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FDRE TECHNICAL & VOCATIONAL TRAINING INSTITUTE

EFFECT OF FOUR LEVELS OF BLANCHING TIME AND THREE LEVELS OF DRYING TEMPERATURE ON PHYISICOCHEMICAL AND SENSORY QUALITIES OF TOMATO *(Solanum lycopersicum)* POWDER.

M.Sc. THESIS

BY

ZELALEM MOTBAYNOR LAKE

MAY 2026

ADDIS ABABA, ETHIOPIA

EFFECT OF FOUR LEVELS OF BLANCHING TIME AND THREE LEVELS OF DRYING TEMPERATURE ON PHYISICOCHEMICAL AND SENSORY QUALITIES OF TOMATO *(Solanum lycopersicum)* POWDER.

A Thesis Submitted to Technical and Vocational Training Institute Faculty of Agro- Processing Technology, Department of fruit and vegetable processing Technology.

In partials fulfillments of the requirements for the award of master's degree in ***food processing Technology*** *(specialized in fruit and vegetable processing technology).*

BY ZELALEM MOTBAYNOR

ADVISOR: ADDISALEM HAILU (PhD)

May 2026

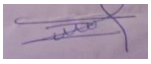
ADDIS ABABA, ETHIOPIA

DEDICATION

To my beloved mother who is not alive at a time, Emewa you was my teacher my doctor and my everything, you are alive in my heart. Next to my mother my beloved wife Dejeselam, my children Minassie and Selomie you are the messengers sent from God to cure me from my aberration,

DECLARATION OF THE AUTHOR

I here by declare that the work which is being presented in this thesis entitled **"**EFFECT OF FOUR LEVELS OF BLANCHING TIME AND THREE LEVELS OF DRYING TEMPERATURE ON PHYISICOCHEMICAL AND SENSORY QUALITIES OF TOMATO *(solanum lycopersicum)* POWDER" is my original work carried out under the supervision of Adisalem Hailu (Phd).It has not been submitted for any degree of any other university/institute and all source of materials used for this thesis are duly acknowledged.

Name of candidate	Signature	Date
Zelalem Motbaynor		24/06/2026

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

Name of advisor	Signature	Date
Addisalem Hailu (PhD**)**		24/06/2026

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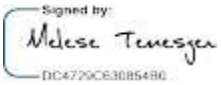
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Addisalem Hailu (PhD)		24/06/2026
Name of Major advisor	Signature	Date

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As member of Board Examiners of the Master of Science (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Zelalem Motbaynor Lake entitled "Effect of four levels of blanching time and three levels of drying temperature on physicochemical and sensory qualities of tomato *(solanum lycopersicum)* powder,,,, We hereby certify that; the thesis is accepted for fulfilling the requirements for the award of the Degree of Master of Science (M.Sc.) in food processing technology(specialized in fruit and vegetable processing technology).

…….	……	……
Board of Examiners	signature	date
Addisalem Hailu (PhD)		24/06/2026
Name of Advisor	signature	date
Melese Temesgen(PhD)		29/06/2026
Name of External Examiner	signature	date
Mulualem Azene(PhD)	……..	……...
Name of Internal Examiner	signature	date

BIOGRAPHIC SKETCH

Zelalem Motbaynor Lake, was born on March 29, 1988 G.C from my father Motbaynor Lake and mother Felegush Zeleke, in Achefer wereda, west gojjam zone. I completed my elementary education at Ahuri primary school, secondary education at Dangila secondary school and preparatory school at Dangila preparatory school, Dangila. Then I joined wukro satellite cumpus under FTI in 2010/2011 and completed with a B.Sc. degree of Fruit and Vegetable processing Technology in June 2013/2014 E.C with great distinction. After graduation, I was employed by Burie poly technic college as teacher of agro processing starting from September 2015.Meanwhile I was also given the chance to start postgraduate study in fruit and vegetable processing technology after one and half year.

ACKNOWLEDGMENT

This work was made possible with the help of my beloved Advisor Dr Adisalem Hailu next to the almighty of God with his mother St Merry. Words are not enough to describe my great honor and thanks towards my advisor Dr Addisalem Hailu for their encouragement, supervision, patient guidance and constructive criticism by spent long tireless hours on this work.

I want to thank my instructors Dr Tilahun Abera, Dr Habtamu Admasie, Dr melese Temesgen, Dr Addisalem Hailu, Dr Ashagrie , Dr sintayehu , Dr Dagim, Dr Bikrietsion, Dr Genene, Assi professor Chala G, Ato Fanta and mom Greace for your life time education with great humanity, I want to thank Dr Mulualem Azene department head, for her unlimited support at the time of regular class arrangement and any support during all over.

I gratefully acknowledge, FTI Agro processing department for allowing and sponsoring me to do my M.Sc Thesis as early as I finished the undergraduate studies.

Finally, I would like to thank my families, friends and colleagues who support me in different direction.

LIST OF ABBREVIATION AND ACRONYMS

ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
FAO	Food and Agriculture Organization
HTST	High Temperature Short Time
PH	Hydrogen Percentage/ Potential of Hydrogen
QDA	Quantitative Descriptive Analysis
Rpm	Revolutions per minute
RR	Rehydration Ratio
TA	Titarable Acidity
TA.	Texture Analyzer
TSS	Total Soluble Solid
UV	Ultraviolet

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ABSTRACT

Tomato (Solanum lycopersicum) is a highly perishable fruit with significant postharvest losses. Drying is an effective preservation method that extends shelf life. This study investigated the effects of blanching time (0, 30, 60, and 120 seconds at 95°C hot water) and hot air drying temperature (50, 60, and 70°C) on physicochemical and sensory attributes of tomato powder derived from the Roma VF variety. Fresh tomatoes were washed, blanched, peeled, sliced uniformly (4 mm thickness) and dried using a hot air dehydrator until constant weight was achieved. The resulting powders were analyzed for moisture content, water activity, rehydration ratio, solubility, bulk density, total soluble solids (TSS), pH, ash content, vitamin C, lycopene content, and sensory properties (color, flavor, texture, and overall acceptability) using a 7-point hedonic scale. The experiment followed a 3 × 4 factorial arrangement in a completely randomized design (CRD) with three replications, totaling 36 experimental units. Data were analyzed using two-way ANOVA with Minitab software (version 22), and means were separated using Tukey's multiple comparison test at a 5% significance level.

Results demonstrated that drying temperature significantly ($p < 0.05$) influenced most physicochemical properties, while blanching time showed significant effects primarily on solubility and lycopene content. Higher drying temperatures (70°C) reducing drying time to 7 hours compared to 50°C (9 hours). Moisture content (9.55%-9.78%),water activity(0.34-0.35), lycopene retention (28.4-29.6mg/100g),vitamin C (20.02-23.9 mg/100g), rehydration ratio(2.97-4.4), solubility(80.3-82.4%), TSS(5.2-5.6^{0}Bric), ash (14.2-15.0gm), ph (4.15-4.35) and density(0.47-0.5g/cm^3).

Keywords: *Tomato powder; Roma VF; Blanching time; Hot air drying; Drying temperature; Physicochemical properties; Sensory evaluation.*

1. INTRODUCTION

1.1 Background

Among the most vastly grown and consumed fruits and vegetables in the world, Tomato is one of the most fruit from which Roma VF tomatoes (*Solanum lycopersicum*) are one of them, which are essential to fulfill food security. The Food and Agriculture Organization (FAO) estimates that 182 million metric tons of tomatoes were produced in 2020 all over the world, from which China, India, and United States being the top producers (Kumar *et al*., 2020). Tomatoes are among the popular according to their many culinary uses mainly their nutritional advantages, like high vitamin C content and antioxidant qualities (Kumar *et al*., 2020).

Tomato production is becoming more significant in Ethiopia currently; because of its economic potential and crucial role in fulfilling food security as population density is increasing. Ethiopia is one of Africa's top producers of tomatoes, it has an estimated production of 400,000 metric tons annually (Kumar *et al*., 2020).The Southern Nations, Nationalities, and Peoples (SNNP), Amhara, and Oromia regions produced the most tomatoes countrywide. The Ethiopian government recognizes the importance of tomatoes in improving rural livelihoods and ensuring food security, as a result the government aiming to improve farming practices, financing irrigation infrastructure and promote researches on identifying disease-resistant varieties in order to increase output (Work, 2023).

Tomato is appreciated for its health benefits and culinary flexibility nature. It has been a good source of vitamins, minerals, and antioxidants, especially lycopene, which has been connected with different health benefits such as reducing the risk of chronic diseases On the contrary, the perishable nature of tomatoes posed enormous challenges in terms of packaging, storage and transportation. Conversion of tomatoes to powder form used to extending shelf life, reduced volume for shipping and convenience as an ingredient in various food products (Yegrem & Ababel, 2022)

Drying is one of the very important unit operation, it involves the application of heat to a material to reduce the amount of moisture inside.(Mujumdar & Menon, 2020). It constitutes an alternative to the consumption of fresh fruits and vegetables and allows

their use during the off-production season. Beyond increasing the shelf life of product drying also helps to reduce the weight (**90% to 95%**) and volume of product(80-90%), which used to minimize costs for packaging, storage and transportation. The processing methods follows, the blanching time and drying temperature has a strong influence on the quality of the tomato powder. Pre-treatment methods such as hot water blanching, osmotic dehydration, and acidification can improve the final quality of product by inactivating enzymes that are responsible for the degradation of nutrients and causing undesirable changes in color and flavor (Ghimire, 2022). Blanching is being applying extensively to keep the color and nutritional value of tomatoes by reducing burdens of microbial and enzymatic loads, mainly osmotic dehydration helps to improve retention of bioactive compounds and shorten drying time which then improved the quality of the tomato powder (Ghimire, 2022).

Even if critics is not important on the works done on processing of tomatoes before, but not much researches done regarding to the interactive effects of blanching time and drying temperatures on the physicochemical and sensory properties of the tomato powder. The main objective of this study is to analyze the combined effects of different blanching time and various drying temperatures on tomato powder. The study emphasizes these relationships in order to provide information on processing of tomato powders for assessing physicochemical and sensory characteristics to food processors. Good quality tomato powder requires an understanding of the interaction effects between blanching time and drying temperatures.

1.2 Statement of the problem

The major problem in tomato fruit production is its short shelf life nature, which can create unexpected loss due to high water content. The postharvest losses of tomato in Ethiopia create a major problem which results unsustainable food security, diminishing farmer's income and reducing agricultural output. The losses occur due to various reasons including lack of good storage, incorrect methods of handling, absence of favourable transportation system and limited access to market (Ahmad *et al*., 2020). Main factors that are responsible to postharvest losses of tomato includes, in sufficient access to storage facilities, improper harvesting distribution and selling

processes, which causes physical damage to the fruit and result in increased spoilage issues, insufficient infrastructure and transportation systems which resulting in increased spoilage rates, limited market access, which causes overproduction in local areas and waste disposal challenges. The current system is trying to experiences major postharvest losses because it lacks effective methods to control pests and diseases. The postharvest period experiences major losses because of inadequate pest and disease control methods, and perishability nature of tomato (Mwankemwa *et al*., 2023). To reduce the perishability and to increase the shelf life of tomato fruit, moisture content reduction is very useful. Tomato powder is one of the ingredient in different food related industries, which has extended shelf life than fresh tomatoes (Beaulah *et al.*, n.d.). Even if the physicochemical and sensory properties including colour and antioxidant activities significantly affected by drying process(Zalewska *et al*., 2022). These effects will be mitigated by pre-treatments and varying drying temperatures, the optimal combination of pre-treatments and drying temperatures is still unclear basically specific metrics like lycopene and colour stability, Studies often examine individual factors in isolation (e.g., hot air drying vs. oven-drying) (Pravitha *et al*., 2024), which lacks a systematic comparison of readily implementable pre-treatments and drying temperature combinations.

Quality of tomato powder can be enhanced by pre-treatments, such as blanching, by inactivating enzymes that causes degradation as well as improving moisture removal efficiency; however, these methods can also lead to nutrient losses (Yegrem & Ababel, 2022). While higher temperatures may reduce drying time of tomato powder, drying temperature itself is another critical factor which can adversely affect the sensory attributes and nutritional quality of the final product (Kaur *et al*., 2020). Until now researches refused studying combination effects of different pre-treatments and drying temperatures, this knowledge gap restricts food processors from making tomato powder which meets the rising demand for high quality products. This research will show how blanching time and drying temperatures can affect the physicochemical and sensory properties of tomato powder, then aims to improve production processes and product quality evaluation. The existing research currently lacks comprehensive studies to assess combination effects of different blanching time and drying temperatures on tomato

powder's physicochemical and sensory properties. This research study intends to examine effects of blanching time and drying temperatures on the physicochemical properties of tomato powder and will try to identify optimal processing conditions which improve tomato powder quality and marketability.

1.3 Significance of the study

The study aims to identify problems and prospects in tomato powder processing and marketing, aiding policy makers in designing effective strategies. It will provide useful insights for producers, traders, and marketing agents, elucidating ways how to change fresh and perishable tomato in to powder, how to preserve tomato powder, how to reduce post-harvest losses, how to increase income and prepare for disasters, emergencies as well as food scarcity and aids in better diets and kitchen waste reduction. Mainly the study aims to preserve nutritional content, keep and improvement of product quality, preservation and improve shelf Life of tomato powder. Innovations in food processing to improve Consumer acceptance, the study will add to the existing body of knowledge regarding to food processing techniques, particularly for dehydrated products.

1.4. Objective of the study

1.4.1 General objective

The general objective of this study is to evaluate the effects of blanching time and drying temperature on physicochemical, functional and sensory properties of tomato powder, and determine the optimal processing conditions.

1.4.2 Specific objective

1. To determine the effects of blanching time on physicochemical, sensory properties and drying kinetics of tomato powder.

2. To determine effects of drying temperature on physicochemical, sensory properties and drying kinetics of tomato powder.

3. To identify the optimal combination of blanching time and drying temperature that yields the highest quality tomato powder.

1.5 Research question

What is the combined (interaction) effect of blanching time and drying temperature on Physicochemical, sensory properties and drying kinetics of tomato powder?

1.6 Scope of the study

The scope of this study on the effect of blanching time and drying temperature on the physicochemical and sensory properties of tomato powder will include, Evaluation of different blanching time: The study evaluated the effects of different blanching time on physicochemical and sensory property of tomato powder, which involved blanching the tomato at different blanching time,(0, 30, 60 and 120 second) with 95 ^{o}C hot water (Sunmonu *et al*., 2021). Assessment of different drying temperature: The study will focus also to assess the effect of different drying temperature (50, 60 and 70 ^{o}C) on physicochemical and sensory property of tomato powder.

Identification of factors affecting tomato powder quality: The study identified the factors that contribute to changes in tomato powder quality, including the combination effect of blanching time and drying temperature. The study conducted in a laboratory setting using fresh Roma VF fruit obtained from Holeta agricultural research center. The research involved duplicating the industrial blanching time conditions and drying temperature used in actual production processes. The study results helped to processors, distributors, retailers and consumers by enhancing tomato fruit pretreatment methods and their drying temperature procedures.

2. LITERATURE REVIEW

2.1 Tomato Production and Consumption

2.1.1 Tomato production

Bringing tomato fruit to mind is probably not too far-fetched since it is originally cited in the region of South America, by the 19th century, tomato cultivation in some regions, such as North America, tomatoes become formed as part of various culinary traditions, then the advent of the canning revolution at the end of the 19th century provided greater attentions into production and consumption of tomatoes, which leads to extending the importation and establishment of large-scale commercial tomato farming. Over a few decades, tomato production spread almost all over the world. Africa has been growing at a tremendous rate; the continent has both fresh-market and processing tomato types. Egypt leads the pack in Africa and Nigeria follows to Egypt as the producer of tomatoes. Other countries follow with Egypt and Nigeria including Morocco, and South Africa (Ajenifujah-Solebo *et al*., 2025).

Tomato production in Ethiopia has a long tradition in agriculture, with an increased expansion in tomato production levels over the years, the Central Statistical Agency (CSA) of Ethiopia reports that tomato production was around 400,000 tons in recent years. Regions that largely growing tomatoes are Southern Nations, Nationalities and Peoples' Region (SNNPR), Oromia, and Amhara. Tomato production hence has an exciting history. Tomatoes are serving as food security and economic development crops beginning from a South American-originated crop and now regarded as an African and Ethiopian staple crop. To address the challenges faced by tomato producers in production improvements and to ensure that farmers earn a sustainable livelihood, research, innovation, and policy support are needed (Ajenifujah-Solebo *et al*., 2025).

Table 1: Top five tomato producing countries

Source; (Shimazu & Motoki, 2022)

Rank	Country	Tomato production/metric tons/
1	China	70,119,694
2	India	20,425,000
3	Turkey	13,300,000
4	USA	12,370.057
5	Egypt	6,211,000

2.1.2 Mode of consumption of tomato

Due to health benefits, Consumption of fruits and vegetables has been increased rapidly at a time (Kaparapu *et al*., 2020)**.** Many of the tropical and temperate fruits and vegetables still do not get proper attentions due to the lack of awareness of their potential, market demand and health benefits. Tomato has got considerable attention in recent years because of the nutritional and health protective values (abu Haraira *et al*., 2022)**.** Since tomato has vitamin C, Lycopene and beta carotene, it highlights its heart friendly attributes. In other parts of the world, dried vegetables; like, carrot, banana, onion and tomato can find in pieces or powders forms, but in Ethiopia such types of products are not available in the market. In our country, tomatoes are widely grown for their fruit utilization that are being used for salad preparation and to be consumed with Ethiopian traditional spongy thin-layer bread (*Injera*) made from cereal grain called teff(ASRAT & Abera, 2024)**.** The other most important food product made from tomato fruit is sauce called as 'Mabay*a'*.which is used for making delicious stew termed as '*Shiro Wott'* and highly used during the period of food scarcity.

2.1.3 Nutritional importance of tomato

Tomato has numerous nutritional values. Tomato is inexpensive agricultural product, which requires the relatively low production costs (M. A. Ali *et al*., 2023)**.** Tomato possesses top quality essential nutrients that are required for many processes in the human body (Amr *et al*., 2022)**.** Tomato is very low in calories but it contains abundant quantities of vitamin c and Lycopene. Many important disease fighting nutrients are also

found in tomato in large quantities in the pulp and seeds including the vitamins C. Furthermore, tomato has antioxidants that boost the human body immunity against cancer and other deadly diseases. Antioxidants are abundant and normally referred to as lycopene, and it is believed that this substance minimizes the risk of chronic diseases, one of which is prostate cancer. Heart Health: Eating tomatoes regularly helps to reduce cholesterol levels and improve blood pressure on account of their high-antioxidant content. Skin Protection: Lycopene is expected to give some protection to the skin against this UV damage and also improve the health of the skin in general. Lakhanpaul and colleagues (2022) state that Bones Health Experts on vitamin K and calcium that support bone density and health in general are tomatoes. Weight Control: tomatoes are low in calories and rich in water, which fills the stomach and creates a sense of fullness that helps in controlling body weight effectively. Diabetes Management: The red fruit tomatoes believed to have high fiber level that helps to reduce the blood sugar level and improve glycemic control (ZH & BEKNAZAR, 2024)**.** Tomato is cheaper as compared to carrots in cost and is abundantly available in market. It is not only a staple in many diets around the world but also offer a range of nutritional benefits and health advantages (Collins *et al.*, 2022). Here is the nutrition profile of tomatoes and their associated health benefits.

Table 2: nutritional profile of tomato/100 gram

Source: (Raza et al., 2022)

Nutrient content	Calories:	18 kcal
	Fat	0.2 g
	Water	: 95%
	Protein	0.9 g
	Carbohydrates	3.9 g
	Fiber	1.2 g
	Sugars	2.6 g
Vitamin content	Vitamin C	13.7 mg
	Vitamin K	7.9 µg
	Vitamin A	833 IU
	Folate	15 µg

Mineral content	Potassium	237 mg
	Magnesium	11 mg
	Calcium:	18 mg
	Iron	0.5 mg
Antioxidants:	Lycopene	2573 µg
	Beta-carotene	449 µg

2.1.4 Health benefit of tomato

Currently, awareness about the health benefits of vegetables in Ethiopia has been increasing (Bachewe & Minten, 2023). Because of public health advocacy on the role of vegetables in human nutrition and health by its provision of antioxidants such as vitamin C and lycopene, since vitamins and antioxidants like lycopene are important in neutralizing free radicals (oxidants) known to cause cancer, heart disease, hypertension, stroke and diabetes. The other reason is because of the rising prices of livestock products such as meat, milk and eggs, which traditionally forms a major component of most Ethiopian diets. As such the increasing consumption of vegetables helps to fight hidden hunger malnutrition.

2.2. Postharvest Problem Associated with Tomato

Even if tomato is known for its high yields, good storage, longer period of consumption, high nutritive value and fitness in transportation, but it is perishable like most vegetable crops (Beaulah *et al*., n.d.). Due to its bulkiness, large size and high moisture content, there are many chances to be spoiled early if it is cut open. Its large size and heaviness nature reduces the consumer acceptance and also poses transport problems. To make tomato available throughout the year, it is essential to reduce the moisture content. Different Preservation methods are required to increase the shelf life, conserve properties to protect it from insect and microbial growth. There are various methods used to preserve fruits and vegetables (Sridhar *et al.*, 2021) One of the most commonly used methods for preservation is drying, which is considered to be the oldest and the most important method of food preservation. All tomatoes to be processed should be well matured, carefully handled and free from injury or decay. Recommended conditions for storage of tomato are 10 to 13 °C temperature with relative humidity of 50 to 70%. Higher RH promotes decay while lower RH causes excess weight loss and texture

deterioration, so the RH is better to be as mentioned above. Storage of tomato at low temperature possess unfavorable physiological processes which resulting in chill damage. The fruit surface should be kept dry and storage room should have good air circulation. (Firdous, 2021).

2.3. Preservation and Processing of Tomato

There are various methods of food processing and preservation today (Talib *et al*., 2024),which includes dehydration, cold and heat treatment, fermentation, irradiation, additives and packaging to prevent growth of microbes such as bacteria and fungi. The biggest challenge in processing fresh produce is loss of nutrients (Shewfelt & Prussia, 2022). The actual losses of nutrient depend on various factors such as food type, processing temperature and processing time, nearly all food preparation and preservation methods lead to losses. Drying has been recognized as the most useful processing technique for prolonging solid foods including vegetables. Food processors and nutritionists need to find ways of minimizing nutritional losses without compromising the health of consumers (Drummond & Brefere, 2021).in order to reduce losses and improve human health, food fortification may be used widely. Tomato needs way of preservation mainly to reduce spoilage, to make it available throughout a year, to maintain desired levels of nutritional properties for the long possible time and to make value added products(Khalid *et al.*, 2024). One of the advantages of dried foods is less storage space requirement than canned or frozen foods. Drying is one of the most cost-effective ways of preserving foods of all variety which involves removal of water by application of heat.

2.3.1. Drying as food preservation method

Drying technique is one of the earliest techniques to removing moisture and preserving the food (Fathi *et al*., 2022), which has a vital role in postharvest processing and has great importance for conserving agricultural products to extending the shelf life. Vegetable drying is generally done either for preserving the perishable raw commodity against deterioration or to reduce the cost of packaging, handling, storing and transporting. The most serious problem for shelf-life enhancement is the activity of micro-organisms (Lohita & Srijaya, 2024). During drying Water in food staff is reduced to a very low level, which helps to achieve better microbiological preservation and retarding many undesirable reactions during storage. In addition to microbial spoilage retardation; drying

technique also influences other characteristics, such as palatability of food, flavor, aroma, viscosity, hardness, and enzymatic activity.

2.3.2. Methods of drying

In today's world, convective drying method is the most effective and common form of processing. (VP, 2020), because of its ability to reduce the moisture content in food and preserved well with short period of time, but it is not economical due to high energy cost, since it runs with fuel and electricity, that make it unsuitable for poor farmers where there is no electricity (Carvalho *et al*., 2021). Convective drying method provides many advantages in using uniform energy, providing low space utilization, supplying healthy sanitation and giving better process control. Microwave method has some drawbacks, which includes; uneven heating, high investment cost and can cause damage to the final products. Freeze drying is a well-known drying process for obtaining high quality products because it reduces nutritional and sensorial degradation (Harguindeguy & Fissore, 2020). In the other hand, the freeze drying method also requires a lot of time and is known as the most expensive form of food drying process.

2.3.2.1. Sun drying

Sun drying is a method where food products are spread on mats or raised in clean platforms to be dried by direct radiation of the sun (Fernandes & Tavares, 2024), which is the simplest and cheapest drying technique widely practiced in the tropical region where the outdoor temperature is high enough (usually 30^0C or higher) to remove moisture from agricultural materials. Sun drying is the evaporation of water from products by sun or solar heat due to movement of surrounding air, this method is relatively slow evaporation of moisture which has a negative effect on final product quality in case of food safety. Open sun drying of various crops is the widest spread conventional method for food preservation practiced in many developing countries. The major disadvantage of this technique is low quality and hygienic problems of the product, because the product can gets contaminated from dust, insects, rodents, and other animals which seriously degrade the food quality (Alp & Bulantekin, 2021). Labor requirement, long drying time and direct exposure of the produce to sun and wind are the further difficulties with this method.

2.3.2.2. Solar drying

Solar drying is differentiated from "sun drying", it operates by use of equipment to collect the suns radiation then the irradiative energy used for drying applications (Fernandes & Tavares, 2024)**.** In many parts of South East Asia, spice crops and herbs are routinely dried using solar dryer. Solar dryers are more rapid, providing uniformity and hygiene to the products being dried and are suitable for industrial food drying processes than sun drying. The reduction of food losses is particularly a problem for small farmers in developing countries who produce more than 80% of the food. Since traditional sun drying is relatively slow process, considerable losses can occur, in addition a reduction in the product quality takes place due to insect infestation, enzymatic reaction, microorganism growth and mycotoxin development (A. Ali *et al.*, 2021) **,** with cultural and industrial development, artificial mechanical drying came into practice this process is highly energy intensive and expensive, which ultimately increases product cost. Thus solar drying is the best alternative as a solution of all the drawback of natural drying and artificial mechanical drying. Solar dryers are used in agricultural and industrial food processing industries (Ekka & Kumar, 2023)**.** They are very useful device from the energy conservation point of view. They do not only save energy but also save time, occupy less area, improves quality of product, make the process more efficient, and also protect the environment. Currently design and development of solar dryer gets attention by food technologists and engineers as result various types of solar dryer has been designed such as; natural convection solar dryer, green house type solar dryer, indirect types solar dryer, Indirect multi-shelf solar dryers, cabinet type solar dryer, tunnel types solar dryer and integral type solar dryers. The system employs a sealed instrument to collect sunlight which results in internal temperatures that reach 72 ^{0}C, which protects materials from outside pollution while delivering better results.

2.3.2.3. Hot air drying

Both industrial and traditional food processing sectors use hot air drying as their primary method to extract moisture from various materials through the process of heated air circulation which operates at temperatures between 40 – 90^{0}C (Ekka & Kumar, 2023)**.** The process uses heated air to remove moisture from products which results in weight loss, protecting product quality and maintaining its stability, this method uses a fan to

blow heated air over the product. It is not weather-dependent, allowing for year-round production, but requires significant energy input.

2.3.2.4 Difference between hot air and solar drying methods

Hot air drying method as described above is better than solar drying methods, because in solar drying methods the product being drying is simply exposed to sun with absence of product coverage which leads the product to be contaminated by dust, animals, rodents, insects and birds. But in hot air drying the above mentioned problems will not occur due to product being drying is in controlled environment (Kingphadung *et al.*, 2022). Some points Hot air drying method is better than solar drying methods due to the following reasons

- Hot air drying is done by indirect heat transfer in controlled environment; this leads to have clean hygienic dried product at end and it helps to dry products regularly consistently in rotation with no season interferences,
- Hot air drying has high efficiency and short drying time; since the hot air rotates through the product being drying by forced convection as adjusted temperature it dries the product very fast almost 5-6 times faster than solar drying methods.
- Hot air drying method has improved structural design; it has often specialized design to have maximum efficiency of drying,

But hot air drying method also requires high operational cost since it use electricity or fuel as energy sources.(Kingphadung et al., 2022)

2.4. Pre-drying Treatments and Importance

Great attention has been given to the prevention or minimization of quality degradation of vegetables during drying at a time (Fathi *et al*., 2022). Dried fruit and vegetable products contain an extensive collection of phytochemicals, such as vitamins, minerals, antioxidants, pigments and other bioactive compounds, associated with health benefits, however, phytochemicals become significantly degraded during drying since they are sensitive to heat, light and oxygen. Several nutrient losses occurred during dehydration being leached from the vegetable tissue with the water removal. Color changes also monitored since they can be directly related to the retention of pigment nutrients, such as carotenoids, chlorophylls and phenols. Different treatments can be applied before the

drying process to minimize nutrient losses and thus improve the nutritional value of dried vegetables (Khalida *et al.*, 2022). Fruits and vegetables usually pre-treated for extending the shelf life, preservation of flavor and color, minimization of nutrients loss, elimination of enzyme activity etc. (Adewoyin, 2023). Since tomato is one of the perishable foods, one way of producing dried products of tomato with good quality is using pre-treatments such as blanching.

2.4.1. Water blanching

Blanching is a unit operation applied on fruits and vegetables prior to drying in which fruits or vegetables are heated for the purpose of inactivating enzymes that are responsible for commercially unacceptable darkening and off flavors (Dar et al., 2022)**.**

There are different methods of blanching products like hot water blanching, hot air blanching, flowing steam and microwave treatment. Steam blanching is more effective than water blanching for the conservation of soluble nutrients. Blanching is the most popular treatment applied to vegetables prior to drying. If applied under optimal conditions, blanching improves the color, flavor, texture, nutritional quality and overall acceptability of dried vegetables. Different researchers investigate on blanching of vegetable for best time temperature combination where the indicator enzymes are inactivating for vegetable crops including tomato**.**

2.5. Quality Parameters of Tomato Affected During Drying

2.5.1. Drying kinetics

Drying kinetics is the study of rate of moisture removal from materials drying within specified time, which is characterized by an initial high moisture loss rate followed by constant-rate and falling-rate periods. The key factors that affect drying kinetics includes temperature, air velocity and thickness of material being dried((Delfiya *et al.*, 2022). . Determining the overall quality of dried products and prediction of the drying kinetics of the food products under various conditions are important for designing of the drying systems and for meeting quality specifications and energy conservation (Fathi et al., 2022). Physicochemical and sensory quality characteristics (color, flavor, texture and overall acceptances) of products can be influenced by drying.

2.5.2. Physical, chemical and nutritional properties

2.5.2.1. Physical parameters

2.5.2.1.1. Rehydration capacity

Most of the dried food products are rehydrated prior to consumption (Aravindakshan *et al., 2021)***.** It is considered as the percentage of the original weight gained by dried samples during rehydration for a given time at a given temperature in water which depends greatly on the porosity of the material being rehydrated. Rehydration is a diffusion process in which water moves from the outside of the cells into the interior part and the rehydration capacities of samples depend on the pretreatment as well as the drying process used. In dried products, rehydration behavior must be known to assure the acceptable properties of the rehydrated products (Ong *et al*., 2020)**.** Rehydration process involves two main cross-current mass fluxes, water flux from the rehydrating solution to the product and a flux of solutes from the food product to the solution. Rehydration behavior can be taken as a measure of the induced damage in the material during drying. The rehydration characteristics of the dried product are also influenced by the method of processing, sample constitution, preparation of the sample prior to rehydration and extent of the structural and chemical changes induced by drying.

2.5.2.1.2. Water activity

Water activity (a_w) is considered as one of the most important quality parameters for dried products especially for long term storage (Tapia *et al*., 2020)**.** It is related with moisture content and responsible for biochemical reactions in the product. It also affects the shelf life, safety, texture, flavor, and smell of foods. While temperature and pH factors can influence how fast organisms will grow in a product. Water activity is the most important factor in controlling spoilage; it predicts stability of product with respect to physical properties, rates of deteriorative reactions, and microbial growth. Foods containing proteins and carbohydrates are susuptable to non-enzymatic browning reactions called Maillard reactions**,** browning of product increases as the water activity increases in the range of 0.6 and more**.**(Lukinac *et al*., 2022)

2.5.2.1.3. Bulk density

Bulk density is defined as the ratio of weight of the powder to the volume of the powder in gram per centimeter cube(g/cm3) (Umoh & Iwe, 2023)**.** Bulk density indicates the

behavior of a product in food formulations, for instance, high bulk density is disadvantageous for the formulation of complimentary foods, but low bulk density is required in such type of formulations. It is an important parameter to determine the packaging requirement of a product, material handling and application in wet processing in the food industry. Bulk density is generally affected by the particle size and density of the powder.

2.5.2.1.4. Solubility

Water absorption capacity describes powder – water association ability under limited water supply. Tomato powder solubility nature is mainly depending on the drying method, which typically ranges between 17% and 90% (Kakar *et al*., 2022). Solubility gives an indication of the amount of water available for gelatinization. Water binding capacity is a useful indicator of powder incorporation ability into aqueous food formulations. Moreover, the water holding capacity could be a function of the protein composition, not only due to the hydrophilic and lipophilic groups exposed but also due to the physical entrapment of oil.

2.5.2.1.5 Moisture content

Moisture content refers to the percentage of water remaining in the tomato powder after a drying process (Bhatkar *et al.*, 2021)**.** This is a critical quality parameter, moisture content reduction results ensuring the product's microbiological safety, chemical stability, and extended shelf life, The moisture content of a tomato powder is typically measured as the loss in weight (expressed as a percentage) when the sample is dried to a constant weight under controlled conditions, often using a hot air oven at a specific temperature.

2.5.2.1.6 Total soluble solid

Total Soluble Solids (TSS) refers to the concentration of dissolved substances in a liquid, that includes sugars, salts, and organic compounds which is measured in degrees Brix (Adjovu *et al.*, 2023). It is an important parameter in food science and agriculture that used to indicate the quality and ripeness of fruits and vegetables, as well as influencing flavor and texture.

2.5.2.2. Chemical parameters

2.5.2.2.1. PH

The acidity or alkalinity nature of a food is usually expressed as pH (Raposa *et al*., 2022)**.** PH is an important parameter to assess the ability of a microorganism to grow in a specific food. The pH of a food can dramatically alter the growth of microbes in food. It is considered as safety indicator with combination of water activity, temperature and packaging of the food product. Yeasts and molds usually grow best between pH 4 and 6 and bacteria usually grow best at pH near 7. When we select a food preservation process that makes a food shelf stable, the initial pH of that food must be considered to minimize the likelihood of bacterial growth in that food.

2.5.2.3. Nutritional parameters

The dried form of fruits and vegetables including their products are good sources of energy, minerals and vitamins (Jayaraman & Gupta, 2020). However, at the time of dehydration process, there are changes in nutritional quality. A more number of vitamins such as vitamin A, C and lycopene are sensitive to heat and oxidative, near 80% of the carotene content decrease in some vegetables, if they are dried without enzyme inactivation, but if the product to be dried is adequately blanched then carotene loss can be reduced to 5%, Steam blanching retains higher amounts of vitamin C in spinach compared with hot-water blanching.

Table 3: Some nutritional components of dried products and their change during drying

Source; (Solchansanj & Jayas, 2020)

Type of nutrients	Possible changes
Calories content	Does not change, but is concentrated into a smaller mass as moisture is removed
Vitamin A	Fairly well retained under controlled heat methods
Vitamin C	Mostly destroyed during blanching and drying of vegetables
Thiamin ,riboflavin and niacin	Some losses during blanching but fairly good retention if water is used to dehydrate is also consumed
Minerals	Some maybe lost during rehydration if soaking water is not used. Iron is

	not destroyed during drying.
Protein	Can undergo heat denaturation, susceptible to light oxidation and may undergo enzymatic degradation
Lipids	May undergo enzymatic hydrolysis in the initial phase of drying. At low water activity
Carbohydrate	Millard browning and changes in flavor under high heat. Sugar can be caramelized and give darker color to dried product

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2.5.2.3.1. Vitamin C

Vitamin C or ascorbic acid is an essential exogenous nutrient, mainly available from fruits and vegetables that play significant role in human development and health (Ding *et al., 2021)***.** Mainly vitamin C used to tissue formation and maintenance, immune system stimulation and works as antioxidant. All drying methods significantly cause loss of vitamin C which shows the fact that vitamin C is highly susceptible to oxidative destruction in the presence of heat, light, oxygen and enzymes (T. A. Bhat *et al*., 2022)**.** More loss of ascorbic acid observed in sun dried un blanched samples compared with cabinet dried blanched sample after 3 months of storage.

2.5.2.3.2 Lycopene content

Lycopene content in tomato powder refers to the concentrated amount of antioxidants (a carotenoid) within the dried product, which often ranging from tens to hundreds(10 to 100) of milligrams per gram (mg/g)**,** the amount of lycopene is significantly higher in dried product than fresh tomatoes due to dehydration, it provides intense color, antioxidant power, and health benefits like heart protection (Wambugu, 2020)

2.5.2.3.3 Ash content

Ash content in tomato powder refers the total amount of minerals remaining in the powder after the organic matters had been completely burned away, which is typically done using muffle furnace at high temperature(550^0C). Ash content is a critical indicator of the total mineral contents, including essential minerals like potassium, calcium and magnesium. Ash content used to assess the quality, purity, and nutritional composition of the tomato powder (Farooq *et al*., 2020)

Overall parameters studied

Physicochemical parameters

- Moisture content
- Water activity
- Rehydration ratio
- Solubility
- Density
- Total soluble solids (TSS)
- Vitamin C
- Ash
- PH
- Lycopene content

Sensory properties

- Colour
- Flavour
- Texture
- Overall acceptability

3. MATERIAL AND METHODS

3.1. Description of Experimental Site

The study was conducted at FDRE Technical and Vocational Training Institute (FTVTI) and Addis Ababa University (4 kilo campus) and Addis Abeba Sceince Technology University (AASTU) food Science and Postharvest Technology Laboratory. The drying experiment was conducted in dehydrator hot air dryer which found under department of fruit and vegetable processing laboratory in FTI. Whereas the laboratory analysis for water activity, moisture content and vitamin c in (AASTU) and the remainder lycopene content was done at postharvest physiology and food analysis laboratories of Addis Ababa university 4 kilo laboratories respectively.

3.2 Raw material

The Roma VF tomato variety was collected from Holeta Agricultural Research Centre. Fruits which have uniform size, color, and free from any type of damage or fungal were used. The reasons to select Roma Vf tomato for tomato powder making is that it has a dense flesh and lower moisture content compared to other varieties, flavour production; they have a rich sweet flavour that intensifies during drying resulting a more flavourful powder, uniform shape: Their oval shape makes them easier to process and slice uniformly, versatility: Roma tomatoes are commonly used in sauce, pastes and powders which makes them a popular choice for processing(Das & Sharangi, 2020)**.** It was washed in water, fruits having the same shape; color and texture were collected with considering that the selected fruits have similar genetic makeup and maturity status. The collected tomatoes grow in similar agronomic condition.

3.3. Experimental Design

The experiment was laid as 3X4 factorial combination arranged in complete randomized Design (CRD) and replicated three times in 36 experimental units. The drying temperature was varied in three levels (50, 60 and 70 ^{o}C) and blanching time of three levels with control levels (0, 30 ,60 and 120 seconds with blanching water that hoted at 95 ^{0}C.

Experimental Layout

Blanching time(second	Initial weight(g)	Drying temperature			Replication
		50 ^{0}C	60 ^{0}C	70 ^{0}C	
0	1000	B0T50	B0T60	B0T70	3
30	1000	B1T50	B1T60	B1T70	3
60	1000	B2T50	B2T60	B2T70	3
120	1000	B3T50	B3T60	B3T70	3

3.4 Pre-treatments of Tomato

The experiment was performed by selecting Roma VF tomato variety, with the weight of 1 kg for each trial and total of 40.5kg. Then the selected tomatoes were washed with 3 Liter tap water for each trial. The clean tomatoes were blanched using 2.5 Liter hot water at 95 ^{0}C using thermometer for each trial, with blanching time of 0, 30, 60 and 120 seconds then peel the blanched tomato properly and slice it with 4mm thickness uniformly using a vegetable slicer(anthem wave tomato slicer item T420 high carbon stainless steel) (Dar *et al.*, 2022).

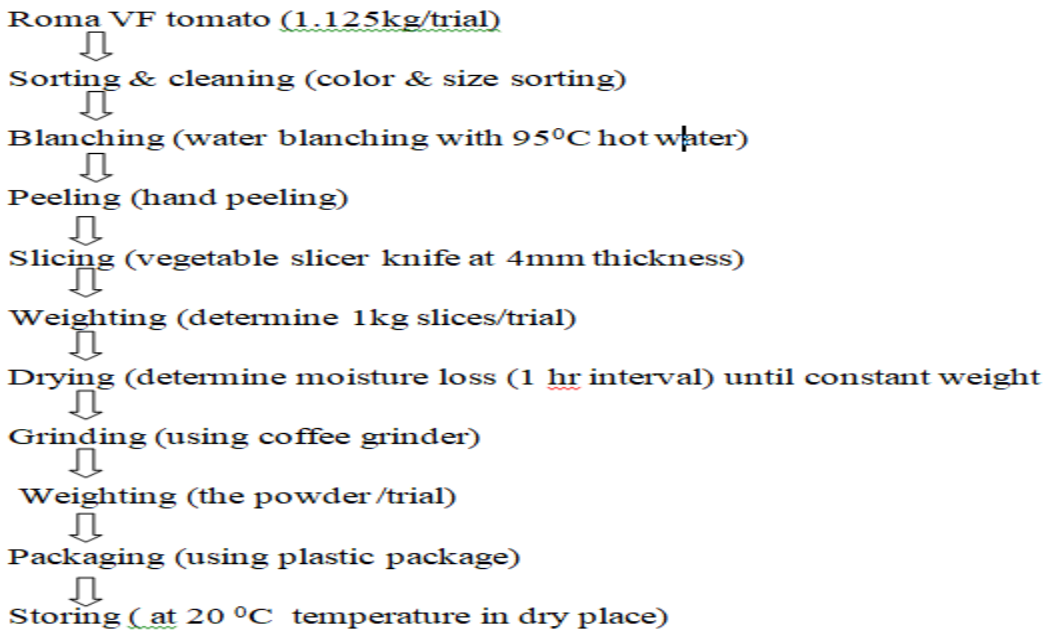


Figure 1 : Flow diagram of sample preparation for drying tomato

3.5 Hot air Drying Process.

One kilogram (1kg) of each blanched samples were placed randomly in the four layers of hot air oven dryer (model of CS950-E-03) for each drying temperatures. The slices were measured and evenly distributed on hot air oven drying trays, after the dehydrator becomes hot enough and tested by thermometer to check the temperature become 50, 60 or 70^0C accordingly the slices would insert and beginning to dry (Nadir, 2024). For drying kinetics determination independent representative samples were placed on small wire mesh and weighed using digital balance with $\pm$ 0.1 sensitivity at the beginning of drying and continue recording in every 1 hour intervals until constant weight was achieved, after the sample has gained constant weight and dried enough, ground into powder using grinder(multi-functional coffee & condiment electric grinder) then packed in polyethylene bags and stored at ambient atmospheric condition during the study period.

3.6. Data Collected

3.6.1 Drying ratio

Moisture Ratio (MR) is a dimensionless parameter used to describe the change in moisture content of a material over time relative to the total moisture change possible under specific drying conditions. It represents the ratio of the driving force for moisture removal at any time.

Moisture Ratio (MR) was calculated using Eq.7

$$Moisture\ ratio = \frac{Mt}{Mi} \ldots\ldots\ldots\

3.6.2. Physical attributes

3.6.2.1. Moisture content determination

Moisture content is the amount of water that remained in the dried Roma VF tomato powder that can affect the shelf life and texture of the powder. Knowing moisture content for oven-dried tomato powder is very crucial in quality control and also in product consistency. Tomato powder moisture content was determined using AOAC 925.10 (1925). The weight loss was used to calculate the moisture content. The clean and dry container was weighed and 5g of tomato powder placed in it. The sample was dried in hot air oven (moisture and Rh testing ovens member USA) at a temperature of 105°C for 5 hours until constant weight is achieved. It was then cooled in a desiccator for 45 minutes which allows the sample to reach at room temperature and then weighed again.

Moisture content was calculated using Eq 1

$$\boldsymbol{Moisture\ Content}(\%) = \frac{(\boldsymbol{Initial\ Weight - Final\ Weight})}{\boldsymbol{Initial\ Weight}} * \mathbf{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{1})$$

3.6.2.2. Water activity

Water activity is the ratio of vapor pressure of water in a substance to that of pure water under the same condition. It was measured using a water activity meter (water activity measurement thermo fisher –AU)**.** Weigh 10 g of tomato powder and put in a dry and clean smaller airtight container, the container was tightly sealed and allowed to stand at room temperature for about 1 hour to ensure that the powder has equilibrated with the air present in the container, turn on the water activity meter(hygrometer) and calibrate it, open the sample holder sealed container and the probe of the hydrometer quickly insert to the sample and closed the container, recorded the reading on the hygrometer in 3 minutes then repeat two times and then the average was taken (Reid, 2020)

3.6.2.3. Rehydration ratio

The rehydration ratio of tomato powder is critical in determining the water absorption capacity of the powder for recovery of its original texture and flavor after drying. Prepare and weigh 10g of tomato powder accurately and mix with 250 ml distilled water at 25 degree centigrade- the controlled temperature was used. Then weighing of the rehydrated sample was done for its weight after hydration. Rehydration capability is expressed in

terms of the weight rehydrated samples against the dried one (KAUSHAL, 2025) .The rehydration ratio was calculated using equation 2.

$$\text{Rehydration ratio} = \frac{weight\ of\ rehydrated\ sample}{weight\ of\ dry\ sample} \quad \ldots\ldots\ldots\

minutes to settle, un dissolved solids were separated by centrifugation at low speed. The solution was filtered through fine mesh (0.1mm diameter) to obtain the clear liquid; the refractometer was calibrated with distilled water, following the manufacturer's recommendation. A small (2 droplets) of the clear filtrate is placed onto the prism of the refractometer and closed the cover then TSS value read through the eyepiece towards light that was indicated in degrees Brix (°Brix).The TSS value directly obtained with the refractometer was the total soluble solids present in the extract of tomato powder.

3.6.3 Nutritional attributes

3.6.3.1. Vitamin content

Vitamin C content in tomato powder was determined using the spectrophotometry method (Ahmed *et al.*, 2020) The materials included a sample of tomato powder; 0.1% metaphosphoric acid solution (for extraction); a standard ascorbic solution for calibration; centrifuge and filtration facilities. 1g of tomato powder was weighed and dissolved in 10 mL of 0.1% metaphosphoric acid solution. This solution is prepared to stabilize the ascorbic acid to avoid its oxidation during the extraction process. Mixing of this solution was carried out vigorously, employing using homogenizer, to ensure complete extraction. The mixture was subjected to centrifugation at about 3000 rpm for 10 minutes, allowing separation of solid residues. The collected supernatant contained the extracted vitamin C was subjected to further analysis. Quantification: The standard ascorbic acid solutions were used to set up the calibration curve. The absorbance was taken by reading the supernatant at 265 nm using a spectrophotometer. The standard curve was subsequently used to calculate the vitamin C content in the sample. instruments named as UV-Vis NIRCLB was used then prepare 100ppm stalk solution , 0.1 molar HCL(used to dilution purpose / to make vitamin c in form of solution b/c vitamin C formally occurred in solid form as salt, then prepare 5ppm, 10ppm, 15ppm, 20ppm and 25ppm solution in which the sample will arrive among them. The black solution used which helps the machine to read only vitamin C:

3.6.3.2 Ash content

The ash content is often determined through the incineration of a known weight sample at high temperatures and measuring the residue left, which is indicative of the inorganic material (Farooq *et al.*, 2020). 5g of tomato powder weighed $W1$ (weight of the sample),

then taken to a clean and dry crucible and was put in an oven at a temperature of 550^0C for 4 hours to convert the sample to ash until a homogeneous gray or white ash resulted. Then the ash sample was allowed to cool for 45 minutes**,** Weighed the ash with the crucible (weight of the ash), ash content was calculated by using the equation 5.

$$\textbf{Ash content}(\%) = \frac{\textbf{Weight of ash}}{\textbf{Weight of sample}} * \textbf{100} \ldots\ldots\ldots\

3.6.4. Chemical properties

3.6.4.1. PH *level*

The pH level of tomato powder had been measured by the electrometric method (pH meter) (Hossain *et al*., 2021). Six gram of sample was weighed and added to distilled water using a ratio of 1:10 (6g of powder in 60 mL of water). The mixture was stirred well for 30 minutes in order to be fully hydrated. The standard buffer solutions were used to calibrate the pH meter for setting of pH 4.00 and pH 7.00. Then the slurry pH was measured using the calibrated pH meter.

3.6.5. Sensory attributes

3.6.5.1: Color

Color of Roma VF tomato powder was evaluated by a Hedonic Scale *(Owureku-Asare et al.,* 2022*),* 100 grams representative powder was prepared. Fifteen (15) semi trained panelists who are familiar with tomato products were selected. It was ensured that they understood the purpose of the study and the hedonic scale. A scale called the Hedonic series was developed to judge the color. Ratings for judgment range from 1, denoting extreme dislike, to 7, denoting extreme like: 1-extremely dislike: 2-moderately dislike: 3-slightly dislike: 4-neither like nor dislike: 5-slightly like; 6-moderately like: 7-extremely like. The evaluation of samples was carried out according to hedonic scale ranging from 1-7. The tomato powder samples were given to the panelists in a controlled environment: consistently illuminated, to eliminate bias. They were asked to evaluate the color of each sample using the hedonic scale. These qualitative data would be complementary to the quantitative data generated. The scores from all panelists for each sample were compiled. Mean scores and standard deviations were calculated to summarize the data. The statistical analysis (ANOVA) was performed on it to find significant difference among the samples.

3.6.5.2: Flavor

Flavor was determined by using a 7-point hedonic scale which involved a structured sensory evaluation process. The hedonic scale allowed participants to express their preferences for the flavor of the product (Jeyaprakash *et al.*, 2020) One tablespoon of tomato powder (6g) weighed and mix with 18 ml distilled water(1:3 ratio) of powder to distilled water prepared for one minute, a panel of 15semi trained panelists who were

familiar with tomato products were selected. A hedonic scale was created specifically for flavor evaluation. Using the 7-point hedonic scale which ranges from 1 for extreme rejection and ends at 7 for extreme acceptance: 1=dislike extremely, 2=dislike moderately, 3=dislike slightly, 4=neither like nor dislike, 5=like slightly, 6=like moderately, 7=like extremely. Keep the mixture prepared in uniform environment, Panelists evaluated the flavor of each of the samples according to a hedonic scale and were invited to provide qualitative feedback on their flavor perceptions, including some specific descriptors of aroma. The ratings given by all the panelists to all samples were collated together. The mean score along with their corresponding standard deviations were calculated to present this data..

3.6.5.3: Texture

The texture was determined using 7 point hedonic scale. Twenty (20) grams of tomato powder was weighed. Based on the fact that the texture of powdered products could be influenced by size distribution, sieve analysis was used to reduce particle size effects in the tomato powder. The smaller particles were determined to contribute smoothness whereas larger particles were said to contribute a grainy mouth feel. The typical 7 point hedonic scale was employed (1 = dislike extremely to 7 = like very much). This method involved 15 semi trained panelists, the panelists' describing specific textural attributes such as smoothness and graininess (among others) with standardized terminology.

3.6.5.4: Overall acceptance

Overall acceptance of tomato powder was determined by using a 7-point hedonic scale, which allowed panelists to express their preferences for the overall acceptance of the product (Jeyaprakash *et al.*, 2020) One tablespoon (6g) tomato powder was weighed for each sample and mixes with 18 ml of distilled water in range of 1:3 ratios for tomato powder and distilled water. The methods were consistent with respect to drying and storage. A panel of 15semi trained panelists who were familiar with tomato products was selected. A hedonic scale was created specifically for overall evaluation using the 7-point hedonic scale which ranges from 1 for extreme rejection and ends at 7 for extreme acceptance: 1=dislike extremely, 2=dislike moderately, 3=dislike slightly, 4=neither like nor dislike, 5=like slightly, 6=like moderately, 7=like extremely. The samples were kept in a controlled setting that every sample was subjected to similar environmental

conditions. Panelists evaluated the overall acceptability of each of the samples according to a hedonic scale, and were invited to provide qualitative feedback on their overall perceptions. The ratings given by all the panelists to all samples were collected together. The mean score along with their corresponding standard deviations were calculated to present this data.

3.6.6. Data analysis

Minitab software package (version 22) used to analysis the collected data. Data collected from sensory evaluation regarding with color, flavor, texture and over all acceptances were analyzed using Minitab software. All data has been using two factor analysis of variance (ANOVA) The Minitab multiple range tests were used to establish the multiple comparisons of mean value. Mean value has been considered at 5% significance level. ($P< 0.05$). Significant treatment means were separated using the turkey multiple comparison test at 5% level (Kenett & Zacks, 2021)

4. RESULT AND DISCUSSION

4.1 Effect of blanching time and drying temperature on Drying Characteristics

Drying behavior of tomato powder was studied by analysis of patterns of moisture loss obtained from three drying temperature zone and four blanching time.

4.1.1. Effect of blanching time and drying temperature on drying kinetics of tomato powder.

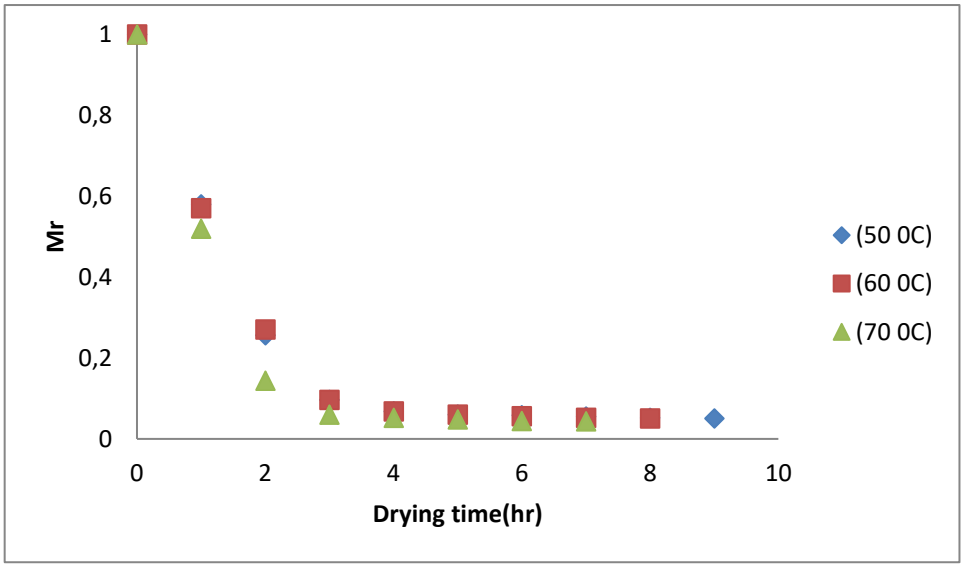
Drying kinetics refers to the study about rate of moisture removal during the drying process of food materials. Fig2. Depict the influence of drying temperature and blanching time on the drying kinetics of tomato slices. The drying behavior of tomato slices at 50 °C, 60 °C, and 70 °C under constant blanching time demonstrates a distinct temperature-dependent pattern. At 50 °C, moisture removal is relatively slow, with the drying curve showing a gradual decline indicative of diffusion-controlled water migration, thereby extending the overall drying duration. In contrast, at 70 °C, drying proceeds much more rapidly, characterized by a sharp initial reduction in moisture content and the shortest time to reach equilibrium. The finding aligned with the report of Delfiya et al. (2022) increasing drying temperature enhances moisture loss from the product (Delfiya *et al.*, 2022).

Temperature affects the drying kinetics of tomato slices being drying, because it controls moisture evaporation rates and the efficiency of drying itself. Those findings indicate that from all drying kinetics being regarded-the experimental drying curves were made for various wide tomato slices being dehydrated at three temperature levels of 50, 60, and 70^0C, using a constant slice thickness of 4 mm with blanching time of 0 ,30 , 60, and 120 seconds respectively.(Bhatkar et al., 2021). At the three drying temperatures tested, drying treatment at high temperature (60 ^{0}C and 70 ^{0}C) registered a higher drying rate compared to 50 ^{0}C. The drying kinetics curves showing the changes in moisture ratio of pre-treated tomato with time at the three drying temperatures of the dryer as indicated in figure 2, According to the results the blanching time has some effect on the moisture removal of the tomato samples as expected. Among the three blanching time and control, the sample dried at 70°C shows fast removal of moisture in all cases, and as drying

temperature slows down to 50^0C rate of moisture removal has been reduced. Even if blanching has no more significant role on moisture removal, but somewhat it had effects on other physicochemical properties.

Table 4; the effect of temperature and blanching time on moisture ratio tomato slices

Blanching (second)	tempretu re(0C)	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr	7 hr	8 hr	9 hr
0	50	0.58	0.256	0.096	0.068	0.06	0.058	0.055	0.052	0.05
30	50	0.57	0.25	0.088	0.068	0.06	0.056	0.052	0.05	
60	50	0.58	0.26	0.084	0.072	0.064	0.06	0.057	0.055	
120	50	0.58	0.25	0.092	0.07	0.062	0.052	0.049	0.047	
0	60	0.57	0.27	0.096	0.068	0.06	0.056	0.052	0.05	
30	60	0.55	0.26	0.08	0.06	0.052	0.048	0.047		
60	60	0.57	0.27	0.092	0.064	0.054	0.051	0.049		
120	60	0.544	0.27	0.096	0.064	0.052	0.048	0.047		
0	70	0.52	0.144	0.06	0.052	0.048	0.044	0.043		
30	70	0.59	0.23	0.084	0.056	0.052	0.052			
60	70	0.63	0.27	0.12	0.054	0.051	0.05			
120	70	0.56	0.2	0.08	0.052	0.048	0.047			



Fig,2 The effect of Temperature without blanching on drying kinetics of tomato slices

B0,T1,T2,T3

B0= no blanching, B1= blanching at 30 seconds,

B2= blanching at 60 seconds, B3= blanching at 120 seconds

Mr= moisture ratio

The drying kinetics data provided shows the weight of tomato slices being dried over temperature 50°C under different blanching times (0, 30, 60 and 120 seconds). Each trial starts with initial weight of 1000 grams and measures the remaining weight at intervals from 1 hour to 9 hours. The weights decrease steadily over time for all treatments, indicating that moisture is being lost as the drying process progresses that are supported by Jimoh *et al,* (2023) who said at the time of drying agricultural products moisture loss occur through phase change during the drying process and the rate of moisture loss depend on temperature (Jimoh *et al.*, 2023). By the end of the 9-hour period, the weights are significantly reduced, with all treatments showing a final weight of near 47-51 grams. The drying kinetics data provided for tomato slices being dried at a temperature of 60°C under different blanching times (0, 30, 60 and 120 seconds). Each treatment starts with an initial weight of 1000 grams and measures the remaining weight at intervals from 1 hour to 8 hours. The weights has been decreased significantly over the drying period, which indicated there was effective moisture loss as time progresses, which is supported by Yi *et al*(2020) who said as drying temperature increase loss of moisture from the material being dried also increase even if the amount of moisture lose reduces through time and its impact on water loss and structural changes during the drying period *(Yi et al.*, 2020). By the end of the 8-hour drying process, all treatments show a final weight of 47.6- 51.5 grams:

The drying kinetics data provided for tomato slices being dried at a temperature of 70°C under different blanching times (0, 30, 60 and 120 seconds). Each treatment begun with an initial weight of 1000 grams and measures the remaining weight at 1 hour intervals up to 7 hours. The weights decrease significantly over the drying period, indicating effective moisture loss as drying temperature and drying time increase which is supported by Yi *et al* (2020) who said as drying temperature and drying period increase loss of moisture from the material being dried also increase even if the amount of moisture lose reduces

through time and its impact on water loss and structural changes during the drying period(Yi *et al*., 2020) .By the end of the 7-hour drying process, all treatments show a final weight of 43.8-52 grams. The pattern of drying curve for 0, 30, 60 and 120 second blanched tomato slices dried at the three drying temperature was almost the same, which is supported by Tilahun Dufera et al(2022),that states while drying temperatures and methods of drying significantly affect moisture removal rates, but treatments can lead to similar outcomes in terms of final quality and moisture loss efficiency (Tilahun Dufera *et al*., 2022). The moisture removal was rapid at in the first one up to four drying hours, and it takes short time to reach a constant weight at 70ºC drying temperature. The reason behind that was its average temperature (70^0C) is high than others, but the drying environment for the three drying temperature was the same. In the contrary drying temperature 50ºC takes more time to reach at constant weight, since rate of moisture lose and heat has inversely proportional(Bradford *et al*., 2020).

4.2 Main effect of drying temperature on physicochemical properties of tomato powder.

Analysis of variance indicated that, higher drying temperatures (50°C to 70°C) show minimal overall impact on most physicochemical properties, with selective declines in heat-sensitive components like solubility, vitamin C, and pH, while ash content slightly increases,

4.2.1 Density

It is one of the physical properties explained as mass of an object to volume of itself. The highest amount of density was recorded at drying temperature of 70 °C due to volume reduction and the lowest was at 50 °C due to volume increment occupied by water which is aligned with research done by Hossain et al 2021 that states temperature has significance effect on density of agricultural products (Hossain et al., 2021). The effect of drying temperature on density of tomato powder had a significant difference ($P<0.05$) on all the three levels of drying temperature as indicated in ANOVA table 13, the F and P values gain are 6.51 and 0.006 respectively, which indicates significance level. Which is supported by research done by Hossain et al 2021 that states temperature has significance effect on density of agricultural products(Hossain *et al*., 2021). The research results obtained through ANOVA shows that the higher drying temperatures

increased the density of dried tomato powder. The mean density at 70^0C (0.5075) is significantly higher compared with those of mean densities at 60^0C (0.4808) and 50^0C (0.4733). The reasons for this fact are that higher temperature allowed a greater collapse and shrinkage of structure during moisture removal, thus resulting in denser material with lower porosity which results high density. It is better to select 70°C than that of 60 and 50^0C for higher density tomato products, to enhancing shelf stability and packaging efficiency, even though balances against potential quality degradation.

4.2.2 Water activity (Wa)

Water activity is the amount of unbounded or free water in the substance, the highest amount of water activity was recorded at 50°C due to lots of water retain and the lowest water activity was recorded at 70°C drying temperature due to los of water from substance, but almost equivalent since the drying time also varies as drying temperature which is supported by research done by Kaur et al (2020) that states even water activity mainly dependent on drying temperature and drying time. The specific effect of drying temperature on water activity of tomato powder significant at any of the three drying temperatures even if held near ~0.35 as indicated in ANOVA table 14. Tukey's pairwise comparisons suggest that all three temperatures can be categorized as belonging to one category (50°C: 0.351, 60°C: 0.348, 70°C: 0.345 wa) without any appreciable differences. The low Water activity values approaching 0.35 across different conditions guarantee microbial stability regardless of temperature which is supported by Kaur et al (2020) that states that water activity as the most crucial factor influencing microbial growth meaning as water activity increases the growth of microorganisms also increases (Kaur *et al.*, 2020)

Table 5: The effect of temperature on physicochemical properties of tomato (explained using mean and standard deviation)

Temperature	Dependent variable									
	Mc (%)	Wa	Rr	Solubility(%)	Density(mg/cm^3	Tss (^{0}B)	Ph	Ash(%)	Vita.C (mg/100g)	Lycopene (mg/100g)
50 °c	9.78±0.16aa	0.35±0.09 ^{a}	4.4±0.4 ^{a}	82.4±0.95 ^{c}	0.48±0.36 ^{b}	5.2±0.1 ^{c}	4.36±0.1 ^{a}	14.27±0.17 ^{c}	23.9±0.8 ^{a}	28.4±1.5 ^{a}
60 °c	9.56±0.07ab	0.35±0.08^a	3.62±0.31 ^{b}	80.5±0.08 ^{b}	0.47±0.06 ^{b}	5.4±0.1 ^{b}	4.19±0.07 ^{b}	14.5±0.2 ^{b}	22.3±0.89 ^{b}	28.9±1.3 ^{b}
70 °c	9.66±0.2b	0.26±0.16^a	2.97±0.27 ^{c}	80.23±0.17 ^{b}	0.38±0.23 ^{a}	5.6±0.23 ^{a}	4.15±0,1 ^{b}	15±0.3 ^{a}	20.0±0.99 ^{c}	29.6±1.5 ^{a}

4.3 Main effect of blanching time on physicochemical properties of tomato powder.

As analysis of variance indicates, blanching time(0, 30, 60 and 120 seconds has minimal overall effects on most physicochemical properties, with slight declines in rehydration ratio, vitamin C, and lycopene, while solubility peaks briefly at 30 seconds.

4.3.1 Water Activity (Wa):

The effect of blanching time on water activity of tomato powder had none significant difference (P>0.05) on all the three levels of blanching time with control as indicated in ANOVA table 14 at which the highest and lowest result is almost 0.35, in which F-value of 1.39 for blanching time with a P-value of 0.270 exceeding 0.05 indicates that it does not exert a significant effect on water activity. Practically, changing blanching time in this range does not materially alter water activity of tomato powder; control of water activity must rely more on other process conditions like temperature and storage in contrary of research done by Kaushal et al(2025) that states on the convective hot air drying of potato flakes, there is a clear relationship between blanching time and the final moisture properties of the product(KAUSHAL, 2025)

4.3.2: Density

The effect of blanching time on density of tomato powder had none significant difference (P>0.05) on all the three levels of blanching time as indicated in ANOVA table 13, on which the highest and the lowest density was recorded near 0.49, The F-value corresponding to blanching time is 0.72 with a P-value of 0.552 which is more than the threshold of 0.05-which implies that the length of blanching had no significant effect on bulk density. According to the Turkey results, all blanching durations (0, 30, 60, 120 seconds) were placed under the same group A with very similar mean densities (0.48-0.49 g/mL), claiming that no statistically distinct differences between times could be observed. Practically, within the tested range, modifying blanching time does not materially change the density/packing behavior of tomato powder; process adjustments to density should focus more on drying temperature than on blanching duration, in contrary of research done by Jorge et al (2018) which states increasing blanching time can lead to a decrease in bulk density and an increase in true density in dried products. This effect is attributed to increased cellular disruption and improved porosity, which aids moisture diffusion during drying(Jorge *et al.*, 2018).

Table 6: Effect of blanching time on physicochemical properties of tomato powder (explained using mean and standard deviation)

Blanching time (seco)	Dependent variable									
	Mc(%)	Wa	Rr	Solubility(%)	Density(g/cm^3	Tss(°Brix)	Ph	Ash (%)	Vita. C(mg/100g)	Lycopene Mg/100g)
0	9.8 ± 0.24 [a]	0.24±0.18 [a]	3.87±0.8 [a]	80.68±0.76 [b]	0.31±0.23 [a]	5.5±0.36 [a]	4.2±0.15 [a]	14.7±0.24 [a]	22.4± 1.8 [a]	29.8±1.8 [a]
30	9.64 ± 0.14 [a]	0.35±0.08 [a]	3.76±0.64 [a]	81.4±1.4 [a]	0.5±0.02 [a]	5.34±0.13 [a]	4.27±0.12 [a]	14.5±0.33 [a]	22.1± 2.1 [a]	28±1.2 [b]
60	9.6 ± 0.96 [a]	0.35±0.07 [a]	3.6±0.63 [a]	81.3±1.3 [a]	0.5±0.02 [a]	5.39±0.16 [a]	4.2±0.1 [a]	14.5±0.5 [a]	21.78 ±2.0 [a]	28.2±1.9 [ab]
120	9.6 ± 0.94 [a]	0.35±0.05 [a]	3.48±0.7 [a]	80.9±0.74 [b]	0.5±0.03 [a]	5.37±0.15 [a]	4.3±0.14 [a]	14.69± 0.52 [a]	22.1± 1.45 [a]	27.4±1.8 [b]

4.4 Interaction effects of drying temperature and blanching time on physicochemical properties

B*D=blanching time*Drying temperature

The interaction effect of blanching time (B) and drying temperature (T) demonstrates that while blanching prepares the tissue structure, the drying temperature acts as the primary driver for nutrient loss and physical concentration(Jorge *et al.*, 2018). As analysis of variance indicated, The interaction between blanching time (0, 30, 60 and 120seconds) and drying temperature (50, 60 and 70°C) reveals synergistic effects on physicochemical properties, where higher temperature amplifies blanching-induced changes, particularly reducing rehydration ratio and vitamin C while stabilizing others.

4.4.1: Moisture content

Blanching time and drying temperature have significant effect on moisture contents of tomato powder ($P < 0.05$) for all three drying temperatures and three blanching times with control as indicated in ANOVA table 12,at which the highest was recorded at 0 second blanching time and 50 ^{0}C drying temperature due to low hot air and the lowest was recorded at 60 second blanching time and 70 ^{0}C drying temperature due to high thermal energy and cell destructions which is supported by Cheng et al (2015) that states blanching and drying temperature have significant impact on moisture retention in yam flours through different mechanisms(Cheng *et al.*, 2025). At 95% confidence level, treatments collected in three groups (A, B, C). Group A comprehended only the lowest drying 50ºC combinations (9.86% at 0 second; 9.83% at 30 seconds), indicating that these retained more moisture without blanching or only short blanching at mild heat. Group B had transitional means (around 9.56-9.71%), over all levels at 50ºC plus early entries up to 60-70ºC with C grouped, the lowest means (9.54-9.55%) are respectively associated with longer blanch times (30 to 120 seconds) during which higher temperatures (60-70°C) were maintained. Moisture decreases with an increase in the temperature; however, time of blanching can affecting drier over the longer period of time: 0 second blanching time at 70 °C (9.57-9.56%) is sustained, while blanching promotes drying efficiency at 60 °C-70°C by striking the moisture content about 0.1-0.3% lower than at 50 °C. Non-overlapping letters (like A for 0 second/50°C only)

confirm that significant differences exist from C-group treatments like 120 seconds/70°C.

Most crucial interactions suggest blanching before drying to higher temperature (>60°C) optimizes moisture reduction for stable shelf-life of tomato powder, while rest at lower moisture (~9.54%) minimizes microbial risk without excessive heat degradation. It further states less blanching or no blanching at 50 °C retains excess moisture if rehydration is desired. Moisture content remains stable (~9.5-10%) across all combinations, with minor elevations at blanching time 0 with drying temperature 70 ^{o}C.

4.4.2 Rehydration ratio

Blanching time and drying temperature significantly affects rehydration ratios of tomato powder at all levels of drying temperatures and blanching times adopted for the study ($P<0.05$) as indicated in ANOVA table 15 at which the highest was recorded at 0 second blanching with 50 ^{0}C drying temperature due to low cellular damage and the lowest was recorded at 120 second blanching time and 70 ^{0}C drying temperature due to high cellular damage which is supported by Degwale et al(2022) that states both dehydration temperature and blanching time significantly impact the rehydration ratio (Degwale *et al.,* 2022) .Turkey analysis with a 95% confidence level had indicated significant interaction effects of blanching time and drying temperature on rehydration ratio of tomato powder ($p<0.05$) with separation into five distinct groups (A-E) from an average of 12. Multiple letters per treatment (e.g. 0 second/50°C solely A at 4.67; 120 seconds/70°C solely E, at 2.80) suggest that the difference observed in pairwise comparisons exceeds the minimum threshold for significance, which implies that the two-way ANOVA interaction term itself is significant (typically $p<0.05$ for Turkey post-hoc).that is supported by Degwale et al(2022) that states both dehydration temperature and blanching time significantly impact the rehydration ratio (Degwale *et al.*, 2022) Maximizing the ratio with 0 to 30 seconds of blanching at 50°C(>4.4); Accept ~15-40% loss with faster drying (70°C) to trade for better rehydration in the efficiency of the instant powder application. There is a compounding negative effect on the Rehydration Ratio (Rr). The highest rehydration is found at blanching 0 second with temperature (50^{0}C (4.66), while the lowest is at blanching 120 second with temperature 70 ^{o}C (2.82).

This indicates that the structural "case hardening" caused by high drying temperatures is degraded when the tomato tissue has been weakened by prolonged blanching. Rehydration ratio declines with both factors, strongest at longer blanching/higher Temperature. (e.g., 4.66 at B0T1 to 2.8 at B3T3), due to cumulative tissue damage.

4.4.3: Solubility

The effect of blanching time and drying temperature on solubility level of tomato powder had been significant difference ($P<0.05$) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 16 at which the highest was recorded at 30 second blanching time and 50 ^{0}C drying time due to less damage on porosity and the lowest was recorded at 60 second blanching time and 70 ^{0}C drying temperature due to gelatinization nature which is supported by research done by by Kaushal (2025) that states in a study on potato flakes dried by convective hot air, Kaushal et al. concluded that blanching time and drying temperature are key factors affecting the final product's physical and structural properties, which influence its solubility and rehydration characteristics(KAUSHAL, 2025).

Blanching time and drying temperature show mild interaction effects on tomato powder solubility, with Turkey groupings (A-D) at 95% confidence indicating some significant differences among the 12 means (83.27% to 80.33%), though many overlap in group D. Low temperature (50°C) supports higher solubility, moderate blanching is better, if excessive blanching may degrade soluble materials, which is supported by Kaushal (2025) that states in a study on potato flakes dried by convective hot air, Kaushal et al. concluded that blanching time and drying temperature are key factors affecting the final product's physical and structural properties, which influence its solubility and rehydration characteristics(KAUSHAL, 2025). Higher heat (70°C) uniformly lowers solubility by ~3%, like protein denaturation, preferred blanching time is 30 to 60 seconds at 50°C for solubility that peeks (>83%) in functional powders; solubility peaks at drying temperature 50 ^{0}C (~81-83%) regardless of blanching, dropping to ~80% at higher temperature with weak interaction.

4.4.4: TSS

The effect of blanching time and drying temperature on TSS of tomato powder had been significant (P<0.05) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 17 at which the highest was recorded at 0 second blanching time and 70 ^{0}C drying temperature due to, high loss of moisture and the lowest was recorded at 60 second blanching time and 50 ^{0}C drying temperature due to availability of moisture which is supported by Kaushal (2025) that states on convective hot air drying of potato flakes do not identify significance level of total Soluble Solids (TSS)(KAUSHAL, 2025). Blanching time and drying temperature exhibit a mild interaction effect on total soluble solids (TSS) in tomato powder, as indicated by Turkey groupings A-C at 95% confidence, with all 12 combinations overlapping significantly in which means tightly clustered from 5.53 to 5.20°Brix. Higher temperatures (60-70°C) raises TSS slightly (~0.2-0.3 units), 50°C yields lowest TSS which implying less extraction. Extensive overlap (all share at least C) points to non-strong interaction, unlike moisture or rehydration data, in contrary of research done by Kaushal (2025) that states on convective hot air drying of potato flakes do not identify significance level of total Soluble Solids (TSS) (KAUSHAL, 2025). Moderate TSS was found at 60 seconds blanch with 70°C drying temperature, which results maximal TSS retention in nutrient-dense powders; Higher temperatures (70^{0}C) consistently increase TSS regardless of blanching time; TSS slightly rises with 70^{0}C across blanching levels (5.46-6.0).

4.4.5: pH

The effect of blanching time and drying temperature on pH of tomato powder had been significant,(P<0.05) on all three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 18 at which the highest was recorded at 120 second blanching time and 50 ^{0}C drying temperature due to the presence of most organic acids and the lowest was at 60 second blanching time and 70 ^{0}C drying temperature due to highly loss of volatile organic acids which is supported by Cheng et al (2015) that states blanching time and drying temperature has a significant effect on the pH of tubers like yam, that generally causing a decrease in acidity (higher pH) as duration increases, drying temperature also plays a role(Cheng *et al*., 2015)

Both blanching time and drying temperature display a weak interaction effect on pH of tomato powder, in which Turkey groupings limited to A-B at 95% confidence, that is supported by Cheng et al (2015) that states blanching time and drying temperature has a significant effect on the pH of tubers like yam, that generally causing a decrease in acidity (higher pH) as duration increases, drying temperature also plays a role *(Cheng et al.*, 2015). All 12 means overlapping (4.47 to 4.13) and no distinct separations beyond minor shifts with a lower pH of 4.1-4.5, tomato powder would allow preservation across the processing, we would recommend 120 second blanching at 50°C temperature. An increase in pH at higher temperature levels (e.g., 4.0-4.13 at temperature 70 with 4.3-4.46 at 50^0C temperature) with an increase in blanching time brings out the interaction effect on pH to be mildly stable: temperature three (70°C) tends to be more pH-acidic than temperature one (50°C); this could be contributed by the concentrating effect of organic acids while water is removed.

4.4.6: Ash content

The effect of blanching time and drying temperature on ash content of tomato powder had been significant ($P<0.05$) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 19 on which the highest was recorded at 120 second blanching time and 70 ^{0}C drying temperature due to high loss of volatile minerals and the lowest was recorded at 60 second blanching time and 50 0C drying temperature due to the presence of volatile minerals which is supported by research done by Kaushall (2025) that states the specific interaction effects of blanching time and drying temperature on ash content potato flakes were not highlighted as a primary finding in a recent analysis of structural and physical properties(KAUSHAL, 2025).Both blanching time and drying temperature demonstrated a pronounced interaction effect on ash content of tomato powder, with Turkey groupings ranging A-E at 95% confidence, which revealing significant differences across the 12 combinations (means 15.27% to 14.13%) in contrast of research done by Kaushall (2025) that states the specific interaction effects of blanching time and drying temperature on ash content potato flakes were not highlighted as a primary finding in a recent analysis of structural and physical properties (KAUSHAL, 2025). To increase the concentration of ash blanching for 60-120 seconds at 70°C results greater than 15%; if less ash is acceptable

blanching time should reduce and dry it on 50 ^{0}C. Add more ash or nutrient content was obtained through blanching period of 60-120 seconds and drying temperature of 70°cthat results >15% as content; Ash increases progressively to ~15% at blanching 60 second with temperature 70°C, or blanching 120 seconds with temperature 70°C, showing positive interaction with concentration. The highest mineral concentration (Ash) is specifically seen in the blanching 120 seconds with temperature 70°C, that results (15.26). This suggests that extensive blanching may facilitate faster moisture loss during high heat drying, leading to more concentrated solute.

4.4.7: Vitamin C

The effect of blanching time and drying temperature on vitamin C content of tomato powder had been significant (P<0.05) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 20 an which the highest was recorded at 0 second blanching time with 50 0C drying temperature due to low thermal heat and the lowest was recorded at 60 second blanching time and 70 0C drying temperature due to high thermal energy which cause leaching this is aligned with research done by Kaushal et al (2025) that states on potato flakes dried with convective hot air concluded that both blanching time and drying temperature significantly impact the retention of heat-sensitive nutrients such as vitamin C(KAUSHAL, 2025). Both blanching time and drying temperature interacted moderately to influence vitamin C retention in tomato powder, as Turkey grouping showed (A-C) at 95% confidence, which show significant separations among means (31.33 to 26.00 mg/100g). Peak retention (group A) occurs with no blanch at 70°C (31.33) or 50°C (30.00), indicating rapid drying preserves ascorbic acid best. group C resulted at longer blanching time (120) second with 60°C (26.00), with mid-B covering most others (26.67-28.67),which is supported by Kaushal et al (2025) that states on potato flakes dried with convective hot air concluded that both blanching time and drying temperature significantly impact the retention of heat-sensitive nutrients such as vitamin C (KAUSHAL, 2025). Prioritize 0 second blanch at 70°C for ~30+ mg/100g vitamin C in fortified powders; limit to <30 seconds blanch overall to retain >27 mg. Vitamin C degrades most at longer blanching with higher drying temperature (24.66 mg/100g at blanching 0 second temperature 50°C to 19.33-20.66 at blanching 60 or 120 seconds drying at 70°C. The combination of the

longest blanching (120 seconds) and highest temperature (70ºC) results in the lowest Vitamin C levels (19.33, 20.66).

4.4.8: Lycopene content

The effect of blanching time and drying temperature on lycopene content of tomato powder had been some significant (P<0.05) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 21, on which the highest was recorded at 0 second blanching and 70 0c drying temperature due to high clarification nature and the lowest was at 120 second blanching time and 60 0C drying temperature due to somewhat low extractability nature which is supported by Kaushal et al (2025) that states on potato flakes dried with convective hot air concluded that both blanching time and drying temperature significantly impact the retention of heat-sensitive nutrients such as vitamin C and lycopene content (KAUSHAL, 2025). At 95% confidence Turkey groups A to C show differences among the mean values (31.33 to 26.00 mg/100g) for lycopene content in tomato powder due to moderating interactions in blanching time and drying temperature, cementing the previous pattern for vitamin C. Group A represents top retention with no blanching as seen with extremes of 70ºC (31.33) and 50ºC (30.00), suggesting that fast drying minimizes isomerization/oxidation of this heat stable carotenoid. Lowest (group C) emerges at 120 seconds blanching with 60°C (26.00), with B bridging intermediates. Target 0-60 second blanch at 70°C for peak lycopene (>30 mg/100g) in functional foods. Lycopene fluctuates (26-31.33) and peaking at extremes on 0 second blanches at drying temperature 70ºC. 60 second blanching at drying temperature of 70ºC, indicating resilience with non-linear interaction. Lycopene shows a unique interaction; while it generally drops at 60ºC, it rebounds at 70ºC across all blanching levels. This suggests that high heat (70ºC) is necessary to release lycopene from the cellular matrix that blanching has already partially softened.

Table 7: Interaction effects of blanching time and drying temperature on physicochemical properties (explained using mean and standard deviation)

Blanching time* temperature		Dependant variables									
Blanching time(second)	Tempratu re (°C)	Mc (%)	Wa	Rr	Solubility(%)	Density g/cm^3	Tss (°Brix)	Ph	Ash (%)	Vita. C (mg/100g)	Lycopene (mg/100)
0	50	9.86±0.3 a	0.36±0.01 a	4.66±0.57 a	81.46±0.83 bc	0.46±0.5 a	5.22±0.15 bc	4.3±0.1 ab	14.5±0.1 bcde	24.66±0.57 a	30.0±1.0 ab
0	60	9.57±0.01 bc	0.35±0.01 a	3.93±0.3 abcd	80.56±0.57 cd	0.47±0.05 a	5.36±0.05 abc	4.2±0.1 b	14.63±0.15 abcde	22.0±0.0 bcd	27.66±1.15 abc
0	70	10±0.0 bc	0.32±0.0 a	3.0±0.0 de	80±0.0 d	0.48±0.0 a	6.0±0.0 a	4±0.0 ab	15.0±0.0abc	20.66±0.57 cde	31.33±0.57 a
30	50	9.83±0.06 ab	0.35±0.01 a	4.46±0.46 ab	83.26±0.23 a	0.5±0.02 a	5.26±0.11 abc	4.36±0.15 ab	14.26±0.11 cde	24.0±1.0 ab	28.0±1.0 abc
30	60	9.56±0.01 bc	0.35±0.01 a	3.66±0.3 bcde	80.5±0.11 cd	0.46±0.005 a	5.36±0.15 abc	4.2±0.1 b	14.43±0.2 cde	22.66±1.52 abc	27.33±1.15 bc
30	70	9.55±0.02 bc	0.34±0.05 a	3.13±0.11 de	80.36±0.11 d	0.5±0.02 a	5.46±0.57 abc	4.23±0.06 ab	14.8±0.4 abcd	19.66±0.57 de	28.66±1.52 abc
60	50	9.73±0.06 abc	0.34±0.05 a	4.2±0.2 abc	83.16±0.49 a	0.49±0.03 a	5.2±0.1 c	4.3±0.1 ab	14.13±0.05 e	23.33±0.57 ab	27.66±1.15 abc
60	60	9.56±0.00 bc	0.34±0.11 a	3.53±0.3 bcde	80.5±0.1 d	0.47±0.005 a	5.43±0.15 abc	4.2±0.b	14.36±0.2 cde	22.66±0.57 abc	26.66±0.57 bc
60	70	9.54±0.01 c	0.34±0.05 a	2.93±0.5 e	80.33±0.05 d	0.5±0.03 a	5.51±0.02 ab	4.13±0.06 b	15.13±0.30 ab	19.33±1.52 e	30.33±1.15 ab
120	50	9.71±0.1 bc	0.34±0.05 a	4.26±0.3 abc	81.8±0.47 b	5.2±0.10 a	5.2±0.1 c	4.46±0.06 a	14.16±0.11 de	23.66±0.57 ab	28.0±2.0 abc
120	60	9.56±0.06 bc	0.34±0.05 a	3.36±0.15 cde	80.5±0.10 d	5.4±0.10 a	5.4±0.1 abc	4.16±0.06 b	14.6±0.25 abcde	22.0±1.0 bcd	26.0±2.0 c
120	70	9.54±0.02 c	0.34±0.05 a	2.8±0.2 e	80.36±0.05 d	5.5±0.11 a	5.5±0.11 ab	4.23±0.06 ab	15.26±0.3 a	20.66±0.57 cde	28.33±0.57 abc

4.5 Main effects of blanching time on sensory properties of tomato powder

As analysis of variance indicated, blanching time had effects on the sensory attributes of tomato powder, with scores (7-point hedonic scale) remaining high (6.4–6.7) across 0, 30, 60 and 120 blanching times, Effects by attribute mentioned as follows

4.5.1 Colour

The effect of blanching time on color of tomato powder had showed none significant difference (P>0.05) on all the three levels of blanching time with control as indicated in ANOVA table 22 on which the highest and the lowest value is recorded as almost the same near 6.4 , the F and P values are 1.40 and 0.242 respectively, at which the P value is more greater than 0.05 and makes it non significance, in contrast of research done by Kaushal (2025) that states that blanching time significantly impacts the color and overall processing quality of potato flakes dried using convective hot air drying(KAUSHAL, 2025). Color Peaks at 60 second blanching (6.53), the optimal inactivation of polyphenol oxidase preventing browning is un blanched (6.39) and longer (6.44 at 120 seconds) show minor enzymatic or heat degradation,

4.5.2: Overall acceptance:

The effect of blanching time on overall acceptance of tomato powder had a significant difference (P<0.05) on all the three levels of blanching time with control as indicated in ANOVA table 25 on which the highest value was recorded at 120 second blanching time due to inhibition of enzymatic reactions and the lowest was recorded at 0 second blanching time due to lack of pretreatments which is supported by research done by Cheng et al (2015) that states blanching is considered a vital pretreatment process that notably enhances the overall acceptance and sensory characteristics of food products, particularly potato chips (Cheng et al., 2015).as indicated by the ANOVA results, the F-value of 3.31 and p-value of 0.020 show a statistically significant main effect at the 5% level, which is supported by Cheng et al (2015) that states blanching is considered a vital pretreatment process that notably enhances the overall acceptance and sensory characteristics of food products, particularly potato chips(Cheng *et al*., 2015) Hence enzymatic reactions can be inhibited by blanching, but length of blanching can cause some nutrient loss or alter the sensory qualities of the product, which gradually affecting

its acceptance. Studies assert that blanching optimizes powder quality when it is complemented with drying, just like this main effect. From 6.44 (0 second) to 6.62 (120 second), overall acceptance increases by balancing color or flavor improvements against textural stability.

Table 8: main effect of blanching time on sensory attributes of tomato powder

Blanching Time (second)	Dependent variables			
	Color	Flavor	Texture	Overall acceptance
0	6.39±0.61 [a]	6.41±0.60 [ab]	6.61±0.52 [ab]	6.44±0.49 [b]
30	6.43±0.57 [a]	6.56±0.58 [a]	6.67±0.47 [a]	6.57±0.49 [ab]
60 s	6.53±0.51 [a]	6.55±0.50 [a]	6.47±0.50 [b]	6.53±0.5 [ab]
120	6.44±0.51 [a]	6.36±0.45 [a]	6.62±0.50 [a]	6.62± 0.5 [a]

4.6 Main effects of drying temperature on sensory attributes

As analysis of variance (ANOVA) indicated, drying temperature has minimal impact on sensory attributes of tomato powder (7-point hedonic scale), with high scores (6.4–6.6) across 50–70°C drying temperature, suggesting effective preservation during dehydration,(Higa, 2016), the key attributes mentioned as follows

4.6.1 Colour

Drying temperatures on tomato powder had none significant effects on the color of the tomato powder on all three levels of drying temperature as indicated in ANOVA table 22 on which the highest and lowest value is almost equivalent near 6.4. The F and P value are 0.76 and 0.46 respectively at which P value is greater than 0.05 indicates that is non-significant. The null hypothesis of equal color means at the 3 temperatures was accepted, in contrary of research done by Higa (2016) that states drying temperature significantly impacts food product color by accelerating pigment degradation and browning reactions through thermal decomposition. High temperatures and extended drying times increase the oxidation of color pigments, leading to greater variation in the final color of dried foods and promoting non-enzymatic browning which reduces brightness(Higa, 2016).

4.6.2 Overall acceptance

The effect of drying temperature on overall acceptance of tomato powder had none significant difference (P>0.05) on all three levels of drying temperature as indicated in ANOVA table 25 on which the highest and the lowest value was almost the same near 6.5, The F-value of 0.59 and p-value of 0.556 indicate no evidence of differences across the 3 levels tested, which is in contrast to research done by Ladi et al (2017) that states drying temperature significantly impacts the overall acceptance of food products, with higher temperatures potentially decreasing sensory scores. The study on dried tomatoes found that drying at 70°C for 7 hours yielded the highest sensorial and physical acceptability, while temperatures above 70°C, especially with longer durations, negatively affected quality and consumer acceptance(Ladi *et al.*, 2017) . Over all acceptances was stable around 6.5–6.57;

Table 9: Main effects of drying temperature on sensory attributes

Temperature (°C)	Sensory attributes			
	Color	Flavor	Texture	Overall acceptance
50	6.41±0.56 [a]	6.57±0.53 [a]	6.63±0.51 [a]	6.57±0.50 [a]
60	6.44±0.55 [a]	6.41±0.56 [b]	6.6±0.49 [a]	6.53±0.50 [a]
70	6.48±0.55 [a]	6.42±0.56 [b]	6.55±0.45 [a]	6.52±0.50 [a]

4.7 Interaction effects of blanching time and drying temperature on sensory properties

As analysis of variance (ANOVA) indicated, the interaction between blanching time (0, 30, 60 and 120seconds) and drying temperature (50, 60 and 70°C) shows little effects on tomato powder sensory attributes (7-point hedonic scale), with scores stable at 6.2–6.8 and no drastic declines. Each attributes explained as follows

4.7.1: Flavour

The interaction effects of blanching time and drying temperature on flavor of tomato powder had significant difference (P<0.05) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 23 at which the highest value was recorded at 30 second blanching time and 50 ^{0}C drying temperature

due to flavor retention and the lowest was at 120 second blanching time and 70 0C drying temperature due to loss of flavor which is supported by Jorge et al (2018) that states the interaction between blanching time and drying temperature is crucial for preserving flavor by inactivating enzymes that cause off-flavors and rancidification (Jorge *et al.*, 2018)

The Turkey post-hoc test indicates a significant interaction effect between blanching time and drying temperature on texture, as combinations fall into multiple groupings (A, B, C) with overlapping but distinct means. Higher means (around 6.6-6.7) cluster in group A for select treatments, while lower ones (6.2-6.4) extend to C, confirming the ANOVA's p=0.024. Flavor most variable (6.2–6.7); excels at short-mild changes like 30 second blanching with 50^0C drying temperature (6.69), drops at long-hot like 120 second blanching with 70^0C drying temperature (6.27)

4.7.2: Texture

The interaction effects of blanching time and drying temperature on texture of tomato powder had significant difference (P<0.05) on all the three levels of drying temperature and three levels of blanching time with control as indicated in ANOVA table 24 on which the highest value was recorded at 120 second blanching time with 50 0C drying temperature due to low thermal energy and the lowest was recorded at 120 second blanching time with 70 0C drying temperature due to high thermal energy that causes flavor loss which is supported by Jorge et al (2018) that states the interaction between blanching duration and drying temperature significantly impacts the texture of food items by modifying cell structure and pectin composition. This interaction can improve textural quality, lead to softening at higher temperatures (Jorge *et al*., 2018). From the Turkey post-hoc analysis, confirmed by the significant interaction emerged between the blanch time and the drying temperature concerning texture. The types of treatment under three groups: A (highest), B (medium), C (lowest). The ranges of means were measured from 7.89 (good) down to 7.07 (bad). It has been proved that improvement in blanching has changed effects of temperature. Temperature control and very short blanching time (on the order of few seconds) at 50°C will ensure good juiciness in that blanched vegetable or fruit. Any longer blanching treatment (120 seconds) largely degrades texture anyway,

particularly when such a temperature induces over-softening; on the contrary, blanched at 60°C yields worst from uneven drying. Texture was high overall (6.3–6.8); 120 second blanching with drying at 50ºC shines (6.76,), but 60 second blanching at 60ºc drying temperature dips (6.36,)which indicates synergies where longer blanch firms structure best at lower drying temps.

Table 10: Interaction effects of drying temperature and blanching time on sensory attributes

B*T		Sensory parameters			
Blanching (second)	Temperature (oC)	Color	Flavor	Texture	Overall acceptability
0	50	6.27±0.58 [a]	6.60±0.58 [ab]	6.60±0.58 [ab]	6.51±0.50 [a]
30	50	6.47±0.54 [a]	6.69±0.46 [a]	6.60±0.49 [ab]	6.67±0.47 [a]
60	50	6.53±0.54 [a]	6.60±0.49 [ab]	6.56±0.50 [ab]	6.47±0.50 [a]
120	50	6.38± 0.53 [a]	6.40± 0.53 [abc]	6.76± 0.48 [a]	6.64± 0.52 [a]
0	60	6.42±0.62 [a]	6.22±0.56 [c]	6.62±0.49 [ab]	6.36±0.48 [a]
30	60	6.40±0.58 [a]	6.51±0.62 [abc]	6.73±0.44 [a]	6.56±0.50 [a]
60	60	6.51±0.50 [a]	6.51±0.5 [abc]	6.36±0.48 [b]	6.53±0.50 [a]
120	60	6.44± 0.50 [a]	6.40± 0.49 [abc]	6.69± 0.47 [ab]	6.69± 0.47 [a]
0	70	6.49±0.62 [a]	6.42±0.62 [abc]	6.60±0.49 [ab]	6.44± 0.50 [a]
30	70	6.42±0.58 [a]	6.47±0.62 [abc]	6.69±0.46 [ab]	6.49±o.50 [a]
60	70	6.53±0.50 [a]	6.53± 0.50 [abc]	6.49±0.50 [ab]	6.60±0.50 [a]
120	70	6.49± 0.50 [a]	6.27± 0.45 [bc]	6.42± 0.49 [ab]	6.53±0.50 [a]

5. CONCLUSION AND RECOMMENDATION

5.1. Summary

Drying of tomato can increase its consumption in the form of various value added products. This will be achieved by investigating an affordable and applicable drying method. Therefore, the present study was conducted to investigate effect of blanching time and drying temperature on physicochemical and sensory properties of tomato powder. The influence of blanching times (0, 30, 60 and 120 seconds) and drying temperature (50, 60, and 70ºC) on drying kinetic, physicochemical and sensory parameters of fresh tomato and tomato powder was investigated. Drying of tomato to change in to powder occurred in falling rate period; no constant rate period of drying was observed, which implies that moisture removal from the material was governed by amount of heat released. The moisture removal of tomato slices to be a powder at 70ºC drying temperatures and blanching time of all four levels were highest when compared to other drying temperatures.

Physical parameters such as moisture content(%), water activity, rehydration ratio, solubility(%), density(g/cm^3) and total soluble solid(^{0}Brix) of tomato powder was found in the range of 9.54±0.015 – 9.86±0.3, 0.32± 0.01 -0.36±0.01, 2.8±0.2 – 4.66± 0.57, 80±0.00 – 83.26± 0.23, 0.46± 0.04 – 0.5± 0.02 and 5.2± 0.10 – 6.0±0.00 respectively, The chemical property (pH) ranges from 4.0± 0.00 – 4.46± 0.057, from the nutritional properties Ash content, Vitamin C and Lycopene ranges 14.13±0.05 – 15.13± 0.30, 19.66±0.57 – 24.66±0.57 and 26.0±2.0 – 31.33±0.57 respectively. At which the lowest and the highest moisture content %(60 second blanching with 70ºC drying temperature and 0 second blanching with 50ºC drying temperature), water activity (0 second blanching with 70ºC drying temperature and 0 second blanching with 50ºC drying time) rehydration ratio (120 second blanching with 70ºC drying temperature and 0 second blanching with 50ºC drying time,) solubility (0 second blanching with 70ºC drying temperature and 30 second with 50ºC), density (120 second with 50ºC and 30 second with 50ºC drying temperature), total soluble solid (120 second blanching with 50ºC drying temperature and 0 second blanching with 70ºC drying temperature), pH (0 second blanching with 70ºC drying temperature and 120 second blanching with 50ºC), Ash content (60 second with 50ºC and 60 second with 70ºC drying temperature), Vitamin C

(30 second blanching time with 70ºC and 0 second with 50ºC drying temperature) and Lycopene(120 second blanching time with 60ºC drying temperature and 0 second blanching time with 70ºC drying temperature) was recorded at respectively.

The sensory properties of color (6.27±0.58 – 6.53±0.54 at 0 second with 50ºC and 60 second with 50ºC), flavor (6.22±0.56 – 6.69±0.46 at 0 second with 60ºC and 0 second with 50ºC), texture (6.42±0.49 – 6.76±0.48 at 120 second with 70ºC and 120 second with 50ºC) and overall acceptability (6.36±0.48 – 6.69±0.46 at 0 second with 60ºC and 120 second with 60ºC) were recorded respectively. Blanching time on most physicochemical properties like moisture content (P=0.270), rehydration ratio (P=0.050 borderline), density (P=0.552), TSS (P=0.986), pH (P=0.306), ash (P=0.242), and vitamin C (P=0.461) has not significant main effects, whether it's complete blanching or not, it doesn't seen significant effects. Highly significant effects are registered on solubility (P=0.001 decreases from 81.4% at 30 seconds to 80.8%) at 0 second and lycopene (P=0.007 from 29.7 mg/100 g at 0 second to 27.4 at 120 seconds).

Keep blanching times very short (less than 120 seconds) to reduce rehydration ratio (3.91 to 3.48) and solubility due to softening of tissues and degradation of pectin, while increasing density (0.31 to 0.50 g/mL) through air removal; high temperature (50-70°C) of drying decreased moisture (from ~9.86% to 9.54%) and water activity (from ~0.36 to 0.34), thus enhancing stability yet added variable damage to heat-sensitive vitamin C (from 31.33 mg/100 g at 0 second blanching with 70 °C drying temperature to 19.33 at 60 second blanching with 70 °C drying temperature) and lycopene. Balanced optimum combinations included: short blanching (0-30 second) at 50°C, for maximum retention of rehydration and vitamin C; longer blanching at 70°C led to increased ash (up to 15.27%) and TSS (5.5 °Brix). Seven-point hedonic scale sensory attributes are all within acceptance ranges (6.2-6.8), where blanching time has a significant effect on flavour (P=0.004 peaking at 30 second blanching (6.56)) and texture (P=0.020). Different low-temperature short blanching conditions (e.g. 30 second with 50°C drying temperature: blanching has disadvantageous effects on flavour and texture when subjected to longer exposures (120 second blanching with 70 °C drying temperature:

No significant difference was observed among treatments for overall acceptance, falling within the range of clusters of 6.4 and 6.7. Short blanching (0-30 seconds) at a moderate drying temperature level (50-60°C) maximizes rehydration and nutrients retention (lycopene ~30 mg/100 g) with sensory appeal, thus being suited for higher-end products; blanching is meant to develop stable and high mineral powders, yet packs a major vitamin C loss. The findings agree with literature for dehydration, indicating that minimal exposure to heat ensures less degradation.

5.2. Conclusion

Higher drying temperatures (70°C) accelerate moisture removal and shorten drying time to 7 hours than the remain two drying temperatures while increasing density, TSS, ash content, and lycopene retention, though it reduced heat-sensitive attributes like vitamin C, rehydration ratio, solubility, and PH. Blanching times (30-60 seconds at 95°C hot blanching water temperature) has minimal impact on drying kinetics of tomato slices being dried, but enhances lycopene (up to 31 mg/100g at 70°C with 60 second blanching) and TSS while protecting sensory attributes like color and flavor; longer blanching (120seconds) accelerates vitamin C loss. All treatments achieve safe moisture content(<10%) and water activity (0.35) which is recommended for microbial stability at 70°C drying temperature with 60 second blanching time. Blanching emerging as optimal for nutrient-dense powder suitable for food applications.

5.3. Recommendation

- It is no possible to conclude that tomato has gained enough attention by the agricultural sector as well as by industrial sector, thus, both sectors should focus on such underutilized crops and explore the information how to process tomato so that small holder farmers, producers as well as consumers could be benefited.
- As a future line of work it will be better to evaluate nutritional parameter of the tomato powder, since more attention is given for its Lycopene and Vitamin C only.
- Future research should explore intermediate blanching temperatures to mitigate vitamin C losses. Adopt 30 second blanching at 50°C for versatile powder balancing physicochemical stability.

- Industry practice: adopt 60-second blanching time at 70°C drying temperature for commercial hot-air drying of Roma VF tomatoes to maximize lycopene and TSS retention.
- Quality control:-Target final moisture content of dried tomato powder to be 9.5-9.6% and water activity of <0.4; and regular monitoring of vitamin C loss as a heat damage indicator during process validation.
- Future research: test hybrid pre-treatments like hot water blanching, shelf-life studies under Ethiopian ambient conditions and economic analysis of scaled dehydrator operations.
- Policy: Promote tomato powder production in high-production regions (Oromia, Amhara) to cut postharvest losses (>30%) and improve farmers income through value-added processing.
- This research recommended to use B1T2 (30 second, 60^{0C}) processing is very essential to keep the balanced sensory property and keep physicochemical properties.

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7. APPENDEX

Table 11:The effect of temperature and blanching time on drying kinetics of tomato

data of drying kinetics

tempreture (oC)	blanching (second)	initial weight (g)	1hr	2 hr	3 hr	4 hr	5 hr	6 hr	7 hr	8 hr	9 hr
50	0	1000	580	256	96	68	60	58.4	55.72	52	51.72
50	30	1000	572	252	88	68	60	56	52	51.64	
50	60	1000	584	260	84	72	64.8	60	56.8	55.56	
50	120	1000	576	249.6	92	69.6	62	52	49.6	47.56	
60	0	1000	568	272	96	68	60	56	52	51.44	
60	30	1000	544	264	80	60	52	48	48.6		
60	60	1000	568	272	92	64	54	51	49.5		
60	120	1000	544	272	96	64	52	48	47.68		
70	0	1000	520	144	60	52	48	44	43.88		
70	30	1000	592	228	84	56	52	51.56			
70	60	1000	632	275	106	54	51	49.4			
70	120	1000	556	204	80	52	48	47.72			

ANOVA tables for main effects and interaction effects of temperature and blanching time on physicochemical properties

Table 12: ANOVA *table for moisture content*

Analysis of Variance

Source	DF	Adj SS	Adj MS	-Value	P- Value
Blanching time	3	0.02183	0.007278	0.77	0.520
Temperature	2	0.41374	0.206869	21.98	0.000
Blanching time*Temperature	6	0.02808	0.004681	0.50	0.804
Error	24	0.22587	0.009411		

Total	35	0.68952

Table 13: ANOVA *table for density*

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	0.001278	0.000426	0.72	0.552
Temperature	2	0.007739	0.003869	6.51	0.006
Blanching time*Temperature	6	0.004639	0.000773	1.30	0.295
Error	24	0.014267	0.000594		
Total	35	0.027922			

Table 14 : ANOVA table for water activity

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	0.000267	0.000089	1.39	0.270
Tempreture	2	0.000206	0.000103	1.61	0.221
Blanching time*Tempreture	6	0.000217	0.000036	0.57	0.754
Error	24	0.001533	0.000064		
Total	35	0.002222			

Table 15:ANOVA table for rehydration ratio

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	1.0386	0.34620	3.00	0.050
Tempreture	2	11.8050	5.90250	51.20	0.000
Blanching time*Tempreture	6	0.1172	0.01954	0.17	0.983
Error	24	2.7667	0.11528		
Total	35	15.7275			

Table 16: ANOVA table for solubility

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	2.467	0.8225	7.75	0.001
Tempreture	2	31.785	15.8925	149.77	0.000
Blanching time*Tempreture	6	5.128	0.8547	8.05	0.000
Error	24	2.547	0.1061		
Total	35	41.928			

Table 17: ANOVA table for TSS

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	0.001456	0.000485	0.05	0.986
Tempreture	2	0.476089	0.238044	23.04	0.000
Blanching time*Tempreture	6	0.023911	0.003985	0.39	0.881
Error	24	0.248000	0.010333		
Total	35	0.749456			

Table 18: ANOVA table for PH

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	0.02972	0.009907	1.27	0.306
Tempreture	2	0.20222	0.101111	13.00	0.000
Blanching time*Tempreture	6	0.05111	0.008519	1.10	0.394
Error	24	0.18667	0.007778		
Total	35	0.46972			

Table 19: ANOVA table for Ash

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	0.2289	0.07630	1.49	0.242

Tempreture	2	3.5000	1.75000	34.24	0.000
Blanching time*Tempreture	6	0.6244	0.10407	2.04	0.100
Error	24	1.2267	0.05111		
Total	35	5.5800			

Table 20: ANOVA table for Vitamin C

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	2.000	0.6667	0.89	0.461
Tempreture	2	89.056	44.5278	59.37	0.000
Blanching time*Tempreture	6	6.500	1.0833	1.44	0.239
Error	24	18.000	0.7500		
Total	35	115.556			

Table 21: ANOVA table for Lycopene content

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	24.222	8.074	5.19	0.007
Tempreture	2	45.500	22.750	14.63	0.000
Blanching time*Tempreture	6	8.944	1.491	0.96	0.474

Error	24	37.333	1.556
Total	35	116.000	

ANOVA tables for main effects and interaction effects of drying temperature and blanching time on sensory qualities of tomato powder

Table 22: ANOVA table for color

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	1.294	0.4315	1.40	0.242
Drying tempreture	2	0.470	0.2352	0.76	0.466
Blanching time*Drying tempreture	6	1.100	0.1833	0.60	0.734
Error	528	162.578	0.3079		
Total	539	165.443			

Table 23: ANOVA table for flavor

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	3.991	1.3302	4.52	0.004
Drying tempreture	2	2.915	1.4574	4.96	0.007
Blanching time*Drying tempreture	6	2.270	0.3784	1.29	0.262
Error	528	155.289	0.2941		

Total	539	164.465

Table 24: ANOVA table for Texture

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	3.185	1.0617	4.34	0.005
Drying tempreture	2	0.559	0.2796	1.14	0.319
Blanching time*Drying tempreture	6	3.604	0.6006	2.46	0.024
Error	528	129.022	0.2444		
Total	539	136.370			

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Table 25: ANOVA table for overall acceptance

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Blanching time	3	2.474	0.8247	3.31	0.020
Drying tempreture	2	0.293	0.1463	0.59	0.556
Blanching time*Drying tempreture	6	1.959	0.3265	1.31	0.250
Error	528	131.378	0.2488		
Total	539	136.104			

Practical operations





Fresh Roma Vf tomato





Blanching of tomatoes





Sliced tomatoes ready for drying





Tomato drying process



Drying kinetics measurement



Dried tomatoes



Tomato powder samples



Tomato samples for sensory analysis




Sensory panelists in partial





weighing and preparing






pH ,Tss and ash determination




Vitamin C determination in AASTU

  Lycopene determination in AAU (4 Killo)

7 scale hedonic scale

1. General Information

Product name (optional):_____

Evaluation date:_____

Panelist name or code:_____

2. Hedonic rating test using 7- point hedonic scale

Instruction: Dear panelist, please evaluate the given sample(s) honestly based on your personal preference and rate each of sensory attribute using the 7-hedonic scale where 1 = dislike extremely, 2 = dislike moderately, 3 = Dislike slightly, 4=neither like nor dislike, 5= like slightly, 6 = like moderately and 7 = like extremely.

Direction:

1. Rinse your mouth before moving to the next sample with clean water.
2. Observe the sample's appearance and color.
3. Smell the sample to assess its aroma.
4. Taste the sample and evaluate its flavor and texture and also crispiness
5. Provide any additional comments or suggestions in the space provided.

Sample code	Sensory attributes			
	Color	Flavor	Texture	Overall acceptability