note.

Even though the ideal temperature for drying tomato is 55- 60 ^{o}C, the mean temperature range of ambient air entering the drying chamber of the solar dryer ranged from 47-74 ^{o}C. The intermittent high temperature reached in the dryer may have "cooked" the slices of tomato in the drying process imparting cooked note to the samples. However, there was no statistical ($p \leq 0.05$) significant product or assessor effect for this attribute (Table 6.6). Fresh blended tomato had the highest intensity for tangy and fresh tomato aroma. Tomato paste was the most metallic and the least intense for tangy and fresh tomato aroma. This implies that solar dried tomato powder retained more of its characteristic tomato aroma than tomato paste which contains additives such as colour, pectin, corn starch and other preservatives. The metallic aroma may have been imparted to tomato paste due to the packaging material (metal can). Solar dried tomato powder seems to retain more of its "tomato" aroma and may be a good substitute to fresh tomato than tomato paste which is a currently the preferred choice for cooking many Ghanaian dishes.



AR- Aroma
*Significant difference at 90% CI
**Significant difference at 95% CI
***Significant difference at 99% CI

Figure 6.6: Profile of the aroma of the RSDP, fresh blend tomato and tomato paste

Table 6.7: ANOVA table for Aroma attributes

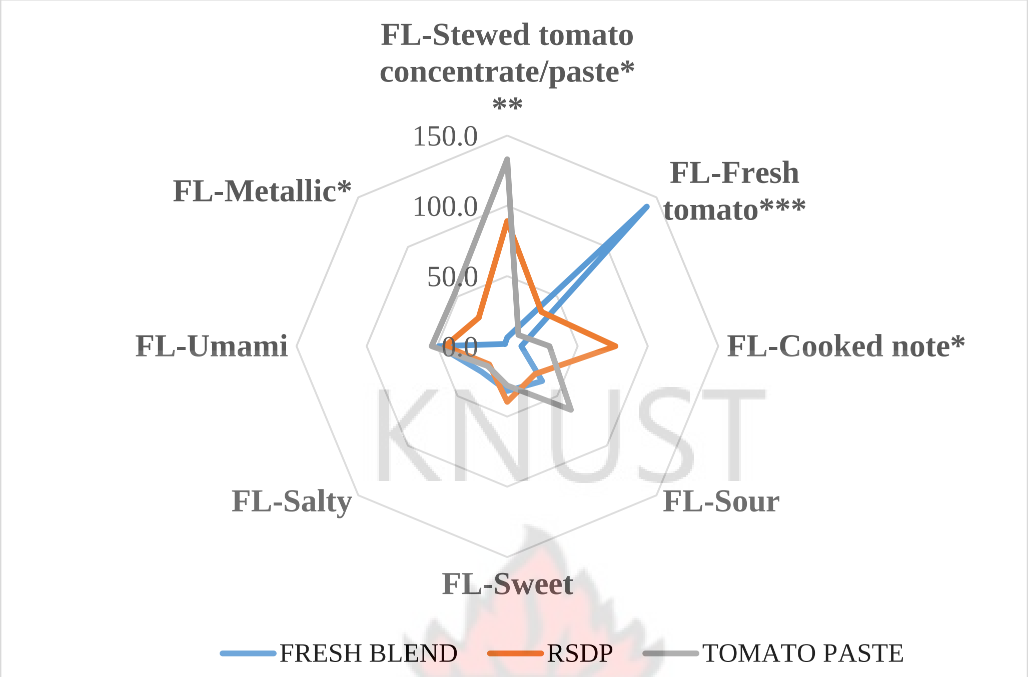
	AR-Stewed tomato concentrate	AR-Fresh tomato	AR-Metallic	AR-Boiled/cooked note	AR - Tangy
R^2	0.875	0.932	0.858	0.870	0.779
F	24.181	47.549	14.063	15.644	12.134
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Product	189.126 < 0.0001	379.994 < 0.0001			39.866 < 0.0001
Assessor			13.994 < 0.0001	2.413 <0.026	

6.6.5.3. Flavour

Significant ($p \leq 0.05$) statistical product differences were observed for stewed tomato concentrate and fresh tomato flavour. Tomato paste sample had the highest intensity for stewed tomato concentrate flavour followed by RSDP. Fresh blend tomato sample tasted more like fresh tomato followed by RSDP. RSDP had the most cooked note (Figure 6.7). There were no other significant ($p < 0.05$) product differences for any of the other descriptors, however there was significant product and assessor interaction effect and statistical significant assessor differences suggesting that assessors did not all agree on the intensities of those attributes in the product set (Table 6.8). Perhaps those attributes did not sufficiently differentiate between the products well. At the 90% CI however there is a trend suggesting a statistical significant difference for the cooked note attribute, with RSDP having the highest intensity for this attribute.

Table 6. 8: ANOVA table for flavour attributes

	Stewed tomato concentrate	**Fresh tomato**	**Cooked note**	**Sour**	**Sweet**	**Salty**	**Umami**	**Metallic**
R^2	0.913	0.918	0.876	0.863	0.858	0.820	0.877	0.879
F	36.299	38.798	16.499	14.670	14.104	10.614	16.594	16.883
Pr > F	<0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Product	285.590	294.658						
	<0.0001	< 0.0001						
Assessor			7.866	22.572	22.857	28.811	26.482	20.614
			< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Product* Assessor	5.138	6.816	20.815	10.719	9.727	1.516	11.650	15.017
	<0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.127	< 0.0001	< 0.0001



FL- Aroma
**Significant difference at 90% CI*
***Significant difference at 95% CI*
****Significant difference at 99% CI*

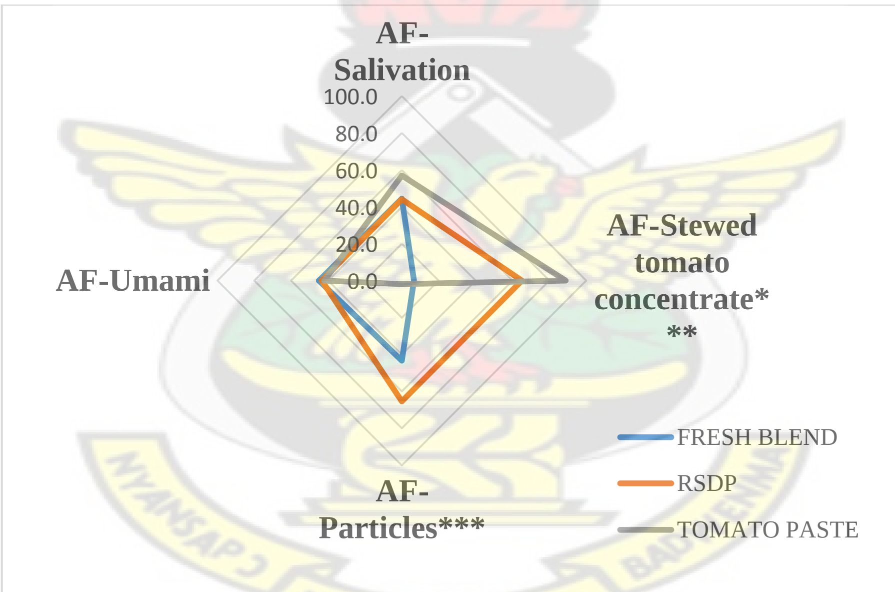
Figure 6.7: Profile of the flavour of the RSDP, fresh blend tomato and tomato paste

6.6.5.4. Aftereffects

The products differed significantly for two attributes after swallowing; stewed tomato concentrate and particles. Tomato paste sample had the highest intensity of stewed tomato concentrate followed by RSDP. RSDP being the most particulate had the highest remnants of particles present in the mouth after swallowing (Figure 6.8).

Table 6.9 ANOVA table for Aftereffects

AF-	Salivation	Stewed tomato concentrate	Particles	Umami
R^2	0.775	0.766	0.888	0.838
F	8.038	22.971	27.359	12.107
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Product		82.317 < 0.0001	125.302 < 0.0001	
Assessor	18.757 < 0.0001	8.135 < 0.0001		27.177 < 0.0001



AF-Aftereffects
*Significant difference at 90% CI
**Significant difference at 95% CI
***Significant difference at 99% CI

Figure 6.8 Profile of the aftereffects of the RSDP, fresh blend tomato and tomato paste.

6.6.6 Product map of reconstituted tomato products

A product map was generated using PCA. All the variance in the map was explained in the first and second dimension with the three products falling in all but the last quadrant as shown in Figure 6.9. The first PC is characterised by stewed tomato concentrate aroma and flavour to the negative side and fresh tomato in the positive direction. Other terms associated with PC1 in the negative dimension include metallic and mouth puckering. Other descriptors characterizing PC1 in the negative direction include tomato juice appearance, peels, tomato juice aroma and flavour and tangy aroma and flavour. The attributes contributing strongly to PC2 are smooth and particulate moving from the positive to the negative direction respectively. The tomato paste sample loaded in the first quadrant of the map was characterized as red, viscous and having a metallic and stewed tomato concentrate aroma and flavour as well as having a mouth puckering effect. Fresh blended tomato loaded in the second quadrant, is best described as having tomato juice appearance, peels, tomato juice and tangy aromas and fresh tomato flavour. RSDP loaded midway between the two extremes and was strongly correlated with PC2 in the negative direction. Products in that area are described as coarse, cooked aroma and stewed tomato flavour notes and particulate mouthfeel and aftereffect.

The sensory attributes of RSDP has attributes which are profiled between that of fresh tomato and tomato paste. This implies that RSDP can be positioned as a substitute for either r fresh tomato or tomato paste.

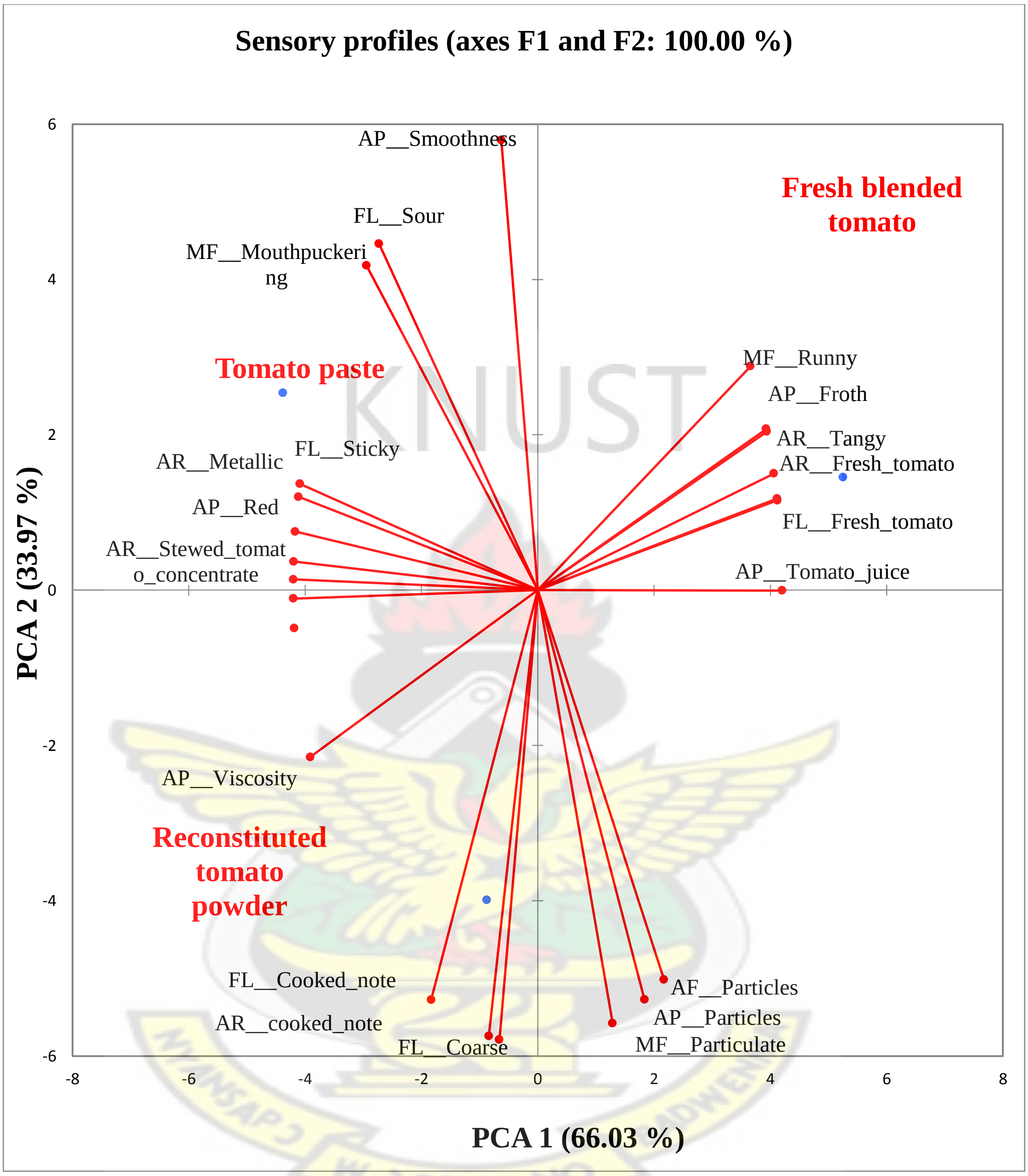


Figure 6.9 **Principal Component Analysis (PCA) showing how RSDP, fresh blended tomato and tomato paste are loaded in the sensory product space.**

6.7 Conclusion

The sensory profile; taste, aroma, texture, appearance of solar dried tomato powder and the market samples differed. Solar dried tomato powder was described as orange, gritty, dry, savoury and tomato market sample profiled as artificial, caking and having a nutty aroma. Solar dried tomato exhibited better sensory attributes for appearance, texture and aroma than the market sample.

Reconstituted solar dried tomato powder had similar sensory characteristics similar to both fresh tomato and tomato paste (tomato products commonly used in cooking). It had a very coarse appearance and texture (as predicted by the particle size distribution and shape profile and parameters of convexity and circularity) and a strong boiled/cooked aroma compared to tomato paste which had a higher intensity of red colour, metallic and stewed tomato concentrate aroma.

Based on the sensory properties of reconstituted tomato powder, it could be used as a substitute for either fresh tomato or tomato paste.

CHAPTER SEVEN: Consumer evaluation on the solar dried tomato powder using Home Use Test

7.1 Introduction

In developing successful products for the market, there is the need to understand and assess consumer preferences. Sensory scientists and marketing professionals, have over the years used various Hedonic testing methods to assess product acceptability during recipe improvement and implementing innovations (Boutrolle *et al.,* 2007). With this premise, the choice of consumer testing methodology is important to the sensory scientist in assessing the degree of likeness and acceptability of a food product.

Central Location Test (CLT) is conducted under controlled conditions in a standardized location and is more often used to compared to the Home Use Test (HUT) which is done under uncontrolled conditions (Hersleth *et al.,* 2005). It has been documented that the HUT yields more realistic hedonic data and products are highly scored than CLT (Boutrolle, 2006). Subjects in HUT freely choose the method of preparation and time of consumption, whiles subjects in CLT eat and assess products during a planned session (Matuszewska et *al.,* 1997). De Graaf *et al.* (2005) reported that CLT better suited snacks than served dishes or products that were used in cooking dishes. The type of product to be tested is key in determining the application or outcome of SST and HUT hedonic (Kozlowska *et al.,*2003; Daillant-Spinnler and Issanchou, 1995).

In a consumer assessment of fermented milk beverages with different sugar and fat content, the scores for likeness were higher for HUT than CLT and the degree of likeness significantly differed for the two methods (Boutrolle *et al.*, 2005). HUT is a more practical approach of getting consumers to use and assess dried tomato powder at home. Consumers use products in the convenience of their home to prepare different dishes of their choice in a much appreciable and accountable manner (Meiselman, 1992). This approach helps to generate responses that are more reliable and representative of the usability and performance of the products. A modified home use test was used in this study and this allowed the participants to take solar dried tomato powder home to use in preparing dishes of their choice, after which they came together as a focus group session to assess the product. The focus group discussion after the participants used the products is a helpful tool in the assessment characterization based on the experience the participants had with the product.

7.2 Specific Objective

The main objective was to conduct consumer assessment of solar dried tomato powder using Home Use Test.

7.3 Materials and Methods

7.3.1 Production of tomato powder

Tomato slices (5 mm) were pre-treated in 1 % Sodium metabisulphite solution for 10 minutes and dried in a mixed mode natural convection solar dryer till it reached a moisture content of 10-12 % over a 3-day period. Samples were milled, packaged in 25 g aluminum foil pouches and stored at ambient temperature (approximately (26 ± 2

^{o}C) for 5 days in a cool dry place prior to use. The market samples were packaged in 50 g low density polythene bags.

Plate 7.1 Solar dried tomato powder (25 g) packaged in aluminum pouch

7.3.2 Methodology

A Home Use Test (HUT) was conducted on solar dried tomato powder where solar dried tomato powder samples were given out to consumers during recruitment to take home to use in cooking and for evaluation. The HUT allowed respondents to use tomato powder (25 g) to prepare any food of their choice. They were provided with log sheets to document the observations they made during the use of the product at home. They attended the focus group discussions with the following information:

- In what form they used the tomato powder (e.g. raw or reconstituted form)
- What meals they used tomato powder to prepare.
- Their impressions about its usability

- Their impressions of its sensory properties

The above questions will give more light on the common uses, medium of use and functionality of the product among the study population. The focus group consisted of three main groups with participants being adults; aged 18 years and above. Table 7.1 shows the three groups used for the focus group and their distribution by gender.

Table 7.1 Number of participants per focus group

Group	Number of respondents	Male	Female
Students	7	3	4
University of Ghana Staff	7	4	3
Caterers	7	0	7
Total	21	6	14

Two focus group discussions were conducted in the Sensory Evaluation Laboratory. Each focus group consisted of between 7 participants engaged between 45-75 minutes. English was used as the language for communication throughout the interviews. A rapporteur hand recorded the interviews and backup audio recording was made.

Plate 7.2 Reconstituted solar dried tomato powder

(a) *"Jollof"* rice **(c) Tomato stew**

Plate 7.3. Dishes cooked with tomato powder by participants of focus group

7.4 Data Analysis

Qualitative data and responses to questions posed during the focus group discussions were documented on paper and voice recording to panel sessions. These responses were analysed using ATLAS. ti software version 8.1. (Berlin, Germany). Graphical representation of the descriptors of quantitative data- product characteristics were provided as histograms and pie charts using Microsoft excel.

7.5 Results and Discussion

In total, twenty-one participants were used for the HUT conducted on solar dried tomato powder. The participants were selected from University of Ghana (UG) and made up of staff and student of UG sampled from a pool of volunteers in the database of the Sensory Evaluation Laboratory of the Department of Nutrition and

Food Science, UG. Seven (7) caterers were selected from canteens and restaurants on the University of Ghana campus (Table 7.1).

7.5.1. Impressions of participants before using tomato powder

Participants recruited for the HUT were asked to prepare foods of their own choice which include vegetable stew, egg stew, "jollof" rice, goat light soup and fresh fish light soup with frequencies of 11, 6, 5, 2 and 1 respectively (Appendix 2). It was observed that all the university students prepared only one dish with the tomato powder whiles the university staff and caterers were more adventurous and prepared at least two dishes each. Most of the participants reconstituted tomato powder with water before using for cooking, with a frequency of 11 whiles the others used the powder directly in food preparation without reconstituting it.

The overall impression of tomato powder by assessors were categorized into two: a) the initial impressions before use and b) The final impressions after use of product. The colour was perceived as pale and not red enough compared with canned tomato. The texture of the product was described as chaffy and gritty; however, the presence of seeds was proof of the authenticity of the tomato product. Some participants indicated that the product was too sweet, speculating that sweeteners had been added to it.

7.5.2. Impressions of participants after product use in food preparation

Comments from the participants after reconstituting tomato powder with water, were that product was easy to use, had an attractive colour and aroma. One caterer remarked that ‘‘It is an innovative product since it saves a lot of time and energy. “The product was described as having a nice taste, easy to use and a good substitute for fresh tomatoes during the lean season. Thus the product appealed more to the participants when product was incorporated in dishes than when they first handled it in its powdered state.

The impressions about the packaging of the tomato powder was that there were no inscriptions of product name, nutritional content and expiration dates. Participants had a good impression about the type of packaging material (aluminum pouches) which prevented the powder from absorbing moisture and caking.

Before using the product, the colour, texture and aroma may not have appealed to most of the participants, there was general observation that tomato powder was easy to use as a substitute to tomato paste.

“Tomato powder worked as a thickener and increased the bulk of the dishes prepared” remarked one participant. tomato powder was liked by participants because of certain sensory attributes including its ability to swell and thicken when water is added, giving bulkiness to the food. The flavour was likened to fresh tomato and the taste described as unadulterated when incorporated in food. ‘‘It was a bit acidic to me when I tasted before use, however the acidic flavour was subdued when added to food.” said one participant.

It was noted that even though tomato powder had a rough texture, the paste was smooth prior to use but formed a smooth when incorporated in food. Other foods participants would consider using tomato powder for are soups such as light soup, groundnut soup and palmnut soup with the exception of green soup, stews such as palava sauce, garden egg stew, *apapransa*, *mportomportor* and weaning food (weanimix-porridge).

Comparing tomato powder to tomato paste, participants indicated that the powder gave a feel of the natural tomatoes and as sour tomato paste.

7.5.3. Evaluation of quality attributes of tomato powder by consumers

7.5.3.1. Ranking of quality attributes of tomato powder

The most desired attribute of the tomato powder was how convenient it was to use with a mean rank score of 5.1 out of 6 as shown in Figure 7.1. This correlates well with the first objective of this study which sought to assess reasons why consumers would patronise tomato powder. Majority of the respondents (65.6 %) indicated that they would patronize tomato products because of convenience of use (Owureku-Asare *et al.,*2016). Taste were also highly ranked (4.4 out of 6) and this correlated well with results obtained from the consumer survey which indicated that the taste (ranked 4.3 out of 5) of dried tomato was the most important sensory quality attribute of importance to consumers. Tomato powder acted as a thickener when added to stews, making it a good substitute for canned tomatoes. The hygroscopic nature of tomato and the ability of tomato powder to act as a thickner was due to the high carbohydrate concentration (20 - 25%). The least desired attribute was the appearance: pale red colour of raw tomato powder and the rough and chaffy texture with rank scores of 1.95 and 2 respectively.

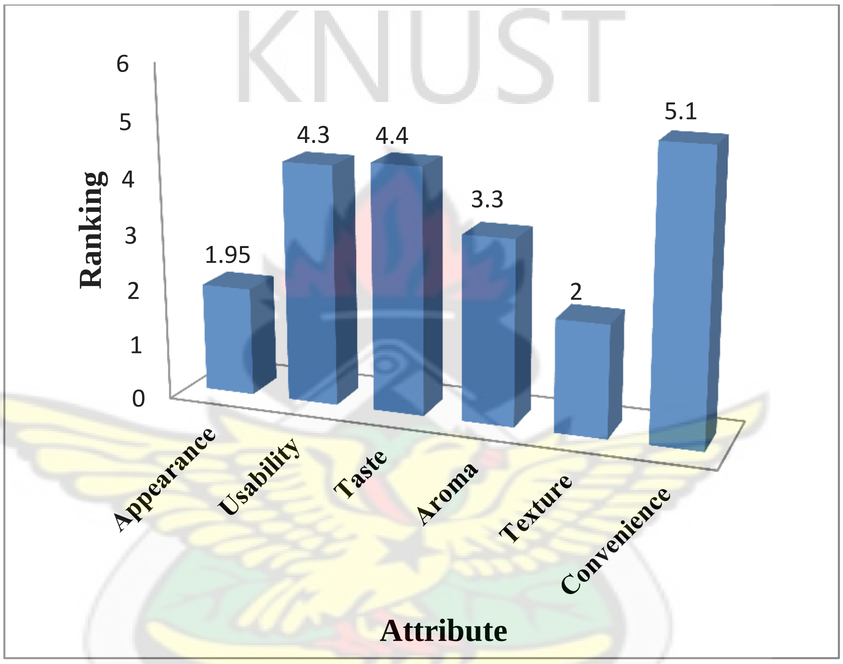


Figure 7.1: Ranking of attributes based on desirability

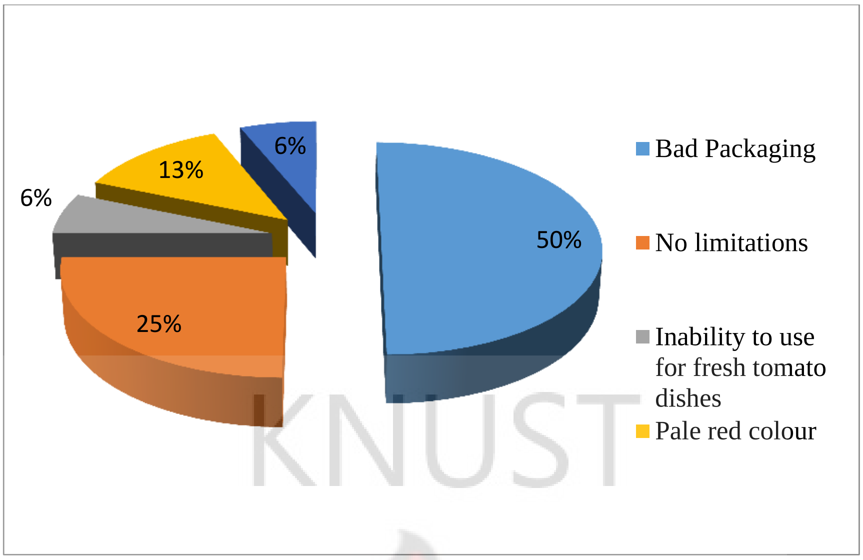


Figure 7. 2: Limitations about usage of tomato powder

From Figure 7.2, 25 % of the participants felt there were no limitations in the usage of the product. Bad packaging indicated by 50 % of the respondents was the main limitation of the product considering that the package was not labelled, had unattractive colour and was small in size. This response is in agreement with the results of the consumer studies (first objective) where most of the respondents (70.5 %) indicated packaging of dried tomato products was the most important quality attribute for production of dried tomato products on large scale (Figure 7.5). Consumers liked the packaging material (aluminum pouches) used but preferred a product that was well branded and labelled with products details. Consumers depend on certain extrinsic quality factors such as price, branding and packaging when assessing quality of food in stores (Bredahl, 2004). A brand notifies consumers about the inherent quality of a food product (Keller, 2003).

Branding is important as it helps in value addition, positioning and foster competitive pricing of the food product (Steenkamp, 1997; Bredahl, 2004). Others also stated that the colour of the tomato powder was not red enough and that a deep red colour was more desirable. One was quoted below as saying; ''Ghanaians like red stew hence it is important to increase the redness of the product by adding colouring agents.''

7.5.4. Purchasing Intent

There was consensus that tomato product will be bought if sold on the market. Figure 7.3 shows that Most of the participants (61 %) were willing to buy the tomato powder at a price of up to Ghs¢2.00 for 25 g pack. A few were willing to pay more (5 %) at a price of ¢ 5.00.

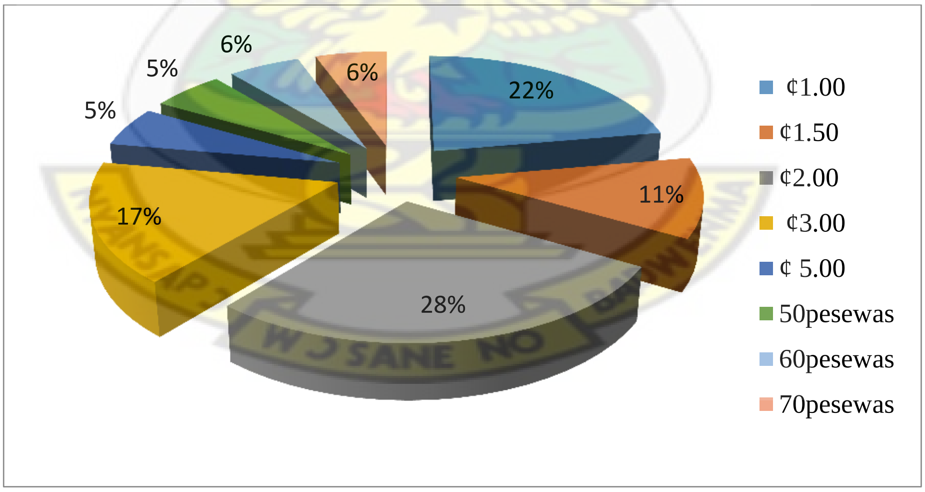


Figure 7. 3: How much participants are willing to purchase product

Figure 7.4 shows the quantity of tomato powder preferred by most participants is 50g (44 %), requesting for an increase in quantity to cater for their food preparations. About 25 % of the participants were satisfied with the 25 g content.

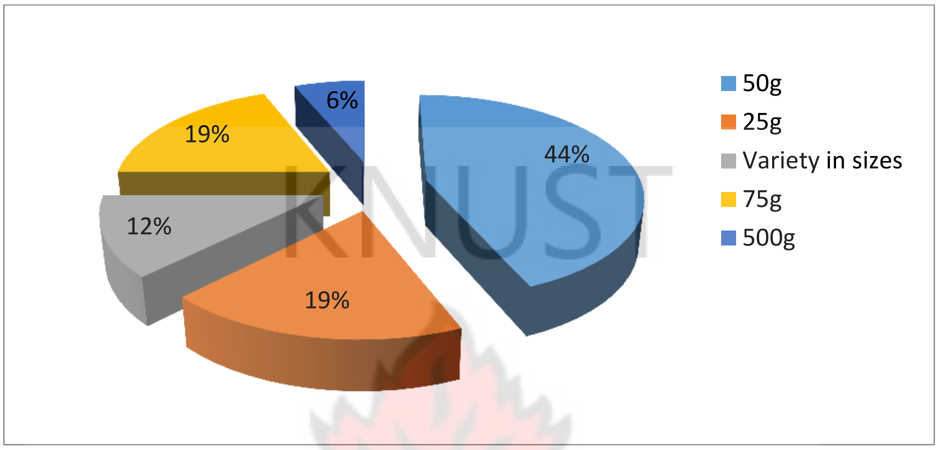


Figure 7.4: Size of tomato powder pack preferred by participants of focus group study

Prior to the study, majority (93 %) of the participants had not used tomato powder before (Figure 7.5). Only one caterer had used “tomato powder” purchased from the open market to prepare “jollof” rice for her client.

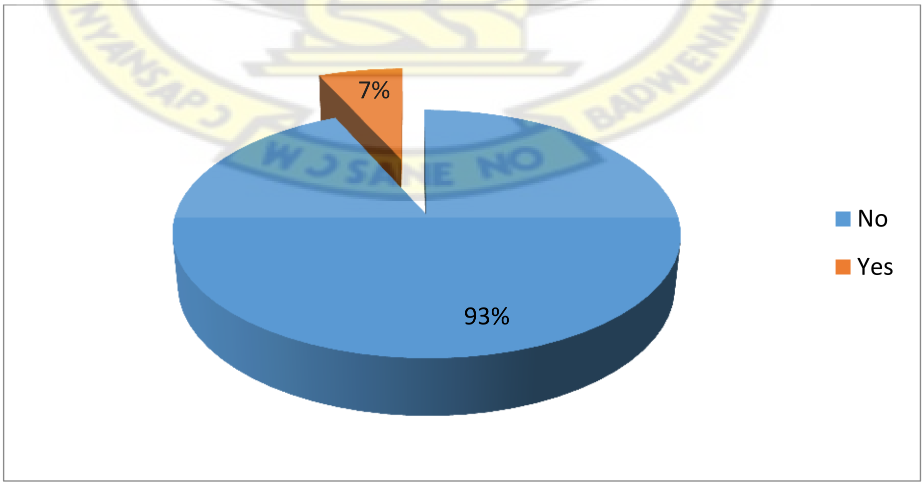


Figure 7.5: Patronage of tomato powder of consumers prior to study

Most of the caterers were oblivious of how tomato powder is made. However, the students and university staff were able to describe how dried tomatoes could be made, proposing sun drying as the most common method of drying tomato.

7.5.5 General perceptions about tomato powder

Participants of the focus group stated that since the product is solar dried; there was the need to ensure the end product was microbiologically safe.

Some participants suggested that the tomato powder should be fortified with vitamins to improve its nutritional content. Whiles some consumers expressed fear about possible adulteration of the product especially with food colours. Taste and colour were assessed by consumers as the main factors that would influence the authenticity of the product.

7.6. Conclusion

Tomato powder was described as a good thickener, with intense tomato flavour and ranked highest (5.1 out of 6) for its' convenience of use. Taste (4.4 out of 6) and usability (4.3 out of 6) were also highly ranked. Tomato powder was used as a substitute to tomato paste by consumers because it imparted similar cooking qualities as tomato paste. Consumers found that solar dried tomato powder was easy to use in preparing a number of local dishes because of its swelling properties. This implies that tomato powder will act as a good substitute and will compete well with tomato paste which is imported into the Country.

CHAPTER 8: General Conclusion and recomendations

8.0 General Conclusions

Ghana is currently a huge importer of tomato paste because local processing of tomato paste has stalled due to a number of challenges. Simple and cheaper alternative technologies like solar drying should be explored to process tomato into shelf stable convenient forms as a move to reducing post harvest loses and providing alternative tomato products to cut down on the high imports of tomato paste.

The study explored the use of a mixed mode convection solar dryer adapted for processing tomato and evaluated the suitability of the dried products for the culinary industry. The materials for building the dryer were locally sourced and required moderate capital for the set up. The efficiency of the dryer was found to be high and enhanced it's performance in producing dried products with very low water activity and improved quality. A baseline study which assessed likely patronage and perceived quality of solar dried tomato products by consumers revealed that even though majority of respondents did not know much about dried tomato they were willing to purchase the product because of it's convenience of use. Most of the consumers in the survey preferred tomato powder over cut dried tomato.

A natural convection mixed mode dryer used in this study facilitated drying using air-heater incident radiation direct from the sun without a secondary source of heating. The first day solar dryer efficiency of 24.2% played a significant role in reducing the moisture content and water activity of tomato to microbiologically safe limits. Pre-treating tomato with potassium metabisulphite before drying enhanced the drying rate of tomato better than pre-treatment with ascorbic acid and control (no pre-treatment).

The colour of tomato powder was an important quality attribute to consumers and tristimulus colour a* for the redness of tomato was higher in solar dried than sun-dried tomato. Higher degradation of the desirable red tomato colour was characterised by darker red to brownish colour for sun-dried tomato. Potassium metabisulphite as a pre-treatment for tomato, had protective effect on lycopene and beta-carotene compared with the other pre-treated samples. Thus from this study, pre-treated solar dried tomato with potassium metabisulphite was a better source of lycopene and beta-carotene compared to the other samples. A combination of solar drying with pre-treatment of 1% potassium metbisulphite preserved carotenoids which are mainly reponsible for imparting the red colouration to tomato. Water activity for solar dried tomato powder was significantly lower (0.35± 0.01 to 0.38± 0.05) relative to the sun-dried tomato powder (0.53 ± 0.002 to 0.57± 0.03). This implies that the potential of high shelf-life stability of the solar dried tomato.

Microbial load for all pre-treated solar-dried tomato was within microbiologically safe limit, which is important in enhancing the wholesomeness of tomato powder. Solar-drying was therefore a more effective method of drying tomato compared to sun-drying. The sulphur dioxide content (740.8 ppm) recorded for solar dried tomato pre-treated with potassium metabisulphite was much lower than the maximum legal limit of 2000 ppm of sulphur dioxide recommended in fruits and vegetables. When processing dried tomato using solar drying technology, 1% potassium metabisulphite as pre-treatment was effective with minimal residual load in enhancing the quality of tomato and reducing the microbial load.

Reconstitution characteristics of tomato powder was influenced by its particle size. Potassium metabisulphite pre-treated solar dried tomato powder particles were more circular in shape compared to the other samples, a desirable characteristics that enhanced the solubility of tomato powder in soups or stews.

“Tomato powder” purchased from the market differed extremely in quality attributes relative to solar dried tomato. They were described as red, artificial colour, nutty, caking and corn flour aroma whiles solar dried tomato had an orange, gritty, tomato and savoury flavour. Therefore, the solar dried tomato powder had a more authentic attribute description of tomato.

Sensory profiling showed that solar-dried tomato powder had properties similar to both reconstituted tomato paste and fresh tomato. The reconstituted paste had a coarse texture and stewed tomato aroma compared with tomato paste which had a higher intensity of red colour and metallic aroma. Fresh tomato on the other hand imparted stronger tangy characteristic aroma and flavour.

Based on its sensory properties and the Home Use Test, solar dried tomato powder could be used as a substitute for either fresh tomato or tomato paste. However, it has a coarse texture and a strong cooked tomato aroma compared to tomato paste.

From this study, high quality tomato powder can be produced using the natural mixed mode convection solar dryer. This has great potential for commercialization and should be promoted.

8.1 Recommendations

1. Shelf life studies should be conducted on solar-dried tomato powder.
2. Studies on the use of different packaging materials for tomato powder should be conducted.
3. Nutritional composition of tomato powder should be evaluated.
4. The capacity of the solar dryer should be scaled up to process higher quantities of tomato.

5. Cost benefit analysis of the tomato products should be done.

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APPENDICES

Appendix 1. Questionnaire for Consumer survey

Kwame Nkrumah University of Science and Technology (KNUST)

<u>Consumer Knowledge, Attitudes, Perceptions and Quality assessment of Dried Tomato in Ghana.</u>

The following questionnaire seeks to gather relevant information on consumption of dried Tomato in Ghana. Instructions: Please tick (√) by the options that best describe your response to the questions asked; and as much as possible, provide complete answers to open ended questions.

SECTION A: DEMOGRAPHICS

1. **Age:** [1] <25 [2] 26 -35 [3] 36 -45 [4] 46 -55 [5] 56+
2. **Gender**: [1] Male …….. [2] Female……..
3. **Nationality:** [1] Ghanaian……… [2] Non Ghanaian…………
4. **Which region do you come from?** (for Ghanaians kindly tick only one box)
   [1] CR……….. [2] GAR………. [3] WR……… [4] ER……… 5] BAR……..
   [6] VR………. [7] NR………. [8] UER……. [9]UWR………. [10] AR …….
5. **Marital status:** [1] Married…. [2] Single…… [3] Divorced/Separated…… [4] Widowed …….
6. **Level of Education (Highest achieved)**: [1] None ……….. [2] Primary………….
7. [3] JHS Secondary/O level …… [4] Senior High School/A level…………… [3] Tertiary………
8. **Main Occupation**.

[1] Unemployed ……. [2] Self Employed ……… [3] Private sector……. [4] Civil/public servant………. [5] Student ……… [6]Apprentice……… [7] Other (specify)………………

SECTION B: KNOWLEDGE, ATTITUDE, PREFERENCE AND PATRONAGE (KAP)

9. How much do you like tomato or tomato products?

   [1]Very much …… [2] Moderately …….. [3] A little………. [3] Not at all……….

10. How often do you consume foods containing tomato (in a week)

    [1] Very often (Every day) …….. [2] Often (at least 3- 6 days in a week)………

    [3] Not that often (at least 1 day in a week) ……… [4] Never ………….

11. What alternative (other) ingredient apart from tomato products do you use when fresh tomato is not available or in season? [1] No alternative ingredients…….. [2] Other (specify)………………

12. Are you aware of the fluctuations in the price of tomato? [1] Yes……….. [2] No………

13. Are you aware of post-harvest losses of tomato? [1] Yes……….. [2] No………

14. **If yes to Q13**, to what extent does Post-Harvest Losses contribute to price fluctuations?

    [1] High ………. [2] Moderate ………. [3] Low……….

15. In what form(s) do you usually consume/use tomato? (Please tick as many as possible).

    [1] Fresh tomato ……. [2] Tin/canned tomato…… [3] Tomato ketchup …. [4] Dried tomato……..

    [5] Tomato juice……….. [6]Other (please specify) ……………..

16. The following are desirable attributes of fresh tomato **(Please score each of the attributes on a scale of 1 to 5 where 1 is most preferred and 5 is least preferred)**

Taste [ ] Colour [ ] Aroma/smell [ ] Texture [ ] Functionality/use [ ]

17. Are you aware of the production or sale of cut dried tomato or tomato powder on the market?

    [1] Yes……………. [2] No…………

18. **If YES, to Q. 17,** have you cooked with dried tomato products such as cut dried tomato or tomato powder before? [1] Yes……. [2] No……….

19**.** **If NO to Q. 17**, would you consider consuming or cooking with cut dried tomato or tomato powder? **(If no, Skip to Q26 if no)**

[1] Yes……. [2] No……

20. If you would consume/use dried tomato products what will you use it for? (Tick as many as possible)

[1] Soup…… [2] Stew……. [3] Salad …….. [4] Sandwich……… [5] Baked products (eg meat

pie)…… [6] Shito (black pepper sauce) ………… [7] Other (specify)…………………

21. For what reason would you consider cooking with dried tomato? (Tick all that apply)

[1] Convenience…….. [2] Availability…… [3] Suitability ……..… [4] Cost………….

[5] Other (specify)…………….

22 How would you prefer to obtain dried tomato?

[1] Prepare yourself……… [2] Purchase from the open market……. [3] Purchase from any

shop…….. [4] Purchase from supermarket…………….. [5] Other (specify) ……………

23. If you would prepare dried tomato yourself what method will you use?

[1]Open sun drying…… [2] Solar drying…… [3] Oven drying ……. [4] Other (specify)………

24. **RANK** your preference for the following products from highest to least **(where 1 is most preferred and 4 is the least preferred)**

a) Dried tomato [ ] b) canned tomato [ ] c) Fresh tomato [ ] d) Tomato powder [ ]

25. Among dried tomato products what would you prefer the most **(Please tick only one answer**).

[1] Half Dried…….. [2] Chopped dried …… [3] Tomato powder.…………..

26. Apart from canning what other method do you think is the most practical and can be used to process tomato or extend its shelf life? **(Please tick as many that apply)**

[1] Drying ….. [2] Freezing …… [3] Refrigeration …… [4] Other (specify) ……… [5] None……

SECTION C: QUALITY ASSESSMENT

27. Do you have concerns about the quality of dried tomato products?

[1] Yes…………. [2] No…………………

28. **If yes** what are your concerns about the quality attributes of dried tomato product?

29. Are you aware that tomato powder is produced and sold in some markets in Ghana?

[1] Yes………. [2]No…………..

30. What are your concerns about the production and quality?

No	Production Quality of tomato powder	b. Tick all that applies	c. Concerns
1	Adulterations	[ ]	
2	Safety/contamination	[ ]	
3	Mode of drying	[ ]	
4	Mode of storage	[ ]	
5	Packaging	[ ]	
6	Other…………….	[ ]	

General comments………………………………………………………………………………

…………………………………………………………………………………………

Appendix 2. Analysis of Variance for moisture content (%) of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	413.455	82.6911	341.07	0.000
drying method	1	7.590	7.5900	31.31	0.000
pretreatment	2	0.181	0.0907	0.37	0.696

tomato sample*drying method	5	12.789	2.5579	10.55	0.000
tomato sample*pretreatment	10	1.587	0.1587	0.65	0.745
Error	12	2.909	0.2424		
Total	35	464.977			

Appendix 3. Analysis of Variance of drymatter of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	413.455	82.6911	341.07	0.000
drying method	1	7.590	7.5900	31.31	0.000
pretreatment	2	0.181	0.0907	0.37	0.696
tomato sample*drying method	5	12.789	2.5579	10.55	0.000
tomato sample*pretreatment	10	1.587	0.1587	0.65	0.745
Error	12	2.909	0.2424		
Total	35	464.97			

Appendix 4. Analysis of Variance of ash of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	11.5442	2.30883	45.92	0.000
drying method	1	4.0612	4.06123	80.77	0.000
pretreatment	2	0.6504	0.32520	6.47	0.012
tomato sample*drying method	5	5.5322	1.10644	22.00	0.000
tomato sample*pretreatment	10	1.7112	0.17112	3.40	0.024
Error	12	0.6034	0.05028		
Total	35	46.1317			

Appendix 5. Analysis of Variance of acidity of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	12.6183	2.52365	3882.54	0.000
drying method	1	0.1008	0.10083	155.13	0.000
pretreatment	2	0.0044	0.00219	3.37	0.069
tomato sample*drying method	5	0.9307	0.18613	286.36	0.000

tomato sample*pretreatment	10	0.0062	0.00062	0.95	0.528
Error	12	0.0078	0.00065		
Total	35	15.5559			

Appendix 6. Analysis of Variance of pH of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	0.057367	0.011473	29.93	0.000
drying method	1	0.030000	0.030000	78.26	0.000
pretreatment	2	0.000200	0.000100	0.26	0.775
tomato sample*drying method	5	0.009600	0.001920	5.01	0.010
tomato sample*pretreatment	10	0.002333	0.000233	0.61	0.780
Error	12	0.004600	0.000383		
Total	35	0.17110			

Appendix 7. Analysis of Variance of brix of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	17.0000	3.40000	*	*
drying method	1	0.0000	0.00000	*	*
pretreatment	2	0.0000	0.00000	*	*
tomato sample*drying method	5	0.0000	0.00000	*	*
tomato sample*pretreatment	10	0.0000	0.00000	*	*
Error	12	0.0000	0.00000		
Total	35	17.0000			

Appendix 8. Analysis of Variance of L* of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	754.625	150.925	151.31	0.000
drying method	1	18.501	18.501	18.55	0.001
pretreatment	2	2.348	1.174	1.18	0.341
tomato sample*drying method	5	4.058	0.812	0.81	0.562
tomato sample*pretreatment	10	20.019	2.002	2.01	0.126
Error	12	11.970	0.997		

Total	35	898.424			

Appendix 9. Analysis of Variance of a* of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	70.940	14.1881	53.25	0.000
drying method	1	26.374	26.3737	98.98	0.000
pretreatment	2	0.265	0.1323	0.50	0.621
tomato sample*drying method	5	8.076	1.6152	6.06	0.005
tomato sample*pretreatment	10	5.174	0.5174	1.94	0.138
Error	12	3.197	0.2665		
Total	35	186.766			

Appendix 10. Analysis of Variance of a* of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	488.395	97.6791	93.83	0.000
drying method	1	12.751	12.7514	12.25	0.004
pretreatment	2	0.099	0.0495	0.05	0.954
tomato sample*drying method	5	8.970	1.7940	1.72	0.204
tomato sample*pretreatment	10	19.093	1.9093	1.83	0.159
Error	12	12.492	1.0410		
Total	35	572.361			

Appendix 11. Analysis of Variance of b* of dried tomato

Source	DF	Adj SS	Adj MS	F-Value	P-Value
tomato sample	5	0.290566	0.058113	129.93	0.000
drying method	1	0.002700	0.002700	6.04	0.030
pretreatment	2	0.000578	0.000289	0.65	0.542
tomato sample*drying method	5	0.004471	0.000894	2.00	0.151

tomato sample*pretreatment	10	0.005096	0.000510	1.14	0.409
Error	12	0.005367	0.000447		
Total	35	0.312464			

Appendix 12. Analysis of Variance for betacarotene of dried tomato

Source	DF	SS	MS	F	P
drying method	1	51773	51773	98.18	0.000
pretreatment	2	37327	18664	35.39	0.001
drying method*pretreatment	2	17847	8923	16.92	0.006
Batch	1	422	422	0.80	0.412
Error	5	2637	527		
Total	11	110005			

S = 22.9633   R-Sq = 97.60%   R-Sq(adj) = 94.73%

Appendix 13. Analysis of Variance for lycopene of dried tomato

Source	DF	SS	MS	F	P
drying method	1	13674	13674	45514.22	0.000
pretreatment	2	190587	95293	317195.39	0.000
drying method*pretreatment	2	68582	34291	114142.15	0.000
Batch	1	1	1	2.60	0.168
Error	5	2	0		
Total	11	272845			

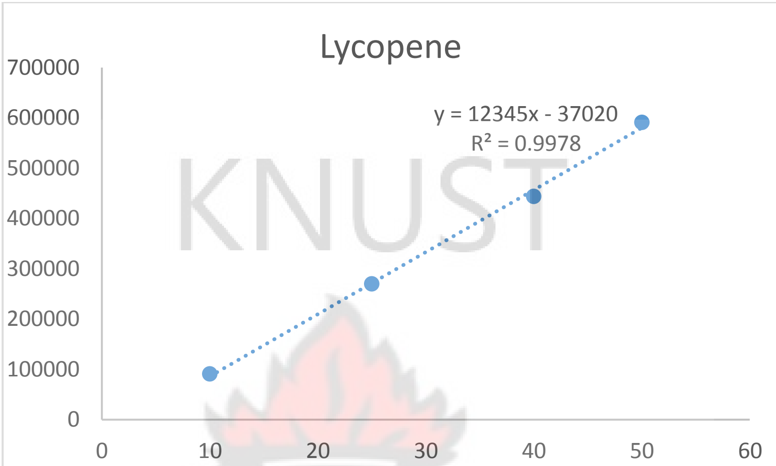
= 0.548110   R-Sq = 100.00%   R-Sq(adj) = 100.00%

Appendix 14. Analysis of Variance for total carotenoids of dried tomato

Source	DF	SS	MS	F	P
drying method	1	312	312	170.61	0.000
pretreatment	2	161093	80547	44115.23	0.000
drying method*pretreatment	2	37855	18928	10366.65	0.000
Batch	1	10	10	5.32	0.069

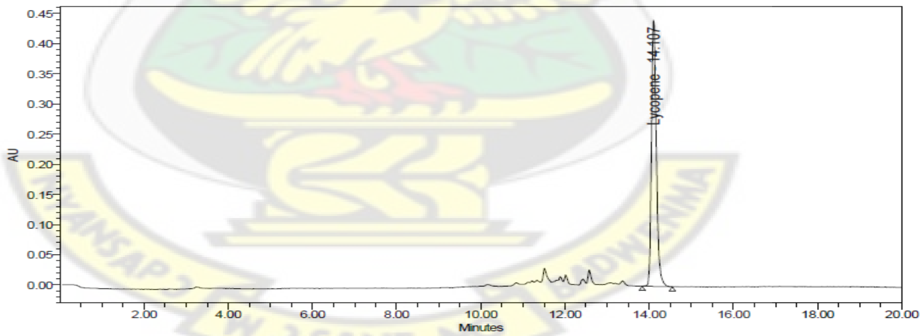
Error	5	9	2
Total	11	199279	

Appendix 15. Standard curve for lycopene standard.



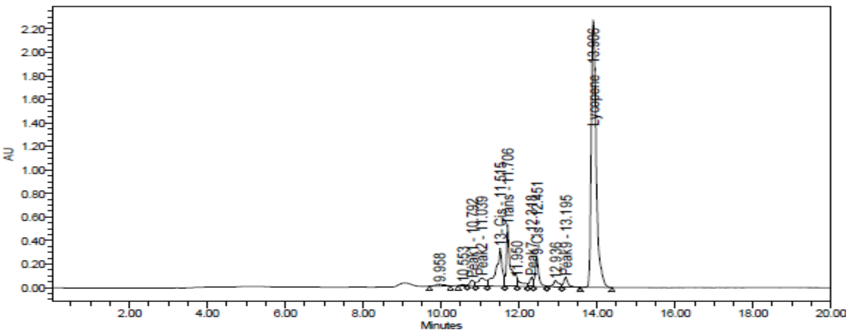
SAMPLE INFORMATION

Sample Name:	Lycopene Std 2	Acquired By:	culab
Sample Type:	Standard	Date Acquired:	1/18/2018 11:04:57 AM
Vial:	1	Acq. Method Set:	Method Set_Tomatoe 2
Injection #:	1	Date Processed:	1/19/2018 5:14:06 PM
Injection Volume:	40.00 ul	Processing Method:	Lycopene processing_2018
Run Time:	20.0 Minutes	Channel Name:	Wvln Ch1
Sample Set Name:	Standards	Proc. Chnl. Descr.:	PDA 472.0 nm

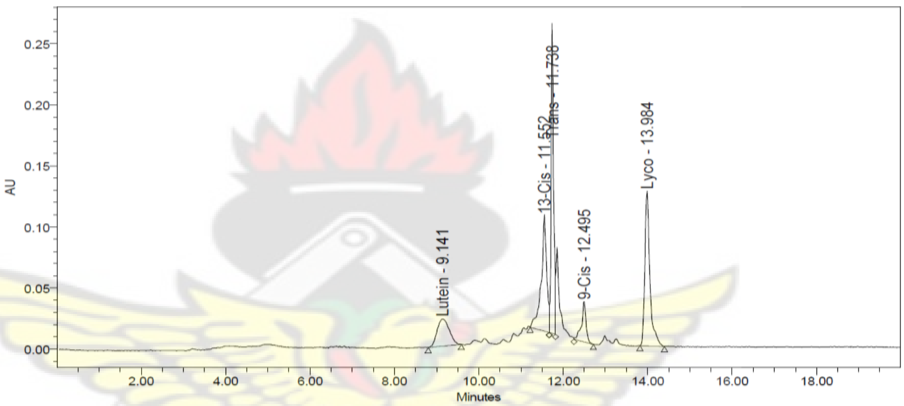


	Peak Name	RT	Area	% Area	Height
1	Lycopene	14.107	3505529	100.00	443629

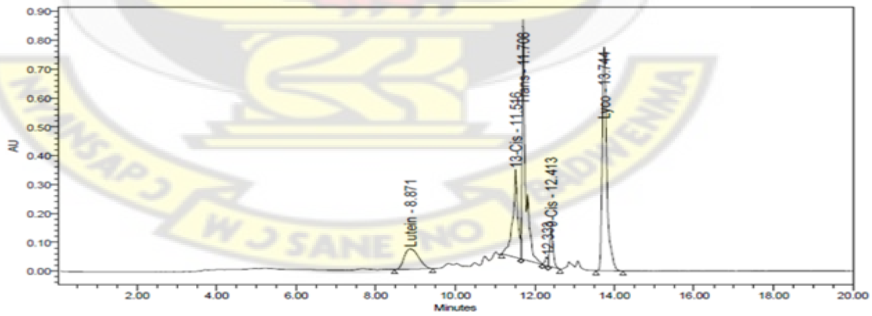
Appendix 16 . HPLC profile of lycopene, carotene, extracted from solar dried tomato powder pre-treated with a) KMS, b) ascorbic acid and c) no pre-treatment.



a)

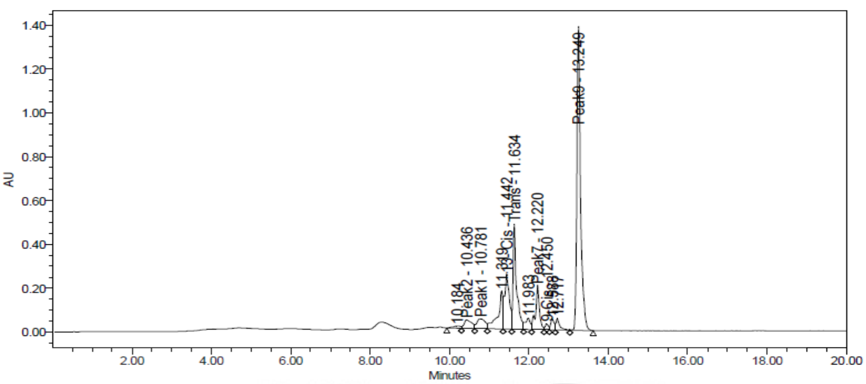


b)

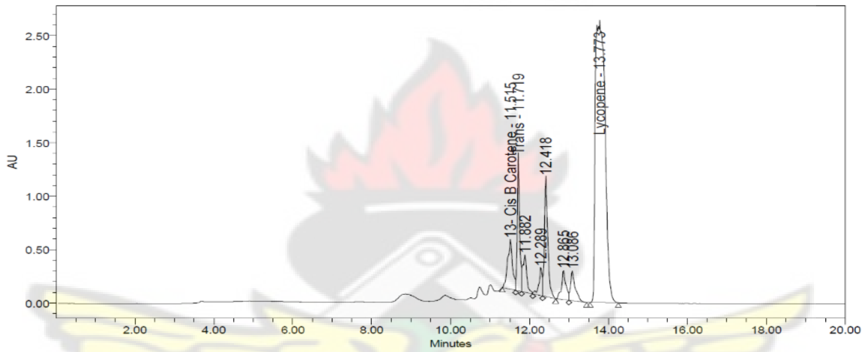


c)

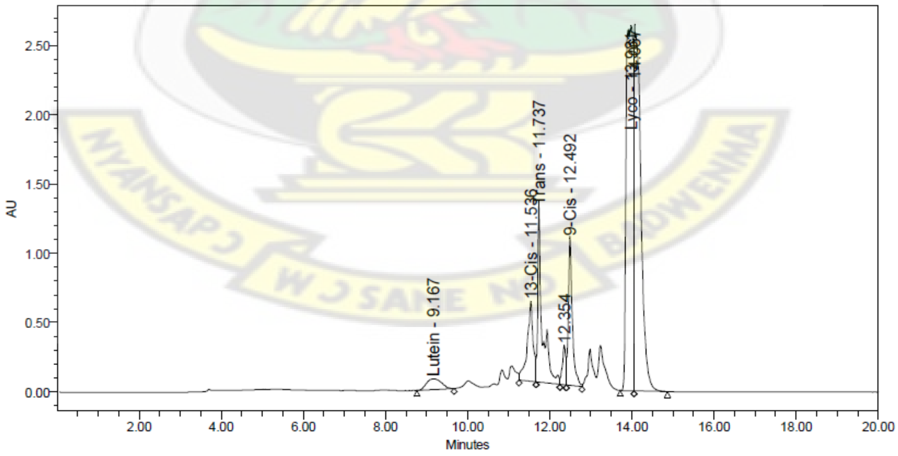
Appendix 17. HPLC profile of lycopene, carotene, extracted from sun dried tomato powder pre-treated with a) KMS, b) ascorbic acid and c) no pre-treatment


AU
Minutes
Peak9 - 13.249
Trans - 11.634
12.220
Peak2 - 10.436
Peak1 - 10.781
10.184
11.983

a)


AU
Minutes
Lycopene - 13.773
13- Cis B Carotene - 11.515
Trans - 11.719
12.418
11.882
12.289
12.865
13.086

b)


AU
Minutes
Lutein - 9.167
13-Cis - 11.536
Trans - 11.737
9-Cis - 12.492
12.354

c)

Appendix 18 Ethical Clearance letter from CSIR Ethical Review Board

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
HEAD OFFICE

P. O. BOX M. 32
ACCRA
GHANA
WEST - AFRICA

TEL: 233-30-2777651-4 (4 Lines)
FAX: 233-30-2777655
E-MAIL: headoffice@csir.org.gh
WEBSITE: www.csir.org.gh

Our Ref: CSIR/IACUC/AL/VOL1

Date: 29th January, 2017

ETHICAL CLEARANCE

RPN 007/CSIR-IRB/2016

On 14th December, 2016, the Council for Scientific and Industrial Research (CSIR) Institutional Review Board (IRB), at a full Board meeting reviewed and approved your protocol.

TITLE OF PROTOCOL : *Sensory evaluation and consumer assessment of Tomato powder*

PRINCIPAL INVESTIGATOR : Mrs. *Mavis Owureku-Asare*

Please note that a final review report must be submitted to the Board at the completion of the study. Your research records may be audited at any time during or after the implementation.

Any modification of this research project must be submitted to the IRB for review and approval prior to implementation.

Please report all serious adverse events related to this study to CSIR-IRB within seven days verbally and fourteen days in writing.

This certificate is valid till 14th December, 2017.

Okyere Boateng
(CSIR-IRB, Chairman)

Cc: Dr. Victor K. Agyeman
(Director General, CSIR)

Appendix 19: Moderators guide for focus group discussion

<u>MODERATORS GUIDE FOR SOLAR DRIED TOMATO POWDER</u>

INTRODUCTION (2 minutes)

The purpose of this discussion is to talk about the use of solar dried tomato powder in food preparation. I will be asking your opinions and your experiences on how you used the tomato powder. All participant comments and opinions will be kept anonymous and confidential. You will be made to sign a consent form before the discussions begin.

I am a sensory scientist, who uses sensory and consumer testing to help in new product development and improve existing products. I believe in integrating consumer needs and wants in developing new products.

INTRODUCTIONS Assistant moderators

GROUND RULES (5 minutes)

1. This session will last about 45-75 minutes.

   This session is being audio taped to use as a backup for what is being recorded by writing. I will take this opportunity to ask if there is anyone who objects to being recorded.

2. Observers who are part of the team are present to observe and also take notes.
3. There are no wrong answers in consumer research; we are looking for different points of view. I want to know what your opinions are.
4. Everyone needs to talk but each person doesn't have to answer each question.
5. Please talk one at a time and in a clear voice, avoid side conversations. It is distracting to the group and I don't want to miss any of your comments.
6. Exchange points of view with each other – you don't need to address all answers to me.
7. This is a confidential discussion in that I will not report your names or who said what to your colleagues or supervisors. Names of participants will not even be included in the final report about this meeting. It also means, except for the report that will be written, what is said in this room stays in this room.
8. We stress confidentiality because we want an open discussion. We want all of you to feel free to comment on each other's remarks without fear your comments will be repeated later and possibly taken out of context.
9. Let me know if you need a break. The bathrooms are located at the Department of Nutrition and Food Science, directly opposite the sensory laboratory. Feel free to enjoy a beverage and a snack.
10. Please put all phones on silent.
11. Does anyone have any questions before we begin?

BACKGROUND (10 minutes)

1. Please take the first few minutes to get to know the person seated next to you.
2. I'm going to ask you to introduce him/her to the group. I'd like you to tell us something about that person such as their interests and hobbies, if they have a family, and how long they have lived in the area.

3. Introduce your friend by adding an adjective with the letter of their first names (18-30 age group)

QUESTIONS (40 minutes)

SECTION A (Experience(s) After Using Tomato Powder)

1. Which type of dish did you use the tomato powder to prepare?
2. How did you use the tomato powder? Did you just pour the powder or reconstitute it?
3. What were your overall impressions about this product?
4. What are your impressions about the tomato powder in terms of the following when you used it:
    a. Packaging
    b. Appearance
    c. Aroma
    d. Flavour (when added to dish)
    e. Usability
    f. Thickness
    g. Texture
5. What other foods would you have used the dried tomato powder for?
6. What do you like about this product?
7. What do you not like about this product?
8. On a scale of 1-6 rank the following attributes in order of the most desired (6) and least desired (1):
    a. Appearance (includes colour)
    b. Usability
    c. Taste
    d. Aroma
    e. Texture
    f. Convenience
9. What is your favourite attribute about the product?
10. What were the limitations about using this product?

SECTION B (Purchase Intent)

1. Would you buy this product?
2. How much are you willing to pay for this product?
3. What will be your reason for buying this product?
4. What quantity of the product would you have preferred in the pack to cater for your food preparation?

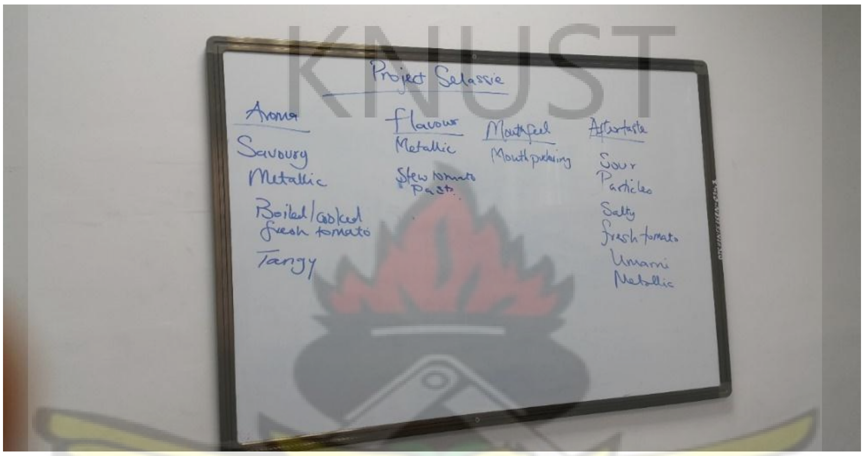
SECTION C (General Perceptions About the Tomato Powder)

1. Prior to this study, had you ever used tomato powder before?
2. If yes:
    a. Where did you obtain the tomato powder from?

b. How did you use it?

3. How do you think tomato powder is made?
4. What are your thoughts about this product knowing it is solar dried?
5. What would be your concerns for the commercial availability of this product?
6. What factors would influence your confidence about the authenticity of this product?

Appendix 20. Generation of terms of reference for the quality attributes of tomato powder



Appendix 21. Correlation matrix for QDA

Correlation matrix (Pearson):

Variables	omato_conce	d_tomato_c	AP__Red	AP__Viscosity	d_tomato_c	AR__Metallic	FL__Metallic	FL__Sticky	_Mouthpucke	FL__Sour	_Cooked_nc	FL__Coarse	oiled/_cooke	AF__Salivation	_Smoothne
FL__Stewed_	1	0.907	0.805	0.766	0.803	0.583	0.473	0.308	0.353	0.324	0.256	0.199	0.041	0.086	0.113
AR__Stewed	0.907	1	0.786	0.746	0.754	0.562	0.452	0.361	0.276	0.263	0.221	0.136	0.065	0.105	0.126
AP__Red	0.805	0.786	1	0.777	0.675	0.530	0.464	0.362	0.206	0.202	0.224	-0.007	0.086	0.169	0.166
AP__Viscosit	0.766	0.746	0.777	1	0.579	0.421	0.360	0.313	0.100	0.128	0.439	0.351	0.375	0.027	-0.154
AF__Stewed_	0.803	0.754	0.675	0.579	1	0.402	0.359	0.381	0.354	0.224	0.107	0.249	0.085	0.188	-0.025
AR__Metallic	0.583	0.562	0.530	0.421	0.402	1	0.941	0.213	0.535	0.534	-0.085	-0.058	-0.143	0.229	0.159
FL__Metallic	0.473	0.452	0.464	0.360	0.359	0.941	1	0.156	0.547	0.559	-0.117	-0.019	-0.075	0.269	0.103
FL__Sticky	0.308	0.361	0.362	0.313	0.381	0.213	0.156	1	0.044	-0.036	0.098	-0.039	0.135	0.233	0.004
MF__Mouth	0.353	0.276	0.206	0.100	0.354	0.535	0.547	0.044	1	0.724	-0.298	-0.141	-0.314	0.324	0.210
FL__Sour	0.324	0.263	0.202	0.128	0.224	0.534	0.559	-0.036	0.724	1	-0.317	-0.092	-0.317	0.185	0.326
FL__Cooked_	0.256	0.221	0.224	0.439	0.107	-0.085	-0.117	0.098	-0.298	-0.317	1	0.424	0.732	-0.095	-0.485
FL__Coarse	0.199	0.136	-0.007	0.351	0.249	-0.058	-0.019	-0.039	-0.141	-0.092	0.424	1	0.541	-0.026	-0.616
AR__Boiled/_	0.041	0.065	0.086	0.375	0.085	-0.143	-0.075	0.135	-0.314	-0.317	0.732	0.541	1	-0.113	-0.635
AF__Salivatic	0.086	0.105	0.169	0.027	0.188	0.229	0.269	0.233	0.324	0.185	-0.095	-0.026	-0.113	1	0.032
AP__Smooth	0.113	0.126	0.166	-0.154	-0.025	0.159	0.103	0.004	0.210	0.326	-0.485	-0.616	-0.635	0.032	1
FL__Umami	0.097	0.099	0.076	-0.035	0.128	0.111	0.068	0.310	-0.206	-0.155	0.034	0.081	-0.012	0.172	0.082
FL__Sweet	-0.085	-0.093	0.013	0.132	0.072	-0.030	0.007	-0.047	0.087	0.141	-0.016	0.035	0.207	-0.188	-0.066
AF__Umami	0.044	0.028	0.010	-0.077	0.175	-0.029	-0.055	0.366	-0.158	-0.278	0.095	0.075	0.036	0.258	-0.039
AP__Syneres	-0.029	-0.010	-0.013	0.042	0.025	-0.093	-0.059	0.217	-0.076	-0.172	0.182	0.084	0.118	0.088	-0.213
FL__Salty	-0.078	-0.086	-0.033	-0.149	0.037	0.144	0.177	0.173	0.242	0.266	-0.052	-0.087	0.023	0.189	-0.029
MF__Particul	-0.185	-0.244	-0.234	0.038	-0.110	-0.239	-0.157	-0.198	-0.276	-0.230	0.535	0.594	0.604	-0.063	-0.725
AP__Particles	-0.287	-0.276	-0.311	-0.040	-0.173	-0.318	-0.246	-0.210	-0.378	-0.266	0.351	0.568	0.544	0.007	-0.640
AF__Particles	-0.299	-0.262	-0.312	-0.071	-0.137	-0.302	-0.236	-0.073	-0.303	-0.202	0.299	0.518	0.402	0.110	-0.624
AR__Tangy	-0.393	-0.399	-0.579	-0.512	-0.373	-0.190	-0.181	0.026	0.065	0.106	-0.097	-0.094	-0.163	0.092	0.013
AP__Tomato	-0.539	-0.499	-0.579	-0.651	-0.441	-0.080	-0.010	-0.155	0.181	0.101	-0.433	-0.359	-0.356	0.088	0.214
AP__Peels	-0.674	-0.679	-0.656	-0.722	-0.504	-0.532	-0.456	-0.185	-0.274	-0.190	-0.117	-0.018	-0.041	-0.052	-0.176
MF__Runny	-0.761	-0.722	-0.698	-0.860	-0.622	-0.433	-0.381	-0.425	-0.184	-0.183	-0.431	-0.393	-0.388	-0.053	0.182
FL__Fresh_tc	-0.783	-0.751	-0.705	-0.716	-0.658	-0.551	-0.504	-0.193	-0.282	-0.217	-0.323	-0.216	-0.274	0.022	0.010
AP__Froth	-0.762	-0.736	-0.781	-0.895	-0.636	-0.479	-0.428	-0.321	-0.150	-0.119	-0.419	-0.280	-0.352	-0.031	0.140
AR__Fresh_t	-0.832	-0.834	-0.745	-0.767	-0.702	-0.566	-0.504	-0.239	-0.253	-0.227	-0.306	-0.226	-0.259	0.000	0.008

Variables	FL__Umami	FL__Sweet	AF__Umami	AP__Syneresis	FL__Salty	MF__Particula	AP__Particles	AF__Particles	AR__Tangy	_Tomato_ju	AP__Peels	MF__Runny	_Fresh_toma	AP__Froth	_Fresh_toma
FL__Stewed_	0.097	-0.085	0.044	-0.029	-0.078	-0.185	-0.287	-0.299	-0.393	-0.539	-0.674	-0.761	-0.783	-0.762	-0.832
AR__Stewed	0.099	-0.093	0.028	-0.010	-0.086	-0.244	-0.276	-0.262	-0.399	-0.499	-0.679	-0.722	-0.751	-0.736	-0.834
AP__Red	0.076	0.013	0.010	-0.013	-0.033	-0.234	-0.311	-0.312	-0.579	-0.579	-0.656	-0.698	-0.705	-0.781	-0.745
AP__Viscosit	-0.035	0.132	-0.077	0.042	-0.149	0.038	-0.040	-0.071	-0.512	-0.651	-0.722	-0.860	-0.716	-0.895	-0.767
AF__Stewed_	0.128	0.072	0.175	0.025	0.037	-0.110	-0.173	-0.137	-0.373	-0.441	-0.504	-0.622	-0.658	-0.636	-0.702
AR__Metallic	0.111	-0.030	-0.029	-0.093	0.144	-0.239	-0.318	-0.302	-0.190	-0.080	-0.532	-0.433	-0.551	-0.479	-0.566
FL__Metallic	0.068	0.007	-0.055	-0.059	0.177	-0.157	-0.246	-0.236	-0.181	-0.010	-0.456	-0.381	-0.504	-0.428	-0.504
FL__Sticky	0.310	-0.047	0.366	0.217	0.173	-0.198	-0.210	-0.073	0.026	-0.155	-0.185	-0.425	-0.193	-0.321	-0.239
MF__Mouth	-0.206	0.087	-0.158	-0.076	0.242	-0.276	-0.378	-0.303	0.065	0.181	-0.274	-0.184	-0.282	-0.150	-0.253
FL__Sour	-0.155	0.141	-0.278	-0.172	0.266	-0.230	-0.266	-0.202	0.106	0.101	-0.190	-0.183	-0.217	-0.119	-0.227
FL__Cooked_	0.034	-0.016	0.095	0.182	-0.052	0.535	0.351	0.299	-0.097	-0.433	-0.117	-0.431	-0.323	-0.419	-0.306
FL__Coarse	0.081	0.035	0.075	0.084	-0.087	0.594	0.568	0.518	-0.094	-0.359	-0.018	-0.393	-0.216	-0.280	-0.226
AR__Boiled/_	-0.012	0.207	0.036	0.118	0.023	0.604	0.544	0.402	-0.163	-0.356	-0.041	-0.388	-0.274	-0.352	-0.259
AF__Salivatic	0.172	-0.188	0.258	0.088	0.189	-0.063	0.007	0.110	0.092	0.088	-0.052	-0.053	0.022	-0.031	0.000
AP__Smooth	0.082	-0.066	-0.039	-0.213	-0.029	-0.725	-0.640	-0.624	0.013	0.214	-0.176	0.182	0.010	0.140	0.008
FL__Umami	1	-0.255	0.796	-0.120	-0.021	-0.023	-0.017	-0.004	-0.017	0.117	0.098	-0.084	0.131	0.004	0.086
FL__Sweet	-0.255	1	-0.048	0.040	0.338	0.136	0.030	0.018	0.128	0.074	0.000	0.014	0.041	0.005	0.050
AF__Umami	0.796	-0.048	1	0.035	0.173	0.139	0.082	0.172	0.141	0.131	0.182	0.013	0.235	0.113	0.175
AP__Syneres	-0.120	0.040	0.035	1	0.430	0.214	0.102	0.282	0.259	-0.053	0.233	-0.004	0.141	0.067	0.103
FL__Salty	-0.021	0.338	0.173	0.430	1	0.241	0.078	0.289	0.519	0.203	0.369	0.182	0.227	0.324	0.230
MF__Particul	-0.023	0.136	0.139	0.214	0.241	1	0.780	0.784	0.186	-0.126	0.382	0.000	0.136	0.055	0.150
AP__Particles	-0.017	0.030	0.082	0.102	0.078	0.780	1	0.700	0.090	-0.051	0.402	0.072	0.250	0.072	0.208
AF__Particles	-0.004	0.018	0.172	0.282	0.289	0.784	0.700	1	0.290	0.019	0.450	0.126	0.307	0.246	0.265
AR__Tangy	-0.017	0.128	0.141	0.259	0.519	0.186	0.090	0.290	1	0.613	0.653	0.481	0.590	0.648	0.598
AP__Tomato	0.117	0.074	0.131	-0.053	0.203	-0.126	-0.051	0.019	0.613	1	0.488	0.643	0.599	0.632	0.620
AP__Peels	0.098	0.000	0.182	0.233	0.369	0.382	0.402	0.450	0.653	0.488	1	0.660	0.792	0.785	0.799
MF__Runny	-0.084	0.014	0.013	-0.004	0.182	0.000	0.072	0.126	0.481	0.643	0.660	1	0.716	0.884	0.767
FL__Fresh_tc	0.131	0.041	0.235	0.141	0.227	0.136	0.250	0.307	0.590	0.599	0.792	0.716	1	0.798	0.960
AP__Froth	0.004	0.005	0.113	0.067	0.324	0.055	0.072	0.246	0.648	0.632	0.785	0.884	0.798	1	0.835
AR__Fresh_t	0.086	0.050	0.175	0.103	0.230	0.150	0.208	0.265	0.598	0.620	0.799	0.767	0.960	0.835	1

MODALITY	**A**	**B**
Appearance		

Aroma		
Texture		

Appendix 22. Sheets for Quantitative Descriptive Analysis

You will be provided with 2 tomato powders. Please describe the modalities stated in the table. Please do not taste the samples.

BALLOT SHEET

Panelist name:

Date:

You will be provided with 3 tomato slurries. Please describe the modalities stated in the table.

MODALITY	A	B	C
Appearance			
Aroma			
Texture			
Flavour			
Mouthfeel			
Aftertaste			

RECRUITMENT QUESTIONNAIRE FOR SENSORY EVALUATION OF SOLAR DRIED TOMATO POWDER

University of Ghana-Department of Nutrition and Food Science Sensory Evaluation Laboratory

Sensory Evaluation of Tomato Powder

LOCATION: …………………………………… TELEPHONE: ………………………..

Background

We would like to invite you to participate in a research study on the use of tomato powder for cooking. You will be provided with 25 grams of tomato powder, an instruction sheet and a log sheet to record how you used the tomato powder in cooking a tomato based dish of your choice. Kindly complete the following short questions to help us determine if you are the right candidate for this study. The questionnaire should take no longer than 30 minutes of your time. If you fit the type of respondents we are looking for, you will be asked to take the tomato powder away today and use it over the next 7 – 10 days to prepare any meal of your choice. You will have to come back once on a mutually suitable date to discuss your experience with the product in a focus group discussion setting. A focus group is a small homogeneous group of six to ten people led through an open discussion by a skilled moderator structured around a set of carefully predetermined questions. The topic for this focus group will be your experience with the tomato powder you used at home.

If you are interested in this study as described above, I will be happy if you would please complete the questionnaire below. Your response to the questions is of uttermost importance to us and will be treated with much care and confidentiality. Thank you.

Please circle the appropriate responses.

1. **Sex:**
   1=Male 2=Female
2. **Age Group:**

   1=10-17 years 5=42-49 years

   2=18-25 years 6=50-57 years

   3=26-33 years 7=58-65 years

   4=34-41 years 8=65 years and above

3. **Ethnicity**

1=Akan 4=Guan
2=Ewe 5=Northerner
3=Ga/Adangbe 6=Other: Specify ……………….

4. **Highest level of education received**

1= None
2= Primary
3= Middle School/JHS
4= Secondary
5= Tertiary
6= Other, specify.......................

5. **Occupation**

Which of the following best describes your current occupation?

1=Student

2=Craftsman/artisan

3=Trader

4=Farmer

5=Stay at home parent

6=Civil servant

7=Health worker

8=Banker

9=Self employed

10=Professional

11=In-between work

12=Other (specify)……………………………….

6. **Income(GH¢)**

What is your individual gross monthly income?

1=Under 500
2=501-1,000
3=1,001-2,000
4=2,001-3,000
5=3,001-4,000
6=4,001-5,000
7=5,001-6,000
8=6,001-7,000
9=7,001-8,000
10=8,001-9,000
11=9,001-10,000
12=10,001-11,000
13=More than 11,000
14=Prefer not to answer

7. **Allergies**

Are you allergic to any of these foods? Tick all that apply.

1= Sea food

2= Milk

3= Gluten

4= Nuts (eg; peanuts)

5= Other, Specify…………………………….

8**. How often do you consume tomato based dishes?**

1= Everyday

2= Several times a week

3= Once a week

4= Once every two weeks

5= Once a month

6= Less than once a month9. **Which type of tomato dish do you consume and how often do you consume the tomato dishes (*Complete the table below: tick as applies*)**

Tomato dish	Number of times dish is prepared in a week							Number of times dish is consumed in a week							
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
Stew															
Soup															
Salad															
Fresh ground pepper															
Jollof															
Shito															
Other: Specify															

10. **Will you like to participate in any other test apart from this one?**

1=Yes

2=No

Thank you for your patience in answering these questions.

The session will be relaxed and informal and you will find it interesting. We protect our participant rights with our ethical clearance obtained from the Ethics Committee for Basic and Applied Sciences, College of Basic and Applied Sciences, University of Ghana.

Would you be available to take part in this test?

1=Yes

2=No

The various categories of participants have been assigned to a day for the focus group discussion. If the date is not suitable, please select which day will suit you.

SESSION SCHEDULE

Session number	Date	Time	Venue	Group
1	21st April, 2017	2:00pm-4:00pm	Sensory lab, NFSD	Students
2	24th April, 2017	10:00am-12:00pm	Sensory lab, NFSD	Caterers
3	28th April, 2017	2:00pm-4:00pm	Sensory lab, NFSD	Workers who reside outside campus

Upon your arrival, you will be required to sign a form acknowledging your consent to participate based on these details. This form also includes a statement that you will not pass on any information about the test to any other person and the information about yourself will be kept confidential.

Could you please provide us with the following details?

NAME: ………………………………………………………………………

CONTACT NUMBER: ………………………………………………………

EMAIL ………………………………………………………………………

DATE OF BIRTH: ……………………………………………………………

SIGNATURE…………………………………… DATE: …………………

SECTION C

You have been provided with 25 grams of solar dried tomato powder. This is a new product we are developing and we would like you to use it like you normally would in the preparation of a tomato based dish. Provide the needed information in the tab

Type of Dish Product Was Used to Prepare	How Did You Use sample	What are Your Impressions About the Tomato Powder in Terms of the Following:	Overall Impression of the Product and Any Other Comments
		Packaging *Appearance* *Aroma* *Flavour* *Functionality* *thickness*	

TEST OBJECTIVE: To determine the sensory profile of solar dried tomato powder.

PANEL DETAILS: Trained Panel

SAMPLE DETAILS: 2 types of powdered tomatoes

SAMPLE PREPARATION: No sample preparation required. Serve approximately 2g of each sample in 25ml shito cups.

SAMPLE	DETAILS	CODE
1	Solar dried tomato powder	A
2	Tomato powder on the market made of milled annatto seeds, corn, cola nuts and E. Color series (To impart red color)	B

TEST PROTOCOL:

Activity 1: Term generation

- Present samples in monadic sequential order. Assessors to evaluate all sensory modalities (Appearance, Aroma and Texture (texture in the hand)) and describe them.
- Assessors to provide brief definitions for descriptors
- Assessors to provide anchors for descriptors

Activity 2: Consensus Building

- Collate all descriptors for Appearance, Aroma and Texture (texture in the hand)
- Come to agreement on terms to use for evaluation
- Provide references for difficult descriptors

Activity 3: Evaluation

- The two products to be evaluated in triplicate by panel using Compusense 5.
- Presentation order as generated by Compusense 5.

Appendix 23: QDA sensory profile of reconstituted solar dried tomato powder.

WORKSHEET

TEST METHOD: Qualitative Descriptive Analysis

TEST OBJECTIVE: To determine the sensory profile of reconstituted solar dried tomato powder.

PANEL DETAILS: Trained panel

SAMPLE DETAILS: 3 types of processed tomatoes

SAMPLE	DETAILS	CODE
1	Reconstituted solar dried tomato powder	A
2	Blended fresh tomato with seeds	B
3	Tomato paste	C

SAMPLE PREPARATION:

❖ Solar Dried Powdered Tomato

Reconstitute 25g of tomato powder with 100 ml of tepid water (30±2) ^{o}C. Mix thoroughly to obtain a slurry.

❖ Fresh tomato

Blend 100g diced fresh tomato with seed at high speed for 2 minutes.

❖ Tomato paste

Add 50ml of tepid water to 50g of double concentrated tomato paste.

Serve about 1 teaspoonful of slurry for each sample to panelists.

TEST PROTOCOL:

Activity 1: Term generation

- Present samples in monadic sequential order. Assessors to evaluate all sensory modalities (Appearance, Aroma and Texture (texture in the hand)) and describe them.
- Assessors to provide brief definitions for descriptors
- Assessors to provide anchors for descriptors

Activity 2: Consensus Building

- Collate all descriptors for Appearance, Aroma and Texture (texture in the hand)
- Come to agreement on terms to use and Provide references for difficult descriptors

Activity 3: Evaluation 1

- Let panel assess samples for attributes present using CATA on Compusense. Other descriptors that did not come up in term generation should also be added to the list and panel will indicate if they are present or not.
- Analyze and the descriptors chosen by most/all the panelist should be used. New descriptors should be defined and understood by the panel.
- Compile final list of descriptors.

SAMPLE	DETAILS	CODE
1	Reconstituted solar dried tomato powder	907
2	Blended fresh tomato with seeds	899
3	Tomato paste	673

Activity 4: Evaluation 2

- The two products to be evaluated in triplicate by panel using Compusense cloud.
- Presentation order as generated by Compusense cloud.

SAMPLE	DETAILS	SESSIONS		
		1	2	3
1	Reconstituted solar dried tomato powder	232	386	527
2	Blended fresh tomato with seeds	248	291	254
3	Tomato paste	114	577	648