EFFECT OF PRETREATMENT AND DRYING TEMPERATURE ON PHYSICOCHEMICAL PROPERTIES OF TOMATO POWDER

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A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuwan University, in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology

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Approval letter

This dissertation entitled *Effect of Pretreatment and Drying Temperature on Physicochemical Properties of Tomato Powder* presented by Kaushal Baral has been accepted as the partial fulfillment of the requirements for the B. Tech. degree in Food Technology.

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(Kaushal Baral)

Abstract

This study was carried out with an objective of analyzing the effect of different chemical pretreatment and drying temperature on the physiochemical properties of tomato powder. The tomatoes were cut longitudinally into eight equal halves and pretreated with 0.2% KMS, 1% $CaCl_2$, 7% NaCl in distilled water for 10 minutes and untreated (control). These tomato slices were dried in a cabinet dryer in different temperature (55, 60, 65ºC) to equal moisture content and flakes were grounded in a blender to obtain tomato powder whose chemical analysis (Total phenolic content, DPPH radical scavenging activity, lycopene and vitamin C) and physical analysis (bulk density, true density, porosity and solubility) were carried out. The obtained data was analyzed statistically by two way of ANOVA at 5% level of significance.

Lycopene, total phenolic content, vitamin C and DPPH radical scavenging activity were found to be significantly affected ($p<0.05$) by different chemical pretreatment in all the drying temperature. KMS treatment combined with drying temperature of 60ºC was most effective method for retaining total phenolic content and DPPH radical scavenging activity whereas same treatment and drying temperature of 55ºC retain the maximum amount of lycopene and vitamin C, resulting the value of 713.3 mg GAE/100g db total phenolic content, 57.26% DPPH radical scavenging activity, 6.117 mg/100 g db lycopene and 18.78 mg /100g db vitamin C. Most of the samples were significantly different ($P <0.05$) at 5% level of significance. In case of physical properties, bulk density and true density were found to be maximum in Control sample dried at 65ºC having the value 0.675 g/ml and 1.354 g/ml respectively whereas porosity and solubility were found to be maximum in KMS treated sample dried at 55ºC having the value 0.527 and 19.73 % respectively. Statistical analysis showed a significant difference ($P<0.05$) at 5% level of significance across all physical properties. Hence, these findings show that drying temperature and chemical pretreatment are important in maintaining the quality of the dried tomato powder.

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List of abbreviations

Abbreviation	Full form
AA	Antioxidant activity
ANOVA	Analysis of Variance
BD	Bulk Density
db	Dry basis
DPPH	1,1-diphenyl-1-picryl-hydrazyl radical
etc	Et cetera
FC reagent	Folin- Ciocalteau reagent
GAE	Gallic acid equivalent
i.e	That is
RSA	Radical Scavenging Activity
TD	True Density
TPC	Total phenolic content
wb	Wet basis

Part I

Introduction

1.1 General introduction

The tomato is the edible berry of the plant *Solanum lycopersicum*, member of the family Solanaceae is tolerant of a wide range of both environmental and nutritional conditions. It is one of the fresh vegetable crops which are widely consumed in the world (Vaughan and Geissler, 2009). It is a perishable food product that starts deteriorating 2–3 days after harvesting (Ochida *et al.*, 2018). It comes in a variety of colors, including red, yellow, green, and even purple, with each type offering its distinct flavor. Botanically, a tomato is a fruit (berry), consisting of the ovary, together with its seeds, of a flowering plant (Petruzzello, 2016). Although the tomato is salty (umami) rather than sweet, it is frequently eaten as part of a salad or the main course of a meal rather than as a dessert. This is why it is referred to as a "culinary vegetable" and has a considerably lower sugar content than culinary fruits. Tomatoes and tomato-based products offer consumers a wide range of nutrients and numerous health advantages. They can be eaten raw or cooked, and in a variety of cuisines, sauces, salads, and beverages. While tomatoes are botanically classed as berries, they are typically utilized in the kitchen as a vegetable ingredient or side dish. Tomatoes are a rich source of umami flavor (Tommonaro *et al.*, 2021)

At ambient temperatures, tomatoes have a short shelf life and are highly perishable. During the producing season, it produces a glut, and during the off season, it becomes scarce. Inadequate processing facilities and short shelf lives result in significant economic loss for the nation. Consequently, the economic value of tomato preservation and processing (Davoodi *et al.*, 2007). The most popular method of tomato preservation is drying. Different drying methods can be used. The tomato's moisture must be removed in a way that doesn't compromise the quality of the finished product (Gaware *et al.*, 2010).

Because of its unique nutritional value, tomatoes are one of the most essential foods for protection. It is a great source of antioxidants such lycopene, carotenes, and phenolics as well as vitamin C (S. Srivastava and Kulshreshtha, 2013). Drying of tomato saves weight and volume, reduces packing and transportation expenses, and allows the product to be stored at room temperature for extended periods of time. The determination of suitable drying conditions, which is a low-cost technique, and the conversion of dried tomato into powder form will significantly help to the reduction of losses and the generation of additional money for the country.

Pretreatment significantly impacts the quality of tomato powder by influencing its color, texture, and nutrient retention. Common pretreatments like potassium metabisulfite (KMS), calcium chloride ($CaCl_2$), and sodium chloride (NaCl) help in preserving lycopene content, reducing enzymatic browning, and improving rehydration properties. KMS acts as an antioxidant, preventing color degradation, while $CaCl_2$ enhances firmness and NaCl aids in moisture regulation. Proper selection of these pretreatments ensures better quality, extended shelf life, and improved functional properties of tomato powder (Joshi *et al.*, 2008).

Dried tomatoes are a rich source of antioxidants: vitamin C, especially phenolic compounds and lycopene. Lycopene as the main natural antioxidant in fresh tomatoes and tomato powder content also accounts for the redness, which is one of the main qualities in industry and consumers now look at. This antioxidant is responsible for the red color of tomatoes and tomato products, which affects the very total quality and sales (Alda *et al.*, 2009). The red color of tomato products is very important attribute and is of total quality (Ranganna,1986). Lycopene is the principle carotenoid found in tomatoes. It is also one of the major carotenoids present in human serum and organs. Tomato and tomato products are the major sources of lycopene in the human diet (Stahl and Sies, 1996).

The development of low-cost preservation methods to perishable products will be beneficial to farmers and consumers. In conventional air drying, high temperatures are employed that adversely affect the texture, color, flavor, and nutritional value of the products. Thus, the maintenance of quality of dried tomato powder is challenging (Selimovic *et al.*, 2023).

1.2 Statement of problem

According to Ghimire *et al.* (2001) tomato is one of the most significant commercial horticultural crops farmed in Nepal. In terms of productivity and total cultivated area, it is ranked third. Over 20,000 hectares are used for tomato cultivation in Nepal on average expansion to 22,566 hectares of planted land with a productivity of 18 tons per ha in fiscal year 2018/2019 from an output scale of 0.3 million metric tons (MOALD, 2020)

Tomatoes are extremely perishable because of their high moisture content, which allows for quick microbial infection while they are still fresh. As a result, there have been significant postharvest losses, roughly half of the harvest, which are estimated. Small-holder farmers suffer significant financial losses as a result of postharvest losses, which also remove excess produce from the market and drive up tomato prices during the tomato off season(Ghimire *et al.*, 2001). This situation may be due to the lack of postharvest preservation methods, one of which is drying. Even though farmers know that tomatoes can be dried but due to a lack of proper drying technique and knowledge, they are facing the problem of preservation, processing, and pricing of tomatoes during dry and flush season of harvesting. Frequently farmers are unaware of pretreatments like Calcium Chloride, Sodium Chloride, Potassium Metabisulfite before drying which consequence severe processing and economic loss to the producer (Lewicki and Michaluk, 2004; Pataro *et al.*, 2019)

1.3 Objectives

1.3.1 General objectives

The general objective of this dissertation was to study effect of pretreatment and drying temperature on physicochemical properties of tomato powder.

1.3.2 Specific objectives

The specific objectives of this dissertation work were as follow

- To carry out proximate and physicochemical analysis of fresh tomato.
- To prepare tomato powder by using different drying temperature and pretreatments.
- To analyze the physicochemical properties of tomato powder

1.4 Significance of the study

Pretreatment before drying enhances tomato quality during the drying process and reduces postharvest losses, which in turn maximizes drying rate and reduces oxidative damage. Using pretreatments like KMS, $CaCl_2$, NaCl etc. before drying would cause the product to dry more quickly in order to reach a safe moisture level, which would preserve the product's physical and phytochemical characteristics. The tomato can be reasonably priced and sold during the off-season once it has been dried (Nzimande *et al.*, 2024).

Dry tomato powder is a potential alternative to artificial flavoring and coloring. It is suitable for both commercial and residential food preparation. It has multiple applications, including masala powder, seasonings, tastemakers, sauces, ketchup, instant food, chips, snacks, and soup mixture, ready meals, beverages, cookies, confectionary, and so on. It can be made without chemicals and stored in its natural state. It is simple to use and combines well with other substances. Using natural tomato flavor powder is cost-effective for commercial establishments.

Due to its high nutritional content and ease of reconstitution, dried tomatoes might be a valuable product in the market. Good quality tomato powder provides advantages such as improved nutrient retention, better flavor, longer shelf life, and more usage in a variety of food applications. These advantages benefit farmers and agro-processors by lowering post-harvest losses and improving profitability through product diversity. The food industry benefits from better processing procedures, which result in more consistent and high-quality goods, while consumers gain access to healthier and more convenient tomato-based components. The findings assist researchers as well, as they contribute to the development of optimum drying technology for agricultural produce.

1.5 Limitation of the study

- Storage stability of tomato powder was not determined
- Microbial analysis were not conducted.

Part II

Literature review

2.1 Historical background

Tomatoes were brought to Europe centuries ago, but its origin remains unknown. The Peruvian and Mexican explanations are currently being contested. Tomatoes were presumably used for human food. Cookbooks from the early 17th century attest to their use in gazpacho, indicating their popularity after their entrance to Europe. Despite its similarities to dangerous Solanum species such as mandrake and belladonna, the tomato has historically been planted solely for decoration. In Italy, the fruit was initially used for adornment and not incorporated into local cuisine until the late 17th or early 18th century. In the mid-18th century, tomato consumption had become common in England. The British ambassador in Aleppo, John Baker, "exported" tomatoes from England to the Middle East and Asia. Tomatoes eventually spread to North America as a result of English colonization. The tomatoes' true domestication of edible vegetables began in the nineteenth century (Bergougnoux, 2014).

Since the latter part of the nineteenth century, various types have been produced through open pollination under the supervision of farms or small collectives. New cultivars were developed through natural outcrossing, spontaneous mutation, or recombination of preexisting genetic variety (Bauchet and Causse, 2012). Livingston and Smith (1998) exemplified tomato breeding by aiming for smooth, consistent, and tasty fruits. He selected tomatoes with as a result, his farm has a variety of traits. Over a five-year period, he saved the seeds, raised them in fields, and selected them to produce larger and more fleshy fruits. Domestication and breeding programs led to significant physiological and morphological changes, but also reduced genetic diversity in farmed tomatoes (Du *et al.*, 2025).

2.2 Taxonomical profile

Tomatoes are part of the Solanaceae family, which includes over 1500 tropical and subtropical species originating in Central and South America (Davies *et al.*, 1981). Recently, the evolutionary classification of Solanaceae was changed, and Lycopersicum was re-integrated into the Solanum genus with new nomenclature (Edeh, 2017). The new classification is given below.

Kingdom: Plantae

Order: Solanales

Family: Solanaceae

Genus: *Solanum*

Species: *lycopersicum*

2.3 Botany of tomato

Tomatoes are an annual plant that can reach heights of more than two meters. The first harvest can occur 45-55 days after flowering or 90-120 days after planting. The form of the fruit varies per cultivar. The colors vary from yellow to red. There are three types of tomato plants: tall (indeterminate), semi-bush (indeterminate), and bush (determinate). Tall varieties are ideal for an extended harvest time. Indeterminate refers to plants that continue to grow even after flowering (Al-Shammari *et al.*, 2023).

However, illnesses and insect infestations will halt growth in tropical climates. The plants usually have greater foliage. This reduces crop temperature and promotes fruit growth in the shade of leaves. So the fruits ripen more slowly. Slower ripening and a high leaf/fruit ratio enhance fruit flavor and sweetness. Indeterminate cultivars grow endlessly and can reach over 10m in a year in a greenhouse. Tall forms require stakes, cages, or trellises. Short types typically support themselves and require no stakes. In extreme weather conditions like typhoons, staking may be necessary determinate kinds will stop proliferating after flowering. They require less labor, so they are popular for commercial cultivation. The botanical features of tomato according to Swamy (2023) are described below:

Root, steam and leaves

Tomatoes have a robust tap root system that can reach a depth of 50 cm or more. The main root forms thick lateral and adventitious roots. Stems can grow erect or prostrate. It grows to a height of 2-4 meters. The stem is solid, coarse, hairy and glandular. The leaves are spirally organized, measuring 15-50 cm long and 10-30 cm wide. The leaflets are ovate to oblong and coated with glandular hairs. The inflorescence is crowded and yields 6-12 blooms. The petiole measures 3-6 cm (Knapp and Peralta, 2016).

Flower

The flowers have a diameter of 1.5–2 cm and are bisexual and regular. They develop in between or across leaves. The persistent sepals are paired with a short, hairy calyx tube. When fully grown, the petals are typically yellow, up to 1 cm long, and reflexed. The style is surrounded by bright yellow anthers with an extended, sterile tip. The stamens are six in number and create a stamina cone when they fuse with the bottom portion of the corolla. The ovary has two or three compartments and is superior. cross-pollinated, but mostly self-pollinated. Bumblebees and bees are the most significant pollinators (Peralta and Spooner, 2007)

Fruits

According to Monforte *et al.* (2013) the fruits are fleshy berry, globular to oblate in shape, and 2-15 cm in diameter. The immature fruit is green and hairy. Ripe fruits range from yellow, orange to red. It is usually round, smooth, or furrowed. The best shape and fullest fruit are a result of complete fertilization of the ovules. Generally, tomato fruit consists of flesh (skin/epidermis and pericarp) as well as pulp (placenta and locular contents)

Skin

Skin or peel of the pericarp consists of the epidermal layer and 3-5 layers of thick-walled collenchyma tissue. The pericarp consists of an outer pericarp, radial pericarp and inner pericarp/columella. As the fruit matures, the pericarp continues to enlarge by cell division and cell enlargement, and then the pericarp cells become large with many intercellular spaces. The locular section contains the seeds that are surrounded by a gel of parenchyma cells (Monforte *et al.*, 2013).

Seeds

Numerous, kidney or pear-shaped. They are hairy, light brown 3-5 mm long, and 2-4 mm wide. The embryo is coiled up in the endosperm. The approximate weight of 1000 seeds is 2.5 – 3.5g (Dorais *et al.*, 2008).

2.4 Structure of tomato

The fruit is made up of an outer shell termed the pericarp, radial pericarp, a core(columella), and locular gel that hold the seeds, which are embedded in a jelly-like parenchyma tissue derived from the placenta (McColloch, 1952). Despite considerable variance, the overall pericarp accounts for around 45 percent of the fruit, with the radial pericarp and core accounting for approximately 35 percent. The remaining 25% is made up of locular gel (Narkviroj and Ranganna, 1976)

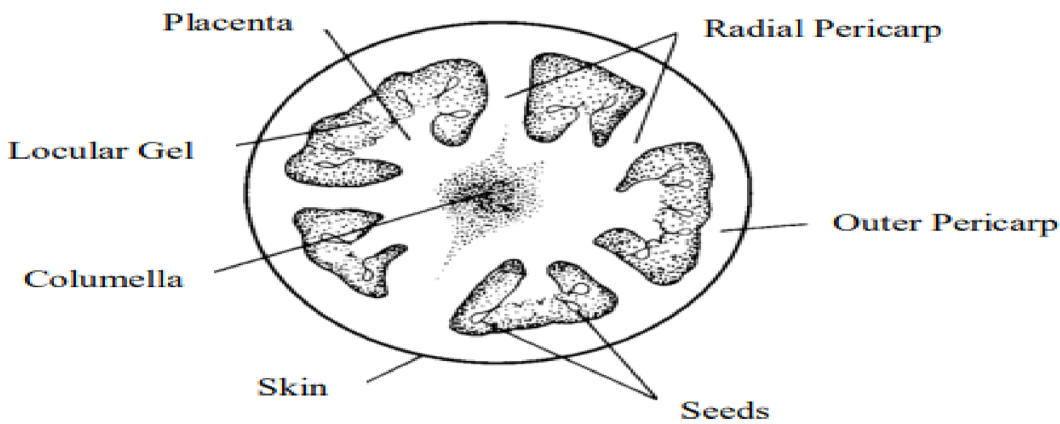

Fig 2.1 Structure of tomato

2.5 Maturity stages of tomato

According to the USDA (1991) standard, the green, pink and red tomatoes maturity coloring index is used to evaluate fruit quality. The maturity stage of fresh tomato fruit is an important factor that affects the fruit quality during ripening and marketability after ripening. The following terms may be used, when specified in connection with the grade statement, in describing the color as an indication of the stage of ripeness of any lot of mature tomatoes of a red-fleshed variety:

Green

Green means that the surface of the tomato is completely green in color. The shade of green color may vary from light to dark.

Breakers

Breakers means that there is a definite break in color from green to tannish yellow, pink or red on not more than 10 percent of the surface.

Turning

Turning means that more than 10 percent but not more than 30 percent of the surface, in the aggregate, shows a definite change in color from green to tannish yellow, pink, red, or a combination thereof;

Pink

Pink means that more than 30 percent but not more than 60 percent of the surface, in the aggregate, shows pink or red color

Light red

Light red means that more than 60 percent of the surface, in the aggregate, shows pinkish red or red: Provided, that not more than 90 percent of the surface is red color

Red

Red means that more than 90 percent of the surface, in the aggregate, shows red color

2.6 Chemical composition

Throughout the world, tomatoes are a popular fresh vegetable due to their high content of important nutrients and phytochemicals that are high in antioxidants. Tomato consists of Minerals, vitamins, proteins, and important amino acids (lysine, valine, histidine, leucine, arginine and threonine) carotenoids (lycopene and -carotenoids), monounsaturated fats (linoleic and linolenic acids), and phytosterols (sitosterol, campesterol, and stigmasterol). The species, ripeness stage, growing year, climate, light, temperature, soil, fertilizer, irrigation, and other cultivation factors all have a significant impact on the tomato's composition (Petro-Turza, 1986)

2.6.1 Sugar

Sugars, which make for around 50 % of the dry matter in tomato fruits, are one of the key ingredients responsible for its quality. The free sugars in commercial tomato fruit are 8 almost reducing sugars, comprising primarily of glucose and fructose in about equal proportions except in the fruit of some Lycopersium species, where it is the major sugar. Sucrose is present on occasion but seldom surpasses 0.1 % of the fresh weights. There have also been reports of trace levels of a ketoheptose. In general, the total sugar content increases significantly during ripening from the mature green stage to red-ripe, while cases of a decrease have been documented once the fruit has begun to color. The tomato is one of the few climacteric fruits in which sucrose is almost non-existent (Beckles, 2012).

2.6.2 Acids

Organic acids, primarily citric and malic acids, account up more than 10 % of the dry weight of tomatoes. In addition to the two primary acid components, the presence of a variety of additional acids was discovered at significantly lower proportions. The acid content of tomatoes changes as they ripen. The acid concentration of the berry increases during growth and ripening, up to the breaker stage, and then decreases. Initially, malic acid predominates; in the mature green stage, the malic acid: citric acid ratio is greater than one; following this, citric acid overcomes malic acid and in the ripe red tomato, the ratio is 0.5 or less (Petro-Turza, 1986). Citric acid accounts for 45-66 % of total acidity in fully ripe fruit in English cultivars, 40-90 % in American cultivars, and 60-85 % in Hungarian cultivars. The quality and quantity of organic acids are vital not only for flavor but also for technology, because butyric, thermophilic, and putrefactive anaerobic microbes cannot grow below pH 4.3 (Agius *et al.*, 2018)

2.6.3 Vitamins

Tomatoes are one of the most versatile and widely consumed vegetables in many countries and are a rich source of vitamins. Vitamins A, B, C, E and K are the main types of vitamins present in tomatoes, with vitamin C reported being the highest. Vitamins C and E exhibit antioxidant activities making tomato a useful therapeutic agent. Tomato consists 614 $\pm$ 248 IU/100 g vitamin A, 15.08 $\pm$ 1.06 µg/100 g vitamin

E, 98.28 ± 0.00 µg/100 g vitamin K, 36.16 ± 29.64 mg/100 g vitamin C etc (Ali *et al.*, 2020b).

2.6.4 Pigments

The pigments that build up in the fruit pericarp (flesh), sub-epidermal layer, and epidermis of tomatoes give their characteristic color. On the other hand, immature fruits' pericarps are primarily green in color because of the presence of the photosynthetic machinery, or chlorophylls, is there and working. During ripening, the thylakoid membranes in the chloroplasts degrade and the plastids become chloroplasts, resulting in a notable rise in the number of certain carotenoids. As a result, the fruit gradually changes from green to yellow, orange, and red as various carotenoids and flavonoids are made, and lycopene, the primary carotenoid in red, ripe fruits, is eventually accumulated. The color changes gradually between the mature green stage, when all of the plastids are still chloroplasts, and the fully ripe stage, when only matured chromoplasts are present (Egea *et al.*, 2010). Tomatoes are climacteric fruits, and significant quantities of ethylene are produced during the commencement of ripening. This hormone regulates many carotenoid biosynthesis genes (Alba *et al.*, 2005).

The pigment called lycopene is mostly in charge of giving ripe tomato fruits and tomato-based products their rich red color. Its biological and physicochemical characteristics particularly its advantages as a natural antioxidant have contributed to its rising popularity. Unwanted degradation of lycopene affects not only the final goods' sensory quality but also the health advantages of eating foods based on tomatoes for humans. Fresh tomato fruits contain the majority of the all-trans structure of lycopene. The two main processes that lead to the deterioration of tomato lycopene during processing are isomerization and oxidation (Shi and Maguer, 2000).

2.6.5 Aroma and volatile constituents

Several researches have been conducted to investigate the composition of tomato aroma volatiles. It.is determined by cultivars, maturity stage, cultivation practice management and postharvest treatments. Despite the fact that over 400 chemicals have been discovered as volatile elements of tomato and tomato products, only a small number are required for tomato flavor. The distinctive aroma of fresh tomatoes does not appear to be due to a single or small set of chemicals (Petro-Turza, 1986)

The aroma was strongly influenced by ten of the chemicals ((Z)-3- hexenal, b-ionone, hexanal, 1-penten3-one, 3-methylbutanal, (E)-2-hexenal, 1-nitro-2- phenylethane, (E)-2-heptenal, 6-methyl-5-hepten-2-one, and 2-isobutylthiazole). Sniffing a tomato sample revealed that five aroma volatiles (hexanal, (E)-2-hexenal, 2-methyl-2- hepten-6-one, 2-isobutylthiazole, and Valero nitrile) were significant contributions to the fresh tomato scent (Wang *et al.*, 2016)

2.7 Nutritional value of tomato

Nutrition value of tomato per 100 g wb is shown in the Table no. 2.1

Table 2.1 Nutritional value of tomato per 100 g wb

Parameters	Value/100 g (unit)	Parameters	Value/100 g (unit)
Energy	74kJ (18kcal)	Potassium	237 mg (5 %)
Carbohydrates	3.9 g	Lycopene	2573 µg
Sugar	2.6 g	Vitamin A equiv.	42 µg (5 %)
Dietary fiber	1.2 g	β-Carotene	449 µg (4 %)
Fat	0.2 g	Lutein/Zeaxanthin	123 µg
Protein	0.9 g	Thiamine	0.037 mg (3 %)
Water	94.5 g	Niacin	0.594 mg (4 %)
Magnesium	11 mg (3 %)	Vitamin B_6	0.08 mg (6 %)
Manganese	0.114 mg (5 %)	Vitamin C	14 mg (17 %)
Phosphorus	24 mg (3 %)	Vitamin E	0.54 mg (4 %)
		Vitamin K	7.9 µg (8 %)

(Butnariu and Butu, 2015)

2.7.1 Proximate composition

2.7.1.1 Moisture

Abdullahi *et al.* (2016b) reported the average moisture content of tomatoes is about 95%. The freshness and hardness of tomatoes are very important factors that determine the deviation in moisture content in tomatoes. There are variations in the moisture content of different species of tomatoes as moisture content is particularly influenced by humidity, the temperature of cultivation, and storage condition.

2.7.1.2 Crude protein

Proteins, which are macromolecules present in food, are important for cellular structure and biological functions. Protein analysis is crucial for nutritional labeling, as well as in describing the biological activities and functional properties of food products. The total protein present in tomatoes ranges from 0.8-1.5 % (wb) (Brodowski and Geisman, 1980).

2.7.1.3 Crude fiber

Tomato is a good source of fiber because it contains plenty of both soluble and insoluble fibers. Tomato is one of the most fiber-rich foods. Fiber content in tomatoes ranges from 0.70-2.25% (wb) which varies within different varieties (Ali *et al.*, 2020a).

2.7.1.4 Total ash

Zaka (2011) states that the total ash of tomatoes ranges from 0.3-0.7% (wb).

2.7.1.5 Fat

Tomato is a low-fat food. Low-fat content, high fiber content, and absence of cholesterol make tomatoes dietician's choice for heart patients. reported 0.62% (wb) fat in tomatoes (Del Valle *et al.*, 2006).

2.7.2 Bioactive components of tomatoes

All tomato-derived products have some level of antioxidant activity, which is attributed to bioactive components such as lycopene, β-carotene, vitamin C, polyphenols, and flavonoids. Tomatoes are therefore an extremely high in nutrients (Brooks *et al.*, 2008b). . Evidence affirms that an increase in fruit and vegetable consumption is a good means of protection against free radicals (Mostapha *et al.*, 2014). Free radicals which include singlet oxygen, reactive nitrogen species are known to cause damage to lipids, proteins, enzymes and nucleic acids that lead to cell or tissue damage implicated in the process of ageing as well as in a wide range of degenerative diseases including inflammation (Chauhan *et al.*, 2011; Martínez-Valverde *et al.*, 2002; Xue *et al.*, 2016).

Epidemiological studies describe an inverse relationship between a diet rich in tomatoes and tomato products and the incidence of cardiovascular diseases (Jacob *et al.*, 2010). However, the antioxidant activity of tomatoes depends on both generic, environmental factors and the ripening stage (Chauhan *et al.*, 2011).

2.7.2.1 Lycopene

Lycopene ($C_{40}H_{56}$) is a lipid soluble bioactive carotenoid found in most fruits and vegetables such as tomatoes, watermelon, pink grapefruits, apricots, red pepper and pink guava (Rao *et al.*, 2008). It has eleven conjugated double bonds and two unconjugated double bonds that are arranged in a linear array thus has a high potency as a singlet oxygen scavenger (Chawla *et al.*, 2008). Lycopene absorbs light during photosynthesis and offers protection from photosensitization in plants (Shi *et al.*, 2004). In tomatoes, it is the predominant carotenoid that is responsible for the red pigment and constitutes 80-90% of the total carotenoids (Burton-Freeman and Reimers, 2011). Research suggests that tomatoes contain lycopene concentration in the range of 0.85-13.6 mg /100 g fresh weight with a two-fold higher concentration being reported in the pericarp than the locular cavity (Chauhan *et al.*, 2011). However, lycopene content of tomatoes depends on species and increases as the fruit ripens (Chauhan *et al.*, 2011).

Lycopene exists in foods primarily in the trans stereoisomeric configuration; however, cooking and processing help convert trans-lycopene to cis-lycopene, which is more readily absorbed. Studies have reported that bioavailability of lycopene increases through matrix disruption during mechanical homogenization and heat treatment (Capanoglu *et al.*, 2010). However intensive heat treatment has been reported to cause lycopene degradation. Degradation is mainly as a result of oxidation and isomerization which is manifested through loss of color and reduced biological value of lycopene (Chauhan *et al.*, 2011) . Elimination of the skin had more effect on the content of lycopene (Vinha *et al.*, 2014).

The major factors that lead to lycopene loss during dehydration include: heat, light and oxygen (Goula and Adamopoulos, 2012). Increase in temperature during dehydration translates to increase in lycopene loss. The thermal damage incurred is directly proportional to the heating temperature and exposure time (Abano *et al.*, 2011). Isomerization of lycopene causes conversion of all trans to cis forms (Yetenayet and

Hosahalli, 2015). Cis isomers generally increase with increase in temperature and duration of processing (Temitope *et al.*, 2009). Therefore, heat processing should be done at low temperatures to avoid significantly high lycopene losses (Ishiwu Charles *et al.*, 2014). The content of lycopene decreases with increase in illumination (Nisha *et al.*, 2011). Exposure of lycopene to light is therefore detrimental to lycopene. Only gold, yellow or red light should be used to minimize lycopene degradation and isomerization (Huawei *et al.*, 2014).

In addition, exposure of lycopene to oxygen has negative effects on lycopene stability during drying. Therefore, gases such as carbon dioxide, nitrogen or vacuum conditions are ideal during heat treatment (An *et al.*, 2013). Use of pretreatments such as calcium chloride and sodium metabisulphite also reduces lycopene degradation (M. Hossain *et al.*, 2008); (Rosemary Mwende *et al.*, 2018b). These solutions remain on the surface layer of the tomato and prevent oxygen from penetrating and oxidizing lycopene (Rosemary Mwende *et al.*, 2018b)

2.7.2.2 Phenolic compounds

Phenolic compounds are secondary plant metabolites, which are important determinants of the sensory and nutritional quality of fruits and vegetables (Bayili *et al.*, 2011). Fruit ripening is typically accompanied by substantial changes in the profile of phenolic antioxidants (Kalt, 2005). The main classes of phenolic compounds include flavonoids, tannins, chalcones and coumarins and phenolic acids. Polyphenolic compounds are synthesized from phenylalanine from the shikimic acid pathway and protect plants from abiotic and biotic stress (Ruiz-García and Gómez-Plaza, 2013). The number of phenolic compounds in fruits is strongly dependent on the degree of ripeness, variety, climate, soil composition, geographic location and storage conditions, among other factors (Ruiz-García and Gómez-Plaza, 2013).

Phenolic compounds relate with corresponding antioxidant activity which has been linked to slow down the ageing process and lowered risks of many prevalent chronic diseases such as cancer and coronary heart diseases (Boonkasem *et al.*, 2015); (Brooks *et al.*, 2008a).Total phenolic compounds are vulnerable to degradation during drying (Kerkhofs *et al.*, 2005). Oxidative reactions set in during the drying process resulting in loss of total phenolics in a food material (Orak *et al.*, 2012). The presence of double bonds and alcohol group in phenolic compounds make them vulnerable to heat damage. It has been reported that activation of oxidative enzymes occurs during thermal dying leading to loss of phenolic compounds (Gümüşay *et al.*, 2015). Reducing exposure of phenolics to heat and oxygen by increasing the drying rate, use of low drying temperatures and also use of pretreatments such as sodium metabisulphate and calcium chloride may result in reduced phenolic loss (Jacob *et al.*, 2010); (Rosemary Mwende *et al.*, 2018c)

2.7.2.3 Antioxidant activity

The antioxidant capacity represents the ability to inhibit the process of oxidation. It is a very desirable property of foods since oxidation plays a crucial role in the pathogenesis of several human diseases and aging. Tomatoes are recognized as a food with high antioxidant properties due to the presence of several natural antioxidants with complementary mechanisms of action (e.g. lycopene, phenolic compounds, ascorbic acid (George *et al.*, 2004) (Martínez-Valverde *et al.*, 2002) (; Martínez-Valverde *et al.*, 2002; Toor & Savage, 2005). The need to account for chemically diversified substances motivated the development of different methods to evaluate the antioxidant capacity of foods. Several assays have been frequently used to estimate antioxidant capacities in plant extracts including DPPH (2,2- diphenyl-1-picrylhydrazyl), ABTS (2,2′-azinobis (3-ethylbenzothiazoline 6-sulfonate)), FRAP (ferric reducing antioxidant potential), and ORAC (oxygen radical absorption capacity) assays (Dudonne et al., 2009).

Generally, DPPH-based radical scavenging activity has been used to evaluate the antioxidant activity of agricultural products. The highest adsorption of the stable free radical DPPH occurs around 517 nm. Total phenolic content was positively correlated with the antioxidant activity to some extent (Kaur *et al*., 2018). The removal of the skin and seeds reduces the ability of the tomato material to capture DPPH (Vinha *et al*., 2014).

The blanching pretreatment and high drying temperature caused the decrease in antioxidant compound (Sengkhamparn *et al.*, 2013). On the basis of experiments performed by (Réblová, 2012) with phenolic acids, the existence of a relationship between the relative decrease in antioxidant activity with increasing temperature and the oxidisability of the antioxidants was found. According to this relationship, the easily oxidisable antioxidants show a decrease in antioxidant activity with increasing temperature (in comparison with their activity at a low temperature) at a slower rate than the less oxidisable ones, and maintain their antioxidant activity also at higher temperatures.

2.7.2.4 Vitamin C

Vitamin-C is a white crystalline compound, relatively simple structure and closely related to the monosaccharide sugars, with sour taste but no smell its empirical formula is $C_6H_5O_6$ and molecular weight is 176. Vitamin C was given the name ascorbic acid by its discoverer (Mottram, 1974). Ascorbic acid is highly soluble compound that has both acidic and strong reducing properties. It is the most unstable of all known vitamins. In solution it easily gets oxidized, especially on exposure to heat. Oxidation is accelerated in the presence of copper and alkaline pH. On mild oxidation ascorbic acid is converted into dehydroascorbic acid. The oxidized form may be reduced back to ascorbic acid. Both ascorbic acid and dehydroascorbic acid have the vitamin C activity. When dehydroascorbic acid is treated with weak acid it is converted into diketogulonic acid (DKG) with no vitamin C activity, it cannot be reduced to dehydroascorbic acid again (Manaya, 2008)

Bhatkar *et al.* (2021) found that, drying of tomato either by sun or oven greatly reduced the ascorbic acid concentration to less than half content of their original values. These results agreed with Das Purkayastha *et al.* (2013).This could be attributed to the fact that ascorbic acid is not stable at high temperature (Negi and Roy, 2000). Ascorbic acid is one of the substances that contribute to the antioxidant capacity in tomato juices and by products. Ascorbic acid degradation during drying depends mainly on temperature, time and metal ions traces (Özkan *et al.*, 2004)

2.8 Tomato products

As an abundant commodity in agriculture, tomatoes are an essential part of the human diet. One of the most adaptable and widely used fruits, they can be eaten raw or used to make a wide range of dishes. Consuming tomatoes and tomato products on a regular basis, have been associated with a decreased risk of cardiovascular disease and many types of cancer. The antioxidants found in tomatoes are responsible for this beneficial effect (Collins *et al.*, 2022).

2.8.1 Tomato paste and puree

Tomato paste is a product made by concentrating tomato pulp after removing the peels and seeds, and it includes 24 % or more natural tomato soluble solids (NTSS). Tomato paste, which is offered in small packs to consumers as a condiment, is also known as tomato puree. Tomato puree refers to tomato paste with a lower proportion of NTSS (8 % to less than 24 %). Unfortunately, tomato puree is also known as 'tomato pulp' in the United States. Color, consistency, and flavor are the primary quality characteristics for tomato paste, and there are other compositional guidelines such as total solid, salt content, ash content, copper content, Vitamin C and many more (Hayes *et al.*, 1998)

2.8.2 Tomato sauce/ ketchup

There is minimal difference between sauce and ketchup. Sauces are often thinner and have higher solid content than ketchups. Sauces contain ingredients such as tomato, apple, papaya, walnut, soybean, and mushroom sauces and ketchups employ the same ingredients and procedure as chutney, but filter the fruit or vegetable pulp or juice before cooking to remove skin, seeds, and stems, resulting in a smoother consistency. Cooking time is increased due to the use of fine pulp or juice (Srivastava and Kumar, 2002).

2.8.3 Tomato pickle

Pickles are processed foods made from fruits, vegetables, fish, or meat that have been preserved with natural salt, vinegar, or oil. Pickles are an edible product that has been preserved and seasoned in a brine and edible acid solution, such as vinegar. In pickling, salt, vinegar, and spices are frequently used in combination (Bhuiyan, 2012). Homemade tomato pickles fermented with vinegar are increasingly popular due to their acidic flavor and improved piquancy (Barigela and Bhukya, 2021).

2.8.4 Tomato chutney

Chutney is produced from a combination of fruits, herbs, and spices. They are frequently made with fresh ingredients, therefore they must be consumed immediately or preserved in the refrigerator (Bhuiyan, 2012).Tomato chutney can be made with both green and ripe tomatoes, as well as onion, sugar, vinegar, and a variety of other ingredients, including spices (Siebert, 2017)

2.8.5 Tomato soup

Soup is a heterogeneous dish that combines vegetables, fish, or meat with water, juice, stock, and and some thickening additives, and is classified as a heterogeneous food (Radha *et al.*, 2015). Heat improves lycopene bioavailability, which is better absorbed by the body when the tomato is cooked, making it perfect for consumption of tomato sauces and soups (Correia *et al.*, 2015).

2.8.6 Canned tomatoes

Canning involves preparing and sealing food components in an airtight container to preserve them. Freeze-dried canned products can last up to 30 years if stored properly (Potter and Hotchkiss, 2012). Processing tomatoes, which have a tougher outer peel and pectin layer, are used in commercial canneries. Tomatoes that have been industrially canned are a significant product that undergoes frequent market study and trade considerations. However, safety precautions must be followed because botulism poisoning can be brought on by inadequately canned tomatoes, whether they are made commercially or at home (Redlinger and Nelson, 1990)

2.8.7 Tomato juice

Tomato juice is made from whole crushed tomatoes that have been properly screened to remove skin and seeds. The juice contains colloidal serum particles greater than 150 m in diameter (Tanglertpaibul and Rao, 1987). Tomato juice viscosity is highly dependent on high molecular weight, water-soluble pectin and their degree of esterification (Fishman *et al.*, 1989). Tomato juice is a substantial source of antioxidants - carotenoids and vitamin E, as well as various minerals and trace elements, in terms of providing a man with micronutrients and minor biologically active chemicals (Ivanova *et al.*, 2018).

2.8.8 Tomato powder

Fruit and vegetable powders can be used in a variety of recipes, including soups, sauces, marinades, infant meals, dips, extruded cereals, fruit purees, and frozen snack fillings. Processing firms can profit from the increasing market of dehydrated tomato powder (Abinaya and Sridevi, 2021). All that is known as tomato powder is simply dried tomatoes that have been ground up and kept for a long period. Since tomato powder is used in a lot of convenience foods, it is highly sought after. The abundance of vitamins

A and C in tomato powder not only preserves the skin and eyes, as well as the immunological system. It also has a high concentration of 18 minerals, including iron, magnesium, potassium, and folate, which support a number of the body's metabolic functions. It can serve as a foundation for liquid tomato preparations like tomato paste and tomato sauce, as well as a spice, flavoring and garnish (Srivastava and Kulshrestha, 2013). The preparation of dehydrated tomato powder is also for the ease of transit, handling, and storage without extra care. If powdered tomato can be manufactured, it will help to reduce wastage, price, and enhance availability throughout the year (Jayathunge *et al.*, 2012). Dehydrated tomato powder can also be used as a raw tomato substitute in the development of fresh food recipes (M. Sarker *et al.*, 2014)

2.9 Preservation of tomato

Tomatoes are a perishable product. As a result, advantageous preservation methods are developed for farmers who produce a significant quantity of tomatoes. A large range of tomato products are manufactured utilizing concentrated juice or pulp, which necessitates expensive technology for high-quality results. As a result, the development of low-cost processing and packaging approaches to manufacture shelf-stable and convenience items is one of the most pressing needs in today's competitive market. As a result, drying is the best way for meeting the following conditions (Jayathunge *et al.*, 2012).

2.9.1 Drying

One of the most significant and ancient physical methods of food preservation is drying. It is most frequently applied to fruits, vegetables, spices, and other items with a high moisture content (>80%) that are thought to be very perishable in order to lower the moisture content of those commodities (Changrue *et al.*, 2006). Drying involves application of heat to a substance that causes moisture within the material to transfer to its surface and then water removal from the material to the atmosphere (Ekechukwu and Norton, 1999).

The most popular method of food preservation that extends shelf life and improves product quality is drying. In addition to preservation, reducing the weight and volume of dried goods minimizes handling, packing, and shipping costs. Additionally, 10% to 15% of the total energy used by the food industries in the industrialized countries is expected to be absorbed by drying (Keey, 2013). Drying is arguably the most long-standing, diverse, and conventional operation. Food drying is a vital technology for the food industry, providing opportunities for ingredient discovery and unique products for customers. There have been significant technological breakthroughs in recent years related to industrial drying of food, including pre-treatments, processes, equipment, and quality (Moses *et al.*, 2014).

2.9.2 Methods of drying

2.9.2.1 Sun drying

Around the world, sun drying is a common practice, especially in tropical and subtropical nations. Due to its abundance, limitlessness, and lack of pollution, solar energy is a prominent alternative energy source that is preferred over other energy sources. In addition, it is affordable, renewable, and ecologically friendly (Basunia and Abe, 2001). The lack of pricey equipment makes the procedure simple. The item to be dried is spread out in the sun, allowing the moisture to gradually evaporate. Despite its simplicity, the procedure has drawbacks such as dust pollution, insect infestation, microbiological contamination, and deterioration due to rainfall. Product dried in this manner is unsanitary and, in certain cases, unsafe for human consumption (Garg and Prakash, 1997). Shrinkage, case hardening, loss of volatiles and nutritional components, and decreased water reabsorption following rehydration may occur as a result of sun drying. As a result, the quality of the sun-dried products degrades (Kulanthaisami *et al.*, 2010).

2.9.2.2 Solar drying

Solar driers can be utilized successfully in developing nations as an appealing drying technique that can assist minimize crop losses and improve dried product quality. Solar drying is used to improve product color, taste, and appearance. Solar drying reduces the possibility of microorganism growth while also preventing insect infection and contamination from foreign debris and toxins. The developed solar drier was capable of producing an average drying temperature ranging from 48°C to 54°C. The solar tunnel drier was compared to open air drying (Rajarajeswari *et al.*, 2016). As air travels through the collector, it is heated and then partially cooled as it picks up moisture from the produce. The product is heated by both hot air and the sun. An indirect type solar dryer is used as an alternative to traditional drying methods and to alleviate the problem of open sun drying (Lingayat *et al.*, 2017).

2.9.2.3 Cabinet drying

An insulated cabinet with shallow mesh or perforated trays that each store a thin layer of food is the basis for cabinet driers. There is heated air in the cabinet tray. Air is directed over and/or through each food tray by means of a duct and baffle system, which facilitates uniform air distribution either vertically or horizontally between the food trays and food. There are various kinds of air heaters, including electrical resistance heaters, steam coil exchangers, and direct gas burners. Because the air is forced past the heater's, heated air is used for dying. It is generally inexpensive to create and maintain, has a flexible architecture, and provides inconsistent product quality due to weak control. It is used alone or in groups, primarily for small-scale (1-20 ton/day) production of dried fruits and vegetables (Fellows, 2022).

For drying fruit and vegetables, cabinet dryers are the most used piece of agricultural equipment. These dryers may be used almost anywhere, have an inexpensive installation cost, and have a simple design. But businesses typically aren't willing to employ cabinet dryers because of the inherent disadvantage of the end product's non-uniform moisture level (Amanlou and Zomorodian, 2010). When compared to sun drying, the drying rate in a cabinet drier with the same feed rate was faster since the temperature was higher and the conditions were monitored (Kaur *et al.*, 2006).

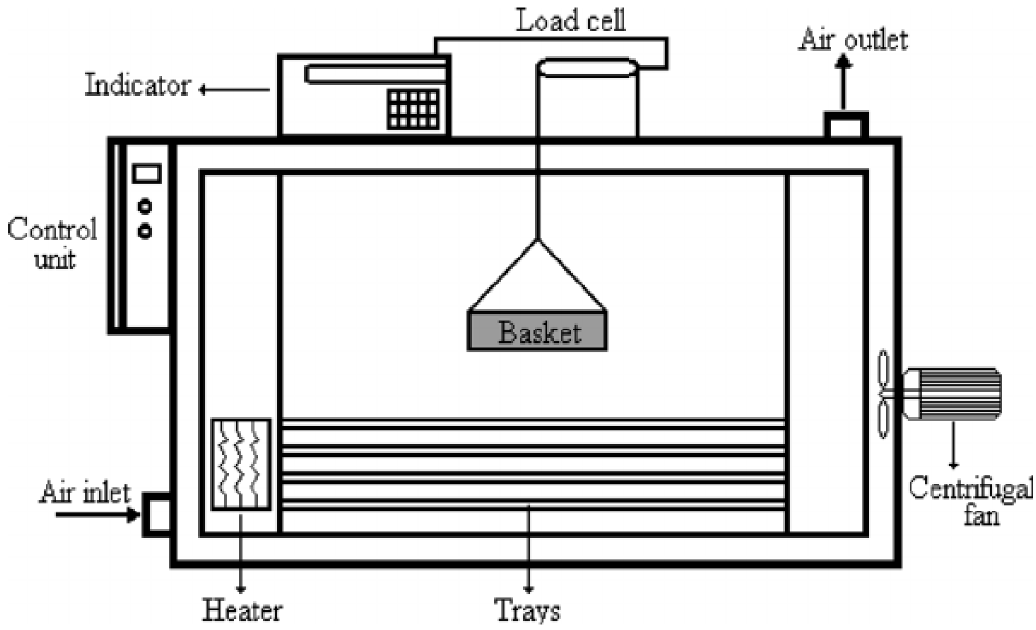

Fig 2.2 Schematic diagram of cabinet dryer

2.9.3 Effect of drying

Drying tomatoes greatly reduces their moisture, which helps preserve them and makes nutrients look higher when measured on a dry basis. Proteins, fats, minerals (ash), fiber, and carbohydrates all become more concentrated as water is removed. However, some nutrients are sensitive to heat. Vitamin C drops a lot during drying, and antioxidants like phenolic compounds also decrease Lycopene may get more concentrated, but too much heat can break it down (Doymaz, 2007).

Physically, drying changes the tomato's structure. The bulk and true density usually increase because the tissue shrinks and packs tighter, while porosity goes down as air spaces disappear. Dried tomato powder can dissolve more easily in water, but if drying temperatures are too high, it may not rehydrate well (Farooq *et al.*, 2020). Overall, drying makes tomatoes last longer but lowers some healthy compounds and alters their texture. Therefore, various pretreatment should be done to overcome these problems.

2.9.4 Significance of drying

For the food sector and customers alike, finding a way to obtain an extended shelf life would be beneficial. There are numerous applications for dried tomatoes in products.

Moreover, higher drying temperatures promote enzymatic reactions that can improve the flavor of dried tomatoes. Pre-treatment methods and drying may contribute to the deterioration of both the eating quality and the nutritive value of a food product. Advances in drying technology and standardization techniques in compound analysis allow for the possibility of using drying for the development of functional foods and nutraceuticals. The selection of the type of dryer or drying system used for a specific situation is based upon the product's characteristics and drying behavior, as well as the end product required (Beaudry *et al*., 2003).

Tomato which comes seasonally cannot be kept for a long time without preservation. Thus, the benefits of dehydrating tomatoes, as water is removed are as follows:

i. To extent the self-life.

ii. To retain its natural color, maximum nutrients, texture, and flavors as in fresh vegetables.

iii. To prevent the spoilage of perishable foods.

iv. To reduce the transportation cost (Vega-Mercado *et al*., 2001).

2.10 Pretreatment

To minimize adverse changes during drying and subsequent storage, tomatoes can be pre-treated with chemicals before drying. Some quality attributes of tomato can by affected by pretreatment, including total solids, fats, proteins, lycopene, vitamin C ,dehydration ratio, rehydration ratio and color (Owureku-Asare *et al.*, 2014) . The most popular/repeated chemical pretreatment used for tomato by different researches are: Potassium Metabisulphite (KMS), Calcium Chloride ($CaCl_2$), Ascorbic Acid ($C_6 H_8 O_6$), Sodium chloride (NaCl) and Sodium Benzoate, are individually or by mixing them in different ratio example ascorbic acid with citric acid, KMS with $CaCl_2$ and with different concentrations etc (R. Mwende *et al.*, 2018a).

2.10.1 Effect of pretreatments

Effect of various pretreatments on tomato slice are discussed below.

i. Calcium chloride ($CaCl_2$): According to A. Baloch *et al.* (2003) $CaCl_2$ almost completely suppressed browning. Pre-treatment with $CaCl_2$ increased water removal and moisture mobility in tomato slices during drying and influenced the drying kinetics of tomatoes by evident changes in the texture of dip-treated tomatoes.

ii. Potassium Metabisulphite (KMS): Potassium metabisulfite is a food preservative that protects against bacteria while preserving the natural color of food. Using potassium powder mixture in food items allows for a significant reduction in sodium content. It works as a preservative, antioxidant, and bleaching agent, extending the shelf life of tomato(Madan *et al.*, 2008).

iii. Ascorbic acid: Ascorbic acid prevents the oxidation and the discoloration of the powder during the storage(F. Sahin *et al.*, 2011a)

iv. Sodium chloride : Better retention of proximate components after drying is observed in the NaCl treated sample(Tilahun *et al.*, 2022).

v. Sodium Benzoate: Better retention of protein, fat and fiber after drying is observed in the Sodium Benzoate treated sample(Tilahun *et al.*, 2022)

2.10.2 Significance of pretreatment

There is various significance of pretreatment, among them some of them are discussed below.

i. Enzyme Inactivation: Pretreatments, such as blanching, deactivate enzymes that contribute to undesirable changes in flavor, color, and texture during drying (Piyalungka *et al.*, 2019)

ii. Microbial Load Reduction: Pretreatment methods, particularly those involving heat, effectively reduce microbial contamination, enhancing the safety and shelf life of dried tomato products (Seth and Chatterjee, 2016)

iii. Nutrient Retention: Pretreatments contribute to the preservation of essential nutrients, such as vitamin C, by minimizing degradation during drying (Amato *et al.*, 2015)

iv. Color Preservation: The use of pretreatments helps maintain the natural color of tomatoes, ensuring an appealing and marketable appearance in the dried product (Rosemary Mwende *et al.*, 2018b)

v. Texture Improvement: Properly executed pretreatments positively impact the texture of dried tomato products, resulting in improved mouthfeel and rehydration properties (Askari *et al.*, 2009)

vi. Synergistic Effects in Combination Methods: Combined pretreatment methods exhibit synergistic effects, offering a holistic approach to achieving multiple processing objectives simultaneously (Ladole *et al.*, 2018)

vii. Extended Shelf Life: Effective pretreatments contribute to the overall shelf life and storage stability of dried tomato products by reducing enzymatic and microbial activity (Dermesonlouoglou *et al.*, 2017)

2.11 Physical properties of tomato powder

2.11.1 Bulk density and true density

Bulk density is a function of particle size, particle size being inversely proportional to bulk density (Omimawo and Akubor, 2012). True density refers to the mass-to-volume ratio of compacted ginger powder without vacant positions. The differences in the particle size may be the cause of various in bulk density of powder. The bulk density of powders is determined by particle density, which in turn is determined by solid density and particle internal porosity, of the particles in the container. Powders have "loose bulk density", that is, a measured density after a powder is freely poured into a container and "compact density", after it is allowed to compress by mechanical pressure, vibration, and/or impact (Sherpa, 2018). Bulk density is a measure of bulkiness of powder and an important parameter that determines the suitability of powder for the ease of packaging and transportation of particulate foods as well as for infant formulations the low bulk density powder can be used (Nelson-Quartey *et al.*, 2007). According to Ishrat *et al.* (2020), the bulk density of tomato powder range from 0.52 to 0.75 g/ml whereas true density of tomato powder is higher than the bulk density whose value ranges from 1.1 to 1.5 g/ml.

2.11.2 Solubility

Solubility is one of the most important physiochemical and functional properties of powder. The high solubility of powder indicated potential applications in formulated food systems by providing an attractive appearance and a smooth mouth feel to the product (Kanpairo *et al.*, 2012). Solubility values of tomato powder ranged from 15-23% for all samples (Abou-Arab *et al.*, 2017).

2.11.3 Porosity

Porosity is also an important physical property of powder. It is due to the colloidal nature of powder itself and position of intergranular space within the bulk of powder. The extent of porosity depends upon the size, shape, elasticity, surface state, dockage level, weight, compactness, storage period and distribution of moisture in the bulk of powder. This physical characteristics in turn influence the movement of air, heat and moisture. Porosity can affect the storage stability of powder. the porosity of tomato powder is commonly reported as 0.45 to 0.55 (Lowell and Shields, 2013).

Part III

Material and methods

3.1 Materials

3.1.1 Raw material used

Good quality tomatoes (*Solanum lycopersicum*) of local variety were purchased from the local market of the Dharan. The fresh samples were taken in batches because of perishability. However, the samples were collected at maturity stage "red" which means that 90 percent of the surface in the aggregate shows red color (USDA, 1991).

3.1.2 Chemical used

All chemicals were used from the laboratory of CCT Dharan which are given in appendix A.1

3.1.3 Equipment used

All equipments were used from the laboratory of CCT Dharan which are given in appendix A.2

3.2 Methods

3.2.1 Experimental plan

The experimental procedure of tomato powder preparation is shown in **Figure. 3.1**

Raw/fresh tomato

↓

Sorting, Cleaning and Washing

↓

Cutting a tomato into 8 equal halves longitudinally (5cm long, 2cm wide and 1cm thick)

↓

Dipping and pretreating with Potassium Metabisulphite, Calcium Chloride, Sodium Chloride and distilled water separately for 10 min (they were washed by dipping in distilled water in 1:1 w/w to remove residue)

↓

Drying each separately by using cabinet dryer at temperature of 55, 60 and 65 ºC for 12 hour, 10 hour and 8 hour respectively

↓

Cooling & grinding with a blender

↓

Dried tomato powder

↓

Packed in aluminum foil

↓

Analysis for different parameter(Gaware *et al.*, 2010)

Fig 3.1 Preparation of tomato powder

3.2.2 Experimental design

Experimental design for laboratory analysis is shown in **Table 3.1**

Sample Code	Pretreatment	Drying temperature(ºC)
A	KMS	55
B	KMS	60
C	KMS	65
D	$CaCl_2$	55
E	$CaCl_2$	60
F	$CaCl_2$	65
G	NaCl	55
H	NaCl	60
I	NaCl	65
J	Control	55
K	Control	60
L	Control	65

3.2.3 Preparation of tomato powder

3.2.3.1 Selection of tomato

Good quality tomatoes var. Trishul were purchased from the local market of the Dharan. The fresh samples were taken in batches because of perishability. However, the samples were collected at a particular stage of maturity i.e red which means that 90 percent of the surface in the aggregate shows red color.

3.2.3.2 Sorting, Washing and Cutting

The collected fresh tomatoes was sorted and washed. The sorted tomatoes were then sliced into eight halves longitudinally (5cm long, 2cm wide and 1cm thick) as part of preliminary preparations. Tomatoes was sliced using stainless steel knives within a clean environment.

3.2.3.3 Chemical pre-treatment

The tomato slices was treated as follows: a) Dipping 2kg tomato slices in 2 liter $CaCl_2$ solution of 1% concentration at room temperature for 10 min. b) Dipping 2kg tomato slices 2 liter KMS solution of 0.2% concentration at room temperature for 10 min and surfacely washed c) Dipping 2 kg tomato slices in 2 liter of NaCl solution of 7% concentration for 10 min d) 2kg Tomato slices dipped in 2 liter of distilled water for 10 min were considered as controlled sample. (Davoodi *et al*., 2007).

3.2.3.4 Drying using cabinet dryer

The pre-treated tomato slices were washed by dipping with distilled water in 1:1 w/w ratio to remove residue. And then taken for drying using air convection drying techniques as described by (Rao *et al*., 2008). The pretreated tomato slices were dried in the cabinet dryer. The tomatoes were placed uniformly on stainless steel trays by spreading the slices as a single layer and drying was conducted at 55, 60 and 65 ºC temperatures and at a constant airflow velocity of 0.7 m/s for various time duration. After cooling at room temperature, the dried tomato flakes were ground by using blender to produce tomato powder. The finished product was used for further analysis.

3.2.4 Analytical Procedure

3.2.4.1 Proximate and physio-chemical analysis

3.2.4.1.1 Moisture content

Moisture content of the sample determined by hot air oven method described by Ranganna (1986) until constant weight was obtained.

3.2.4.1.2 Crude protein

Crude protein content of the sample was determined indirectly by measuring total nitrogen content by micro Kjeldahl method with conversion factor 6.25 described by Ranganna (1986).

3.2.4.1.3 Crude fat

Crude fat content of the sample was determined by solvent extraction method using Soxhlet apparatus described by Ranganna (1986).

3.2.4.1.4 Crude fiber

Crude fiber content of the sample was determined by the method described by Ranganna (1986).

3.2.4.1.5 Carbohydrate

The carbohydrate content of the sample was determined by difference method described by Ranganna (1986).

Carbohydrate (%) = 100 – (crude protein + crude fat + crude ash + crude fiber)

3.2.4.1.6 Total ash

Ash content was determined by method described by Ranganna (1986) by using muffle furnace.

3.2.4.1.7 Lycopene

Lycopene content was determined by method described by Suica-Bunghez *et al.* (2011). 0.5 g of sample was accurately weighed into a 125 ml Erlenmeyer flask and 50 ml of mixed solvent was added into it. Mixed solvent consists of hexane: ethanol: acetone in the ratio 2:1:1. The flask was sealed and after about 10 minutes of extraction, 7.5 ml of water was added to separate the phases. The upper phase was separated and its absorbance was determined at 503 nm on spectrophotometer.

The lycopene concentration is given by:

$$\text{Lycopene (mg/100g db)} = \frac{A \times 171.7}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots..(3.1)$$

where A_{503} is the absorbance and W is the exact weight of tomato taken, in grams.

3.2.4.1.8 Total phenolic content

Preparation of extract

The extract was prepared by cold percolation method according to Niroula *et al.* (2019) and Stankovic (2011) with some modifications. About 2g of sample was extracted into 20ml methanol, extracts were subjected to magnetic stirrer for 2h for each sample. Then the extract was filtered through Whattman no. 1 filter paper. The filtrate was collected in a 50ml volumetric flask covered with aluminum foil. After volume made up to 50ml with methanol, the fresh sample was used for TPC analysis.

Determination of total phenol content

Total phenols was determined with the Folin-Ciocalteau reagent according to Niroula *et al.* (2019) and Stankovic (2011) with some modification. 1ml sample was mixed with a 10 ml (80%) methanol solution. Then the solution was mixed with 1ml of Folin-ciocalteau reagent, and 5 minutes later, 2.5 ml of sodium carbonate (7.5% w/v) and 2.5ml of distilled water was added. Then the mixed sample was placed in dark condition for 45min. The absorbance was measured using a UV-VIS spectrophotometer at 765nm. A typical calibration plot ($R^2 \geq 0.99$) was prepared with Gallic acid as standard [10-100 ug/ml] and used to determine the total phenolic content in investigated samples as Gallic acid equivalent [GAE].

3.2.4.1.9 Determination of Radical Scavenging Activity

Preparation of extracts

The tomato ethanolic extract was made in accordance with G. Singh *et al.* (2010). 30 ml of methanol were used to extract 1 g of tomato powder, and the mixture was centrifuged at 4000 rpm for 15 min at 32°C. Using Whatman filter paper 41, the resulting supernatant was filtered. Methanol was added to create a volume of 50 ml.

DPPH method for determination of antioxidant activity

Free radical scavenging activity of sample was measured in vitro by DPPH (2,2-diphenyl-1-picrylhydrazyl) assay as described by G. Singh *et al.* (2010). 0.5ml of sample extracts was mixed with 4.5ml of methanolic DPPH solution of 0.004% (4 mg of DPPH in 100 ml of methanol). After incubation in dark for 30min at room temperature, the absorbance was measured at 517nm using an UV-Visual spectrophotometer. A typical calibration plot ($R^2 \geq 0.99$) was prepared with Ascorbic acid as standard. The DPPH scavenging percentage by samples and AA was calculated using the equation.

$$\text{DPPH radical scavenging activity (\%RSA)} = \frac{A0\text{-}A1}{A0} \times 100 \ldots\ldots\ldots\ldots..(3.2)$$

Where, A0 is the absorbance of the DPPH radical + methanol;

A1 represents the absorbance of the DPPH radical + sample or standard.

3.2.4.1.10 Vitamin C

Vitamin C(Ascorbic acid) was determined by 2,6 - dichlorophenol indophenol visual dye method as described by Ranganna (1986). To measure vitamin C, the fresh and dried tomato was ground and extracted by 3% meta-phosphoric acid (HPO_3).

Dye factor was calculated by using the formula

$$\text{Dye factor} = \frac{\text{mg of ascorbic acid}}{\text{ml of dye}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.3)$$

Vitamin C was determined by the formula

$$\text{Vitamin C (mg/100 g)} = \frac{\text{Titer} \times \text{dye factor} \times \text{volume made up (ml)} \times 100}{\text{ml of aliquot} \times \text{ml(g)of sample taken}} \ldots\ldots\ldots\ldots(3.4)$$

3.2.4.2 Analysis of physical properties

3.2.4.2.1 True density

Density is one of the physical properties of substance, defined as the mass contained in a given volume. It is determined by the method suggested by Ishrat *et al.* (2020). In this method a known weight of sample is taken and placed in a measuring cylinder containing known volume of toluene. The volume of toluene displaced is noted and then the density is determined as;

$$\text{True density} = \frac{\text{weight of sample}}{\text{volume of toluene displaced}} \quad \text{.........................(3.5)}$$

3.2.4.2.2 Bulk density

The bulk density was determined according to the method described in Kanpairo et al. (2012) with some modifications. 25 g of sample was gently filled into a dried 50 ml graduated cylinder, tapped gently the cylinder for 25 times. The volume of the powder was recorded. The bulk density was calculated as following relationship.

$$\text{Bulk density} = \frac{\text{Weight of powder (g)}}{\text{Volume of powder (ml)}} \quad \text{...................(3.6)}$$

3.2.4.2.3 Porosity

Porosity of the powder samples was calculated using the relationship between the bulk and the true density of the powder as shown below:

$$\text{Porosity} = \frac{\text{True density - Bulk density}}{\text{True density}} \quad \text{.....................(3.7)}$$

3.2.4.2.4 Solubility

The method of Goula *et al.* (2004) was adopted for determination of solubility. Powder dispersions of samples were prepared by dispersing 1 g of powder in distilled water and made up to 10 ml. It was allowed to settle for 15 min after which 2 ml of the supernatant was transferred using a pipette into a weighed, dry Petri dish. It was evaporated to dryness and reweighed. The total soluble solids (TSS) were then calculated.

$$TSS\ (\%) = \frac{Vs \times (Me\text{-}Md)}{2Ms} \times 100\% \text{........................}(3.8)$$

Where, Vs = Total supernatant/filtrate

Md = Mass of empty Petri dish

Me = Mass of petri dish plus residual solids after evaporative drying

Ms = Mass of flour sample used in the preparation of the dispersion

3.2.5 Statistical analysis

The experiment was conducted in triplicate. All general calculations, graph and diagram construction were performed in Microsoft Office Excel (2019). The data were subjected to statistical analysis and were analyzed by two-way analysis of variance (ANOVA), at 5 % level of significance using statistical software Genstat (Version 12). The calculated mean value was compared using Least Significant Difference with 5 % level of significance to determine whether the samples were significantly different from each other and also to determine which one is superior between them.

Part IV

Result and discussion

The purpose of the research was to investigate how various pretreatments and drying temperature affected the physicochemical characteristics of tomato powder. Following the successful operation of washing and slicing, tomato was pre-treated with KMS, NaCl, $CaCl_2$ and distilled water (as control) and then dried in various temperature (55, 60, 65ºC). Then the dried tomato powder was subjected to physicochemical analysis. The results and discussion of the overall study are described in the following headings:

4.1 Analysis of fresh tomato

4.1.1 Proximate composition of fresh tomato

The proximate composition of fresh tomato is given in Table 4.1

Table 4.1 Proximate compositions of fresh tomato

Parameters	Values (%)
Moisture content (wb)	94.96±0.27
Crude fat (db)	4.20±0.67
Crude protein (db)	16.28±1.66
Crude fiber (db)	11.45±0.97
Ash (db)	8.44±1.74
Carbohydrate(db)	59.62±5.02

* Values in the table are arithmetic mean of triplicate samples ± S.D.

The moisture, crude fat, crude protein, crude fiber, ash and carbohydrate were found from the analysis as shown in Table 4.1. The moisture content of raw tomato (94.96 %) was comparable to the result obtained by Abdullahi *et al.* (2016a) i.e. (93.8 %). The fat content of tomatoes were found to be 4.20 % which is similar to the data obtained by

Del Valle *et al.* (2006) i.e. (5.85 %). The protein content of tomato was found to be 16.28 % which is lower as compared to data given by Brodowski and Geisman (1980). The variations could be due to varietal influence, environmental conditions, or other agronomical procedures used during production (Agbemafle *et al.*, 2015). The ash content of tomato was found to be 8.44 % which lies within the range given by Zaka (2011). The crude fiber content of tomato was found to be 11.45 % which is similar to that obtained by Ali *et al.* (2020b). The carbohydrate content was found to be 58.41 %. Similar data was obtained by Abdullahi *et al.* (2016a). According to Idah and Abdullahi (2010), the percentages of moisture and carbohydrate increase and decrease respectively as the storage period increases.

4.1.2 Bioactive components of fresh tomato

The bioactive components of fresh tomato are given in Table 4.2

Table 4.2 Bioactive components of fresh tomato

Parameters	Values*
Vitamin C (mg/100 g db)	39.26 ± 3.42
Lycopene (mg/100 g db)	13.48± 0.64
Total phenolic content (mg GAE/ 100 g db)	1364.28 ± 24.66
Radical scavenging activity (%RSA)	68.2 ± 0.97

* Values in the table are arithmetic mean of triplicate samples ± S.D.

The values for all parameters were found to be consistent with several studies(Burton-Freeman and Reimers, 2011; Orak *et al.*, 2012; Özkan *et al.*, 2004; Sengkhamparn *et al.*, 2013) . This study found that, the TPC of fresh tomato is 1364.28 ± 24.66 mg GAE/100 g db, which is similar to the value of TPC obtained from the study of Orak *et al.* (2012). We found that the radical scavenging activity of fresh tomato is 68.2 ± 0.97 % RSA, which correspondence with the results obtained by Sengkhamparn *et al.* (2013). The values for vitamin C and lycopene of fresh tomato were 39.26 ± 3.42 mg/100 g db and 13.48± 0.64 mg/100 g db respectively, which match with the results obtained from Özkan *et al.* (2004) and Burton-Freeman and Reimers (2011). A slight variation in all the parameter may be due to the variety, location, season, harvesting time, and maturity.

4.2 Effect of chemical pretreatments on the chemical properties of tomato powder dried on different temperature

4.2.1 Effect on the total phenol content (TPC).

The total phenol content of tomato powder dried at three different temperature at four different pretreatment method were compared by two-way ANOVA between all the sample at 5% level of significance. The total phenol content was found to be significantly higher ($p<0.05$) in powder treated with KMS and dried at 60ºC i.e., 713.3 mg GAE/100g db (Fig 4.1, Appendix . Vinha *et al.* (2014) has achieved similar pattern of TPC as in the present study. This is also related to drying time. According to Yusufe *et al.* (2017), low temperature for long time and high temperature for a significant time results the higher TPC destruction. The interaction effect of four pretreatment and three drying temperature have also been observed to be significantly different ($p<0.05$) in total phenol content.

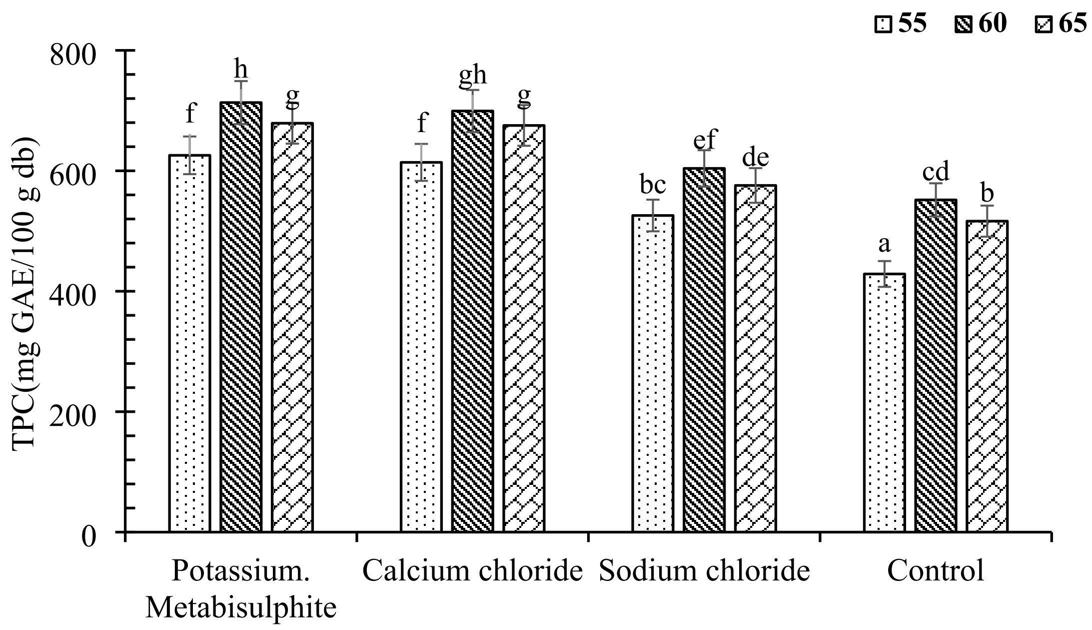

Fig 4.1 Effect of chemical pretreatment on the total phenolic content of dried tomato powder.

In this study, the maximum phenolic content (713.3 mg/GAE 100g db) was recorded in KMS treated powder dried in 60^0C followed by $CaCl_2$ treated powder dried in 60^0C (699.3 mg/GAE 100g db), KMS treated powder dried in 55^0C (679 mg/GAE 100g db) and $CaCl_2$ treated powder dried in 60^0C (675.3 mg/GAE 100g db). Orak *et al.* (2012) has done the study on broccoli where they reported similar pattern of results as in present study. They observed that, thermal degradation of phenolic components occurs mostly in controlled sample. The potassium metabisulphite and calcium chloride reduce oxidative reactions and tissue injury to slow down phenolic degradation after pretreatment compared to the control (Gümüşay *et al.*, 2015). In the case of Sodium chloride, Salt stress can induce the synthesis of phenolic compounds, such as flavonoids and phenolic acids as a defense mechanism (Jacob *et al.*, 2010)

4.2.2 Effect on the DPPH radical scavenging activity.

The two-way ANOVA between all the sample at 5% level of significance were conducted between the three temperature and four pretreatment method and their interaction effect on DPPH radical scavenging activity of dried tomato powder were studied. DPPH RSA of tomato powder ranged from control sample dried at 55ºC (32.81%) to KMS treated sample dried at 60ºC (57.26%). The tomato powder that has been pretreated with KMS and dried at 60ºC had the highest radical scavenging activity (57.26%) as compared to that of $CaCl_2$ treated sample dried at 60ºC (54.59%) and KMS treated sample dried at 65ºC (54.4%). These results are consistent with those reported in literature concerning studies with other fruits and can be interpreted considering the effect of drying time and temperature on the concentration of antioxidant activity in tomato powder (Sengkhamparn *et al.*, 2013; Vinha *et al.*, 2014). The interaction effect of four pretreatment method and three drying temperature have also been observed and found to be significantly different ($p<0.05$) in antioxidant activity.

Unpretreated tomato powder (control) showed the lowest DPPH radical scavenging activity. Dudonne *et al.* (2009) found that KMS acts as a potent antioxidant and antimicrobial agent. Its application inhibits enzymatic browning and microbial growth during drying, thereby preserving the antioxidant compounds in tomatoes. Thus, Antioxidant activity of KMS treated sample was found to be significantly higher followed by $Cacl_2$, NaCl and control sample. Réblová (2012) has also done similar study in oats grain. It was concluded that KMS and $CaCl_2$ are effective in enhancing the antioxidant activity of tomato powder by inhibiting oxidative reactions and reinforcing cellular structures, respectively. The role of NaCl in this context is less pronounced but may contribute to preservation through moisture reduction.

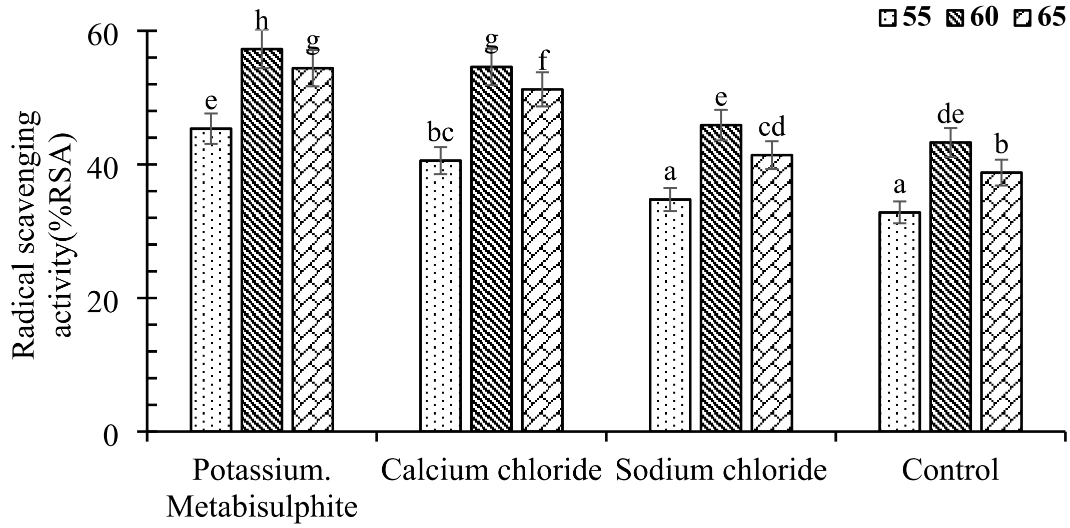

Fig 4.2 Effect of chemical pretreatment on the radical scavenging activity of tomato powder

4.2.3 Effect on the lycopene content.

Lycopene being the most predominant carotenoid in tomatoes has been reported to be highly susceptible to heat and oxygen (Shi *et al.*, 2004). The lycopene content of dried tomato powder dried at three different temperature and four different pretreatment method were compared by two-way ANOVA between all the sample at 5% level of significance. There was a significant difference ($p<0.05$) in lycopene content of all the drying temperature and pretreatment. Among all the samples, highest levels of lycopene (6.117 mg/100 g db) was observed in the KMS treated sample dried at 55ºC followed by $CaCl_2$ treated sample dried at 55ºC (6.017 mg/100 g db) and KMS treated sample dried at 60ºC (5.775 mg/100 g db). This finding is consistent with the pattern obtained in the results of Chauhan *et al.* (2011) who showed that higher temperature destroy the lycopene content. Abano *et al.* (2011) found the lycopene is unstable above 60ºC, it starts to degrade rapidly. The interaction effect of four pretreatment and three drying temperature have also been observed significantly different ($p<0.05$) in lycopene content.

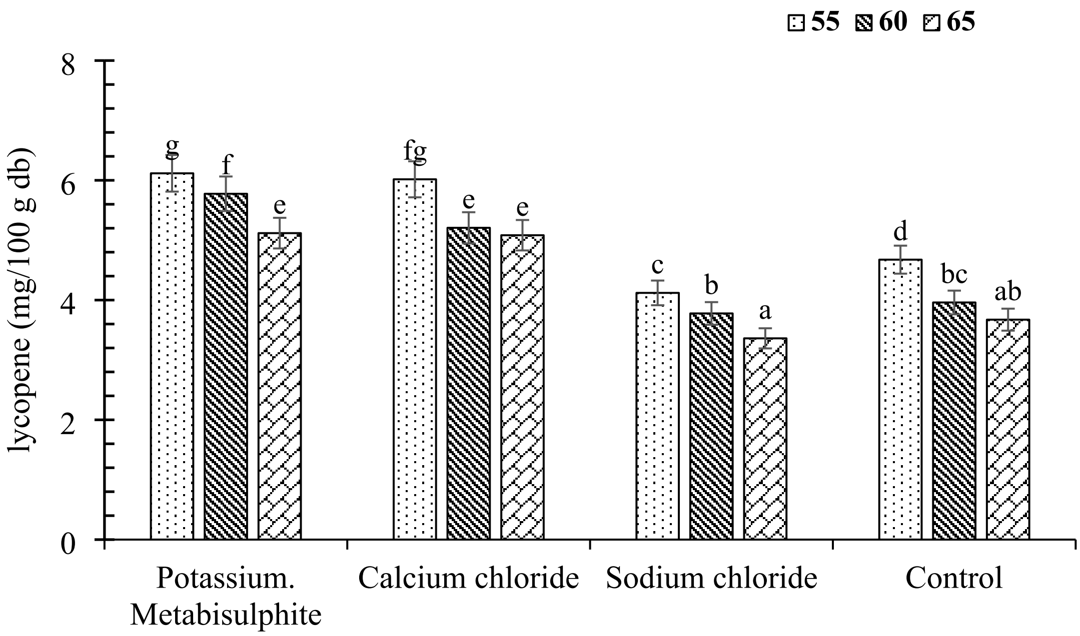

Fig 4.3 Effect of chemical pretreatment on the lycopene content of dried tomato powder

The least lycopene content was observed in NaCl treated sample dried at 65ºC (3.361 mg/100 g db) followed by control sample dried at 65ºC (3.673 mg/100 g db). The result obtained had correspondence with data from study of Ghavidel and Davoodi (2009). It stated that salt stress induces osmotic stress and ionic toxicity, resulting in cell membrane damage and decreased metabolic efficiency, which further reduces lycopene content. Results regarding the effect of KMS were qualitatively similar to those reported by Sharma and Le Maguer (1996) and W. A. Baloch *et al.* (1997). This shows that calcium chloride and potassium metabisulphate was better effective in controlling the extent of lycopene degradation as compared to the control and sodium chloride. It is possible that the pretreatments remained on the surface of the sample during drying thus preventing oxygen from penetrating and oxidizing lycopene. A similar effect was reported in tomato slices pretreated with citric acid, ascorbic acid, ethyl oleate and potassium carbonate (F. H. Sahin *et al.*, 2011b). The researcher attributed the higher retention in lycopene to the protective role of the pretreatments against lycopene degradation as compared to the untreated samples. Lycopene loss is due to oxidation reaction which results in fragmented products such as acetone, glyoxal and methylheptenone (Chawla *et al.*, 2008).

4.2.4 Effect on the Vitamin C content.

The Vitamin C content of tomato powder dried at three different temperature and four different pretreatment method were compared by two-way ANOVA between all the sample at 5% level of significance. Vitamin C was also found to be significantly different ($p<0.05$) among dried tomato powder of all temperature. The maximum Vitamin C was found in tomato powder treated with KMS dried in 55ºC (18.78 mg /100g db) followed by $CaCl_2$ treated sample dried at 55ºC (16.6 mg/100 g db) and KMS treated sample dried at 60ºC (16.42 mg/100 g db). From the above statistical analysis high temperature drying had a lower retention of Vitamin-C compared to low temperature. Ascorbic acid (vitamin C) is sensitive to heat and light. The vitamin C content was higher at lower drying temperatures. This may be due to comparatively less loss of vitamin-C at lower temperature. Similar findings were observed by P. Singh and Singh (2011). When amla were dried in solar-assisted heat pump dryer at different temperature, the lowest temperature showed the maximum retention of vitamin C whereas drying temperature around 70^0 C degrade most of the vitamin C. The interaction effect of four pretreatment method and three drying temperature have also been observed not significantly different ($p>0.05$) in total phenol content.

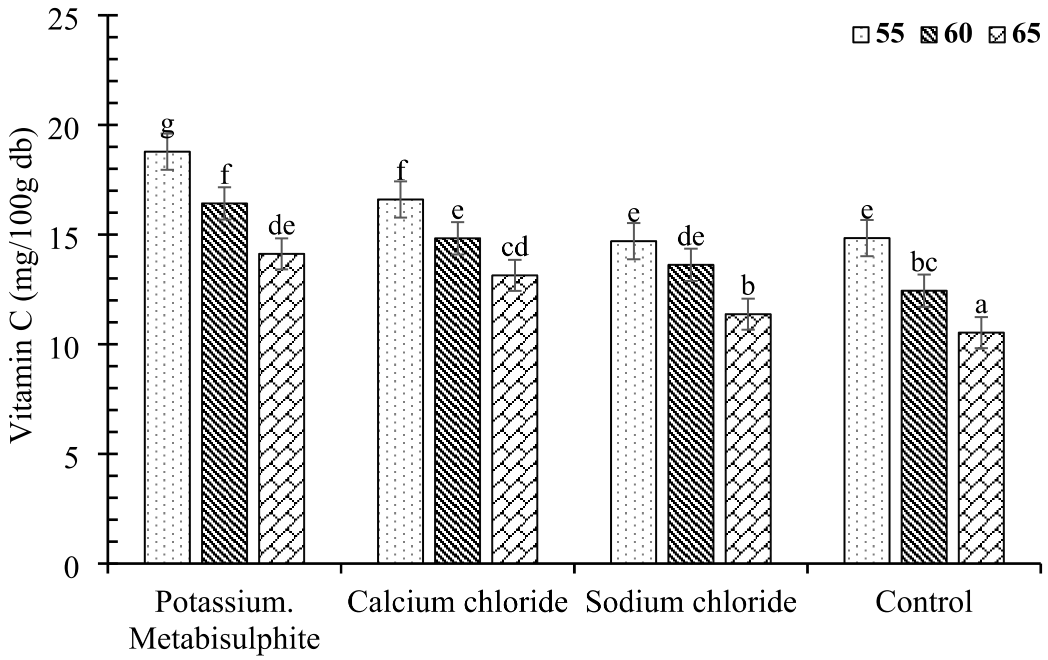

Fig 4.4 Effect of chemical pretreatment on the vitamin C content of dried tomato powder

The statistical analysis showed significant difference ($p<0.05$) in Vitamin C content of different chemical pretreatment method as shown in Figure 4.4. The highest vitamin C content was observed in KMS treated tomato powder dried at 55^{0}C (18.78 mg/100g db) whereas least was observed in control sample dried at 65ºC (10.53 mg/100g db) followed by NaCl treated sample dried at 65ºC (11.37 mg/100 g db) The result obtained had correspondence with data from study of Prajapati *et al.* (2011). He reported that pre-treatment of sulphiting followed by low temperature drying was the best treatment combination. Beneficial effect of KMS/sulphitation on retention of ascorbic acid content of 46 dried product was also observed by many workers (Sagar and Rajesh Kumar, 2006; Sethi, 1986; Tripathi *et al.*, 1988) in amla. It may be due to inactivation of oxidase enzyme. M. A. Hossain *et al.* (2021) reported that Nacl treatment retain minimum amount of vitamin C due to osmotic behavior of salt. When tomato slices are treated with NaCl, osmosis causes water loss along with some water-soluble vitamins like vitamin C.

4.3 Effect of chemical pretreatment on physical properties of tomato powder dried on different temperature

The physical properties of the dried tomato powder, such as true density, bulk density, porosity, and solubility were evaluated. These properties are inherent characteristics of the substance that can be observed or measured without altering its identity (Pant *et al.*, 2022).

4.3.1 True density

True density was maximum for control sample dried in 65ºC i.e (1.354 ±0.015 g/ml) and minimum for the sample pretreated with NaCl and dried in 55ºC i.e (1.141 ±0.005 g/ml) as shown as in table 4.3, this finding is similar to the result of Goula *et al.* (2004). He reported that true density is not influenced by pretreatment but slightly affected by drying temperature. This data showed that true density increases with increase in temperature and but not significantly affected by pretreatment. The interaction effect between three drying temperature and four different pretreatments is also observed significantly difference ($p<0.05$) in true density.

4.3.2 Bulk density

Bulk density was maximum for control sample and dried in 65ºC i.e (0.675 ±0.001 g/ml) following by KMS treated sample dried in 65ºC i.e (0.665 ±0.0015 g/ml) whereas minimum for NaCl treated sample dried in 55ºC i.e (0.609 ±0.0015 g/ml) as shown as in the Table 4.3, this results correspondence with the result of Sidhu *et al.* (2019). This work reported that increase in bulk density with increase in temperature. The data indicates that higher temperatures correspond to an increase in bulk density. This may be due to break down of all capillaries during drying. The interaction effect between three drying temperature and four different pretreatments is also observed significantly difference ($p<0.05$) in bulk density.

4.3.3 Porosity

The surface area-related characteristic of particulate systems is called porosity. Increased porosity among powders results in increased blocked air, which oxidizes the particles and decreases storage stability (Amunugoda *et al.*, 2020). Porosity was found maximum in sample pretreated with KMS and dried in 55ºC i.e (0.527 ±0.002) followed by NaCl treated sample dried in 55ºC i.e (0.522 ±0.001) and minimum in $CaCl_2$ treated sample dried in in 65ºC i.e (0.499 ±0.002) as shown as in the table 4.3. This finding was similar to the result obtained by Sousa *et al.* (2008). The interaction effect between three drying temperature and four different pretreatments is also observed significantly difference ($p<0.05$) in porosity.

4.3.4 Solubility

Solubility was found to be maximum in KMS treated sample dried in 55ºC i.e (19.73±0.025 %) followed by NaCl treated sample dried in 55ºC i.e (19.58±0.023 %) and minimum in NaCl pretreated sample dried in 65ºC i.e (17.46 ±0.044%) as shown as in the table 4.3. This results is similar to the findings of Castoldi *et al.* (2015). A. Sarker *et al.* (2021) states that higher treatment temperatures cause decreased solubility coefficients. The decrease in solubility is due to the degradation of pectic compounds during processing and structural alterations caused by water removal and all dried powder showed solubility below 20%. The interaction effect between three drying temperature and four different pretreatments is also observed significantly difference ($p<0.05$) in solubility.

Table 4.3 Bulk Density, True Density, Porosity and Solubility of tomato powder sample.

Treatment	Bulk density (g/ml)	True density (g/ml)	Porosity	Solubility (%)
KMS 55	0.617^{ab} ±0.002	1.266^{bcd} ±0.03	0.527^{e} ±0.002	19.73^{g}±0.025
KMS 60	0.64^{c} ±0.003	1.24^{abc} ±0.023	0.517^{cd} ±0.002	19.37^{e}±0.051
KMS 65	0.665^{ef} ±0.0015	1.344^{cd} ±0.014	0.503^{a} ±0.001	18.43^{c}±0.043
$CaCl_2$ 55	0.619^{ab} ±0.0015	1.175^{ab} ±0.019	0.516^{cd} ±0.001	19.58^{f}±0.023
$CaCl_2$ 60	0.641^{c} ±0.001	1.32^{cd} ±0.005	0.515^{cd} ±0.001	19.31^{de} ±0.01
$CaCl_2$ 65	0.646^{cd} ±0.003	1.324^{cd} ±0.015	0.499^{a} ±0.002	18.44^{c}±0.021
NaCl 55	0.609^{a} ±0.0015	1.141^{a} ±0.005	0.522^{de} ±0.001	19.63^{fg}±0.019
NaCl 60	0.641^{c} ±0.002	1.307^{cd} ±0.011	0.517^{cd} ±0.002	19.24^{d}±0.022
NaCl 65	0.656^{de} ±0.0017	1.33^{cd} ±0.015	0.504^{ab} ±0.001	17.46^{a}±0.044
Control 55	0.625^{b} ±0.0025	1.27^{bcd} ±0.011	0.521^{de} ±0.001	19.55^{f}±0.023
Control 60	0.645^{cd} ±0.003	1.331^{cd} ±0.027	0.517^{cd} ±0.002	19.24^{d}±0.017
Control 65	0.675^{f} ±0.001	1.354^{d} ±0.015	0.512^{bc} ±0.002	18.17^{b}±0.034

*Values in the table are arithmetic mean of triplicate samples ± S.D

* Figures with same super script within the same column are not significantly different

* Figures with different super script within the same column are significantly different

Part V

Conclusion and recommendations

5.1 Conclusion

On the basis of this study, following conclusions were drawn.

1. The proximate composition of fresh tomato was found to be 94.96% moisture with 4.20% crude fat, 16.28% crude protein, 11.45% crude fiber, 8.44% ash, and 59.62% carbohydrate on a dry weight basis, respectively.
2. The physical properties of tomato powder, including bulk density and true density, increase within the temperature range of 55-65°C. However, the solubility and porosity decreased with the increase in temperature.
3. KMS treatment and drying temperature of 60°C was found to be the most effective for retaining total phenolic content and DPPH radical scavenging activity whereas KMS treatment with temperature of 55°C was found to be most effective for retaining vitamin C and lycopene.
4. The tomato slices should be pretreated with KMS and should be dried below 60ºC for better quality.

5.2 Recommendations

On the basis of this study, following recommendations were made.

1. KMS treatment and drying temperature of 60ºC produce the better quality tomato powder.
2. Microbial study and storage stability of dried tomato powder with various packaging materials and storage environments can be carried out.

Part VI

Summary

Tomato is one of the most popular and widely grown vegetable crops in Nepal. It is a great source of antioxidants such as lycopene, carotenes, and phenolics as well as vitamin C. Tomatoes have a limited shelf life at room temperature and are highly perishable. Short shelf lives combined with insufficient processing facilities cause a huge loss of revenue for the nation.This work is mainly focused on the proper utilization of the perishable tomatoes by drying and processing it into powdered form. Study was carried out to know the effect of different pretreatment (KMS, NaCl, $CaCl_2$, Control) and drying temperature (55, 60, 65°C) on physiochemical properties of dried tomato powder. The raw tomato was cleaned, sorted, cut longitudinally into 8 halves and pretreated with 0.2% KMS, 1% CaCl2, 7% NaCl in water solution for 10 minutes and control sample of each fraction of tomato was also prepared by using distill water. These pretreated samples were dried in a cabinet dryer in three different temperature. After drying, the dried tomato flakes were ground by using grinder to obtain tomato powder and were analyzed for physical and chemical parameter. The obtained data was analyzed statistically by two way of ANOVA at 5% level of significance.

The results showed that KMS treatment with the drying temperature of 60°C indicates more retention of total phenolic content and DPPH radical scavenging activity whereas KMS treatment with temperature of 55°C was found to be most effective for retaining vitamin C and lycopene resulting in value of 713.3 mg GAE/100g db total phenolic content, 57.26% DPPH radical scavenging activity, 6.117 mg/100 g db lycopene and 18.78 mg /100g db vitamin C. All data were significantly different ($p<0.05$) among chemical properties except the interaction effect on vitamin C. On other hand, physical properties like bulk density, true density increased with increase in temperature whereas solubility and porosity decrease with increase in temperature. Based on physical properties, the control sample dried at 65°C showed the highest bulk (0.675 g/ml) and true density (1.354 g/ml), while the KMS-treated sample dried at 55°C exhibited the highest porosity (0.527) and solubility (19.73%). Overall the study shows that appropriate pretreatment and drying temperature are key to improving the quality and nutritional value of tomato powder.

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Appendices

Appendix A

Table A.1 List of chemicals used

S.N	Chemicals	S.N	Chemicals
1.	Calcium chloride	2.	Sodium chloride
3.	Potassium metabisulphite	4.	Dilute sulphuric acid
5.	Sodium hydroxide	6.	Methanol 80%
7.	Sodium carbonate	8.	Acetone
9.	Hexane	10.	1,1-diphenyl-1-picryl-hydrazyl radical (DPPH)
11.	Folin-Ciocalteau reagent	12.	Gallic acid
13.	Phenolphthalein	14.	Petroleum ether
15.	Distilled water	16.	Alcohol (50% and 95%)

Table A.2 List of equipment used

S.N	Equipment	S.N	Equipment
1.	Cabinet dryer	2.	Hot air oven
3.	Muffle furnace	4.	Spectrophotometer
5.	Soxhlet assembly	6.	Beakers
7.	Volumetric flask	8.	Conical flask
9.	Pipettes	10.	Burette
11.	Stands	12.	Desiccator
13.	Grinder	14.	Weighing balance
15.	Kjeldahl digestion and distillation	16.	Test tubes
17.	Filter paper	18.	Aluminum foil
19.	Water bath	20.	Crucible
21.	Hot plate	22.	Electric stirrer

Appendix B

Table B.1. Two-way ANOVA (no blocking) for TPC

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	183969.3	61323.1	473.69	<.001
Temperature	2	54569.7	27284.9	210.76	<.001
Pretreatment. Temperature	6	2164.5	360.8	2.79	0.034
Residual	24	3107.0	129.5		
Total	35	243810.6			

Table B.2 LSD table for TPC

Sample	Mean	
Control 55	428.7	a
Control 65	516.4	b
NaCl 55	525.8	bc
Control 60	551.7	cd
NaCl 65	575.7	de
NaCl 60	604.0	ef
CaCl2 55	614.0	f
kms 55	625.7	f
CaCl2 65	675.3	g
kms 65	679.0	g
CaCl2 60	699.3	gh
kms 60	713.3	h

Table B.3 Two-way ANOVA (no blocking) for DPPH RSA

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	1187.8731	395.9577	504.06	<.001
Temperature	2	884.2991	442.1495	562.86	<.001
Pretreatment. Temperature	6	23.3189	3.8865	4.95	0.002
Residual	24	18.8530	0.7855		
Total	35	2114.3441			

Table B.4 LSD table for DPPH RSA

Sample	Mean	
Control 55	32.81	a
NaCl 55	34.75	a
Control 65	38.77	b
CaCl2 55	40.57	bc
NaCl 65	41.39	cd
Control 60	43.29	de
kms 55	45.35	e
NaCl 60	45.88	e
CaCl2 65	51.23	f
kms 65	54.40	g
CaCl2 60	54.59	g
kms 60	57.26	h

Table B.5 Two-way ANOVA (no blocking) for lycopene

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	24.55646	8.18549	681.47	<.001
Temperature	2	5.17983	2.58991	215.62	<.001
Pretreatment. Temperature	6	0.36993	0.06166	5.13	0.002
Residual	24	0.28828	0.01201		
Total	35	30.39450			

Table B.6 LSD table for lycopene

Sample	Mean	
NaCl 65	3.361	a
Control 65	3.673	ab
NaCl 60	3.777	b
Control 60	3.963	bc
NaCl 55	4.120	c
Control 55	4.675	d
CaCl2 65	5.083	e
kms 65	5.118	e
CaCl2 60	5.207	e
kms 60	5.775	f
CaCl2 55	6.017	fg
kms 55	6.117	g

Table B.7 Two-way ANOVA (no blocking) for Vitamin C

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	80.2257	26.7419	123.53	<.001
Temperature	2	93.2179	46.6090	215.29	<.001
Pretreatment. Temperature	6	2.6705	0.4451	2.06	0.097
Residual	24	5.1957	0.2165		
Total	35	181.3098			

Table B.8 LSD table for Vitamin C

Sample	mean	
Control 65	10.53	a
kms 65	11.37	ab
Control 60	12.44	bc
CaCl2 65	13.14	cd
kms 60	13.62	cde
NaCl 65	14.12	de
kms 55	14.70	e
CaCl2 60	14.83	e
Control 55	14.84	e
NaCl 60	16.42	f
CaCl2 55	16.60	f
NaCl 55	18.78	g

Table B.9 Two-way ANOVA (no blocking) for True density

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	0.017121	0.005707	4.34	0.014
Temperature	2	0.098340	0.049170	37.43	<.001
Pretreatment. Temperature	6	0.037464	0.006244	4.75	0.003
Residual	24	0.031526	0.001314		
Total	35	0.184451			

Table B.10 LSD table for True density

Sample	Mean	
NaCl 55	1.141	a
CaCl2 55	1.175	ab
kms 60	1.240	abc
kms 55	1.266	bcd
Control 55	1.270	bcd
NaCl 60	1.307	cd
CaCl2 60	1.320	cd
CaCl2 65	1.324	cd
NaCl 65	1.330	cd
Control 60	1.331	cd
kms 65	1.344	cd
Control 65	1.354	d

Table B.11 Two-way ANOVA (no blocking) for Bulk density

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	0.00100911	0.00033637	15.81	<.001
Temperature	2	0.01127506	0.00563753	264.95	<.001
Pretreatment. Temperature	6	0.00085139	0.00014190	6.67	<.001
Residual	24	0.00051067	0.00002128		
Total	35	0.01364622			

Table B.12 LSD table for Bulk density

Sample	Mean	
NaCl 55	0.6090	a
kms 55	0.6170	ab
CaCl2 55	0.6197	ab
Control 55	0.6253	b
kms 60	0.6400	c
CaCl2 60	0.6410	c
NaCl 60	0.6417	c
Control 60	0.6450	cd
CaCl2 65	0.6463	cd
NaCl 65	0.6567	de
kms 65	0.6653	ef
Control 65	0.6757	f

Table B.13 Two-way ANOVA (no blocking) for porosity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	2.245E-04	7.484E-05	9.39	<.001
Temperature	2	1.915E-03	9.576E-04	120.11	<.001
Pretreatment. Temperature	6	2.157E-04	3.595E-05	4.51	0.003
Residual	24	1.913E-04	7.972E-06		
Total	35	2.547E-03			

Table B.14 LSD table for porosity

Sample	Mean	
CaCl2 65	0.4997	a
kms 65	0.5030	a
NaCl 65	0.5040	ab
Control 65	0.5120	bc
CaCl2 60	0.5153	cd
CaCl2 55	0.5167	cd
Control 60	0.5177	cd
kms 60	0.5177	cd
NaCl 60	0.5177	cd
Control 55	0.5217	de
NaCl 55	0.5220	de
kms 55	0.5277	e

Table B.15 Two-way ANOVA (no blocking) for Solubility

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Pretreatment	3	0.847589	0.282530	208.85	<.001
Temperature	2	14.806822	7.403411	5472.75	<.001
Pretreatment. Temperature	6	1.162844	0.193807	143.27	<.001
Residual	24	0.032467	0.001353		
Total	35	16.849722			

Table B.16 LSD table for Solubility

Sample	Mean	
NaCl 65	17.46	a
Control 65	18.17	b
kms 65	18.43	c
CaCl2 65	18.44	c
NaCl 60	19.24	d
Control 60	19.24	d
CaCl2 60	19.31	de
kms 60	19.37	e
Control 55	19.55	f
CaCl2 55	19.58	f
NaCl 55	19.63	fg
kms 55	19.73	g

Appendix C

Drying temperature	Pretreatment	TPC(mgGAE/100g db)	Antioxidant activity(%RSA)	Lycopene (mgGAE/100g db)	Vitamin C (mgGAE/100g db)
	KMS	625.7	45.35	6.117	18.78
	$CaCl_2$	614	40.57	6.017	16.6
55^0 C	Nacl	525.8	34.75	4.12	14.7
	Control	428	32.81	4.675	14.84
	KMS	713.3	57.26	5.775	16.42
	$CaCl_2$	699.3	54.59	5.207	14.83
60^0 C	Nacl	604	45.88	3.777	13.62
	Control	551.7	43.29	3.96	12.44
	KMS	679	54.4	5.118	14.12
	$CaCl_2$	675.3	51.23	5.083	13.14
65^0 C	Nacl	575.7	41.39	3.361	11.37
	Control	516.4	38.77	3.673	10.53

Appendix D

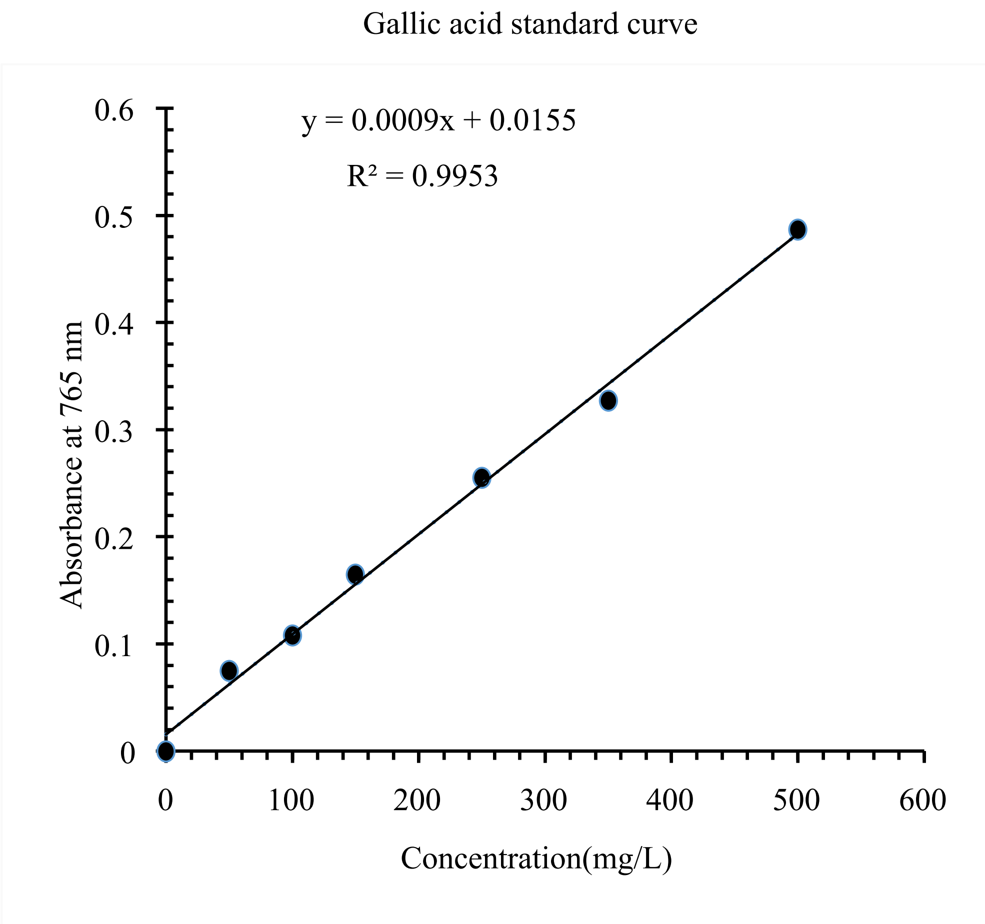

Fig C.1 Standard Gallic acid curve.

Color Plates

P1: Cutting of tomato

P2: Preparation for drying

P3: Grinding of sample

P4: Spectrophotometric Analysis

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Approval letter

This dissertation entitled *Effect of Pretreatment and Drying Temperature on Physicochemical Properties of Tomato Powder* presented by Kaushal Baral has been accepted as the partial fulfillment of the requirements for the B. Tech. degree in Food Technology.

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