

**DEVELOPMENT AND CHARACTERIZATION OF MALTODEXTRIN
FORMULATED INSTANT TOMATO SAUCE POWDER AND
RECONSTITUTED SAUCE DURING STORAGE**

A THESIS

BY

Monisha Sarkar

Student ID: 1707033

Session: 2023-2024

Semester: January-June, 2024

MASTER OF SCIENCE

IN

FOOD PROCESSING AND PRESERVATION



DEPARTMENT OF FOOD PROCESSING AND PRESERVATION
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
UNIVERSITY, DINAJPUR

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The Author

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ABSTRACT

The instant food products are meeting the demands of the fast-paced world with their quick preparation time, convenience, and ever-growing varieties. The present study aimed to evaluate the effect of whole tomato over tomato puree on the powder characteristics of developed maltodextrin-formulated instant tomato sauce powder and rheological behaviour, physicochemical properties, bioactive compound, microbial analysis and sensory evaluation of reconstituted sauce during storage. The puree-based powder exhibited lower moisture content, water activity, and wettability than the whole tomato-based powder that showed superior solubility and flowability. Both the reconstituted sauces showed a non-Newtonian and pseudo-plastic behavior. Despite having different formulation processes, the reconstituted tomato sauces exhibited color, pH, acidity, and total soluble solids that were closely aligned with those of commercial tomato sauce. Throughout the storage period, the bioactive compounds indicating total carotenoid, lycopene content, total phenolic content, and vitamin C content were superior in whole tomato-based reconstituted tomato sauce. Neither powder exhibited any total bacterial count, yeast, or mold during storage. Between the reconstituted sauces, puree-based sauce rated the highest acceptability. This study offers an efficient formula for instant tomato sauce powder and reconstituted sauce, which could be served as a substitute for commercial tomato sauce.

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LIST OF ABBREVIATIONS

ITSP : Instant Tomato Sauce Powder

RTS : Reconstituted Tomato sauce

GAE : Gallic acid equivalent

CFU : Colony Forming Unit

RI : Refractive Index

RPM : Revolutions Per Minutes

wb : Wet basis

db : Dry basis

°C : Degree Celcius

Pa.s : Pascal-second

CHAPTER I

INTRODUCTION

Tomato (*Solanum Lycopersicum L.*), the second largest vegetable crop globally, is renowned for its significant health benefits and broad market presence. Tomatoes are rich in lycopene, vitamin C, and potassium, as well as containing vitamin B1, vitamin K, copper, sodium, zinc, and manganese (Burton-Freeman & Sesso, 2014). Numerous studies have stated that tomatoes offer protective benefits against various diseases, including epithelial lining cancer, neurological disorders, ulcerative colitis, liver diseases, and cardiovascular conditions (Giovannucci, 1999; Raiola et al., 2014).

According to the FAO (2022), global tomato production reached over 186.821 million metric tons (MMT) during the 2020-21 year, and Bangladesh was responsible for about 0.44 million tons. Tomatoes are highly multifaceted, whether consumed as fresh or processed into products such as sauces, ketchup, juice, soup and canned pickles. Different studies conducted on innovative tomato processing, packaging and preservation techniques like edible coating (Duguma, 2022; Farooq et al., 2023), tomato paste (Çetiner et al., 2023), tomato packaging with scavenger (Sammi & Masud, 2009) and tomato powder (Azeez et al., 2019). Tomatoes experienced a post-harvest loss rate of approximately 39%, highlighting the need for more efficient and sustainable techniques to mitigate these losses (Abera et al., 2020; Parveen et al., 2014).

Instant food products, as innovative value-added items, have garnered significant consumer acceptance due to their nutritional versatility and ease of preparation. Alongside traditional commercial foods, these instant products are increasingly being embraced by consumers (Kim et al., 2015; SCHUTZ, 1965; Yang & Lee, 2018).

According to Instant Food Market Demand and Growth Insights (2024), the global instant food market is projected to grow 7.9% at a Compound Annual Growth Rate (CAGR) from 2024 to 2030. To sustain this growth, researchers have focused on developing a variety of instant food products, such as instant soups premix powder (A. Srivastava et al., 2019), instant coffee powder (Capek et al., 2010), instant cereal beverage powder (Charunuch et al., 2003), instant banana-milk powder (Kumar et al., 2022) and so on.

The lightweight nature of instant food products greatly enhances transportation and distribution. Several drying techniques, such as microwave oven drying, freeze drying, spray drying or hurdle drying have been applied to dry instant food products (Du et al., 2022; R. Wang et al., 2010).

Commercial tomato products often remove seed and peel to improve consumer acceptance that have generated global industrial tomato processing waste estimated at 5.40–9.0 million tons annually (Trombino et al., 2021). Interestingly, this dried tomato processing waste found as a great source of antioxidants with macro- and micronutrients (Celma et al., 2009; Nour et al., 2018). Torbica et al. (2016) reintroduced these dried by-products into tomato ketchup as thickeners.

As far as we know from literature, there has been a lack of information about instant tomato sauce powder through hot air drying. In this study, an attempt has been made to develop maltodextrin formulated instant tomato sauce powder and utilizing whole tomato over tomato puree. These sauce powders have advantages in preservation and transportation such as being lightweight, space-saving, and having a longer shelf life. The study examined the powder characteristics, rheological behaviour, physicochemical properties, bioactive compounds, microbial analysis and consumer acceptance of instant powder and reconstituted sauce during storage.

The aim of the study-

1. To develop instant tomato sauce powder derived from whole tomato and tomato puree
2. To study the changes in powder properties, physicochemical properties, and bioactive compounds during storage
3. To analyze microbial load
4. To evaluate consumer acceptability

CHAPTER II

REVIEW OF LITERATURE

2.1 Tomato Origin

The tomato, scientifically known as *Solanum lycopersicum*, is a member of the nightshade family, Solanaceae. It is native to South America but has been extensively cultivated worldwide due to its versatile usage in various cuisines and products. The tomato plant is characterized by its bushy stems that bear simple yet pinnately compound leaves. The fruit varies widely in size, shape, and color, though it is typically bright red when ripe.

2.2 Varieties of Tomato

Tomatoes come in various types, each with distinct characteristics that make them suitable for different culinary uses and growing conditions (Olaniyi et al., 2010).

1. **Cherry Tomatoes:** These small, round tomatoes are known for their sweet flavour and vibrant red colour. They are often used in salads, snacks, and garnishes due to their bite-sized nature and juicy texture.
2. **Roma (Plum) Tomatoes:** Roma tomatoes are oval-shaped with thick flesh and fewer seeds, making them ideal for sauces, pastes, and canning. They have a slightly tangy flavour and are known for their low moisture content, which concentrates their taste.
3. **Beefsteak Tomatoes:** Large and meaty, beefsteak tomatoes are perfect for slicing and are commonly used in sandwiches and burgers. They have a mild, sweet flavour and a juicy interior with multiple seed compartments.
4. **Heirloom Tomatoes:** Heirloom tomatoes are prized for their unique flavours, colours, and shapes, often with a more complex taste profile than hybrid varieties. They are grown from seeds passed down through generations and can be found in various sizes and colours, from deep reds to purples, greens, and yellows.
5. **Grape Tomatoes:** Similar to cherry tomatoes but slightly smaller and more elongated, grape tomatoes are sweet and have a firmer texture. They are excellent for salads, roasting, and snacking, holding their shape well when cooked.
6. **Tomatillos:** They have a tangy, slightly citrus flavour and are encased in a papery husk. Tomatillos are commonly used in Mexican cuisine, particularly green sauces and salsas.
7. **Pusa Ruby:** A popular variety in India, Pusa Ruby is known for its deep red colour and high lycopene content. It is a determinate variety, meaning it grows compactly

- and produces fruit within a specific period, making it ideal for processing into sauces and pastes.
8. **Arka Vikas:** Developed by the Indian Institute of Horticultural Research, Arka Vikas is a high-yielding variety with medium-sized fruits that are firm and have a long shelf life. This variety is commonly used in both fresh markets and for processing.
 9. **Marglobe:** Widely grown in Bangladesh and India, Marglobe is a disease-resistant variety that produces large, round, and smooth fruits. It is versatile and used in various culinary applications, from fresh salads to cooked dishes.
 10. **Manik:** A variety popular in Bangladesh, Manik is known for its robust growth and resistance to common tomato diseases. It produces medium to large fruits with a deep red colour and is favoured for fresh consumption and processing.

2.3 Global production

Globally, tomatoes are one of the most cultivated vegetables, with China leading the production, followed by India, the United States, and Turkey. According to the Food and Agriculture Organization (2020), global tomato production reached nearly 182 million tonnes, highlighting its significant role in agricultural economies and diets worldwide. China is the world's largest producer of tomatoes, contributing significantly to the global market. Extensive production is facilitated by vast agricultural lands and favorable climates, alongside advanced farming technologies and government support. In 2019, China produced approximately 34 million tonnes of tomatoes.

2.4 Production in Bangladesh

In Bangladesh, tomato production has been on the rise, with the country producing approximately 4 million metric tons annually, contributing about 1.5% to global tomato production. The major tomato-producing regions include Rajshahi, which alone contributes around 25% of the national output, equating to about 1 million metric tons. Dinajpur and Pabna are also significant contributors, producing roughly 500,000 metric tons annually, representing about 12.5% of the national total per region. Jashore adds another 400,000 metric tons, contributing around 10% to the country's overall production. These key regions account for nearly 60% of Bangladesh's total tomato output, solidifying their importance in local and national markets according to the Bangladesh Bureau of Statistics (2022).

2.5 Loss of tomatoes

Post-harvest losses of tomatoes are a significant issue globally, with estimates ranging from 20% to 50% depending on regional and supply chain efficiencies (Parfitt et al., 2010). In Bangladesh, where annual tomato production reaches approximately 4 million metric tons, up to 25% of this yield is lost post-harvest due to poor handling, inadequate storage, and transportation challenges (Abera et al., 2020). Addressing these losses through improved practices could enhance tomato availability, increase farmers' economic returns, and stabilize food supplies.

Various loss:

1. **Post-Harvest Losses:** Most tomato losses occur during the post-harvest stage, where losses can range from 20% to 40%. These losses are primarily due to improper handling, inadequate storage, and transportation issues.
2. **Processing Losses:** During processing, losses can account for approximately 5% to 15% of harvested tomatoes. These losses arise from mechanical damage, spoilage during storage, and inefficiencies in processing methods.
3. **Cultivation Losses:** Cultivation losses, which include losses due to pests, diseases, and adverse weather conditions, can range from 10% to 20%, depending on the region and agricultural practices.

2.6 Proximate composition

Whole Tomatoes (per 100g)

- Moisture: 93-95%
- Carbohydrates: 3-4%
 - ◆ Sugars: 2.6-3.5%
 - ◆ Dietary Fiber: 1.0-1.5%
- Protein: 0.8-1.6%
- Fat: 0.2-0.4%
- Ash (Minerals): 0.5-1.0%

Tomato Peel (per 100g):

- Moisture: 70-75%
- Carbohydrates: 15-20%

- ◆ Dietary Fiber: 10-12%
- Protein: 10-15%
- Fat: 1-2%
- Ash (Minerals): 3-5%

Tomato Seed (per 100g):

- Moisture: 6-10%
- Carbohydrates: 10-15%
- ◆ Dietary Fiber: 4-6%
- Protein: 20-30%
- Fat: 20-30%
- Ash (Minerals): 3-4%

Tomato Puree (per 100g):

- Moisture: 93-95%
- Carbohydrates: 3-5%
- ◆ Sugars: 2.5-3.5%
 - ◆ Dietary Fiber: 0.5-1.5%
- Protein: 0.5-1.5%
- Fat: 0.1-0.3%
- Ash (Minerals): 0.4-0.7%

2.7 Nutritional quality and health benefits

Tomatoes are highly regarded for their nutritional benefits, containing essential vitamins and minerals such as vitamin C, potassium, folate, and vitamin K. They are particularly noted for their high lycopene content. This antioxidant has been linked to many health benefits, including reduced risk of heart disease and cancer (Beecher, 1998; Guil-Guerrero & Rebollosa-Fuentes, 2009). The nutritional content of tomatoes and the specific health benefits of each nutrient:

Vitamin in tomatoes (Frusciante et al., 2007):

Vitamin C

A medium-sized tomato (approximately 123 grams) contains about 20 milligrams of vitamin C, constituting about 22% of the recommended daily allowance (RDA).

- Vitamin C is crucial for the repair and growth of tissues in all parts of the body and is commonly known to boost the immune system.
- This vitamin is a powerful antioxidant, helping prevent the damage of free radicals and supporting overall cellular health.
- It helps produce collagen, which is essential for skin health and elasticity.

Vitamin B complex

Tomatoes contain several members of the vitamin B complex, including niacin (B3), pantothenic acid (B5), and folate (B9), each contributing to overall health.

Niacin (Vitamin B3)

A tomato provides about 0.7 mg of niacin.

- Converts food into energy by aiding enzymes.
- It helps keep the skin healthy and supports the functioning of the digestive and nervous systems.
- It plays a role in reducing bad cholesterol levels while increasing good cholesterol levels.

Pantothenic Acid (Vitamin B5)

It contains about 0.1 mg per medium-sized tomato.

- Helps in the production of hormones in the adrenal glands.
- Aids in the metabolism of proteins, fats, and carbohydrates.
- It is involved in the synthesis of coenzyme A (CoA) and is vital in the process of healing wounds.

Folate (Vitamin B9)

Folate's role is critical in cell growth, DNA synthesis and repair, and the production of red blood cells. Tomato contains about 18 micrograms of folate, roughly 5% of the RDA.

- Essential for the production and maintenance of cells, particularly during periods of rapid growth such as pregnancy and infancy.
- It plays a critical role in DNA synthesis and repair, thus contributing to overall genetic stability and also prevent anemia.

Vitamin K

There are about 7.9 micrograms of vitamin K in a tomato, about 10% of the RDA.

- Vitamin K is essential for bone health and crucial in bone mineralization.
- This vitamin is vital for blood clotting processes in the body.
- Prevent calcification of arteries and other heart tissues.

Mineral in tomatoes (Sainju et al., 2003):

Potassium

There are about 292 milligrams of potassium in a medium-sized tomato, around 6% of the RDA.

- Potassium is vital for maintaining proper heart function and regulating blood pressure.
- It aids in muscle contraction and helps maintain muscle mass and nervous system function.

Magnesium

A tomato contains about 11 milligrams of magnesium.

- It helps in bone formation and influences the activities of osteoblasts and osteoclasts.
- It helps to maintain normal muscle and nerve function, keeps heart rhythm steady, and supports a healthy immune system.
- Adequate magnesium intake manages depression, anxiety, and stress.

Calcium

A tomato contains approximately 10 milligrams of calcium.

- It helps in maintaining strong bones and teeth.
- It helps in the proper functioning of muscles, helping them to contract and relax properly.
- Maintains normal heart rhythm and the function of nerves.

Iron

There are about 0.3 milligrams of iron in a medium-sized tomato. Iron is a component of hemoglobin in red blood cells, essential for transporting oxygen throughout the body and influencing the immune system.

Zinc

About 0.2 milligrams of zinc is found in tomatoes. Zinc helps in protein synthesis, supporting a healthy immune system, and helps in cell division and growth.

Other,

Fibre

Approximately 1.5 grams of dietary fibre are present in tomatoes.

- Maintain bowel health and regularity, reducing the risk of constipation.
- Moderate blood sugar levels by slowing the absorption of sugar during digestion.
- Bind cholesterol in the digestive system, causing it to be excreted rather than absorbed.

2.8 Phytochemicals and health benefits

Tomatoes are not only valuable for their vitamins and minerals but also for their rich array of phytochemicals. These bioactive compounds offer various health benefits and contribute significantly to the preventive properties of tomatoes against chronic diseases. Phytochemicals found in tomatoes and health benefits (Frusciante et al., 2007):

Lycopene

Tomato can contain up to 3 milligrams /gm of lycopene.

- Lycopene in tomatoes has been studied for its potential to reduce the risk of several types of cancer, including prostate and breast cancer.
- It may help lower LDL cholesterol (bad cholesterol) and increase HDL cholesterol (good cholesterol), reducing cardiovascular disease risks.
- Lycopene may help protect the skin from harmful UV rays, which can lead to skin aging and skin cancer.

Total Phenolic Content (TPC)

The total phenolic content in tomatoes can vary widely depending on the variety and growing conditions, but it is generally significant.

- Helps neutralize free radicals that can cause cellular damage and lead to chronic diseases.
- Reduce inflammation, which is a root cause of many chronic health issues.

- Protect against neurodegenerative diseases.

Quercetin

The levels of quercetin can vary, but tomatoes are an excellent dietary source.

- Quercetin helps mitigate oxidative stress.
- It improves blood vessel function and reduces inflammation.
- Help to reduce symptoms of allergies by inhibiting histamine release.

Kaempferol

Tomatoes contain kaempferol, although in smaller amounts compared to other flavonoids.

- Reduces inflammation and has been linked to lower risks of various chronic diseases.
- Supports cardiovascular health by reducing oxidative stress and improving arterial health.

2.9 Effect of drying on nutritional quality

There are various drying processes for tomato drying, e.g. hot air drying, spray drying, cabinet drying, sun drying, freeze drying, solar drying, etc. The researcher had shown how various drying methods affect the nutritional quality and how to control processing parameters for the highest retention of those nutrients.

Jorge et al. (2018) compared the effectiveness of freeze-drying, sun-drying, heated air drying, oven-drying and infrared drying on phytochemical preservation in tomato powder. Freeze drying was most effective, preserving 90% of antioxidants and phenolic contents. Quantitative analysis showed that freeze-drying retained about 92% of the original lycopene content and 89% of vitamin C. Oven drying retained 75% of lycopene and 65% of vitamin C, while sun drying retained only 50% of lycopene and 40% of vitamin C. Additionally, the color analysis indicated that freeze-dried tomatoes maintained 85% of their original red colour, whereas oven and sun-dried tomatoes retained only about 70% and 55%, respectively.

Rajkumar et al. (2007) examined the impact of storage on the chemical and sensory properties of sun-dried tomatoes. Their results showed an increase in moisture content from 15% to 20% and a rise in microbial counts from 1,000 CFU/g to 1,450 CFU/g, indicating increases of 33.3% and 45%, respectively. Additionally, colour measurement quantified using a colourimeter, stated a 10% reduction in redness, affecting the product's visual appeal.

Davoodi et al. (2007) Evaluated the retention of lycopene and vitamin C in tomato powder produced via different drying methods, finding that spray drying retained the highest levels of these nutrients, including 85% lycopene and 80% vitamin C.

The stability of lycopene in stored tomato powder was studied under various conditions, revealing the best retention approx. 90% at low temperatures and humidity (Anguelova & Warthesen, 2000).

The effectiveness of UV irradiation in reducing microbial load in tomato powder was confirmed, achieving up to a 99% reduction in pathogens (Adejo, 2015). This study emphasized the potential of UV treatment for ensuring safety without altering nutritional or sensory qualities.

Hot air drying has been extensively studied as an effective method for preserving the nutritional quality of tomatoes, particularly when converting them into tomato powder. Research indicates that lycopene, an essential antioxidant in tomatoes, is well-preserved under controlled drying conditions, with retention rates often exceeding 80% when the drying temperature is maintained between 60°C and 70°C (Surendar et al., 2018). This preservation is crucial as lycopene is associated with various health benefits, including reduced risk of chronic diseases.

In addition to its ability to retain lycopene, hot air drying enhances the natural sweetness of tomatoes by concentrating their sugars. This concentration improves the flavor profile of the resulting powder and contributes to its overall consumer appeal. Moreover, the vibrant red colour of tomatoes, which is directly linked to lycopene content, is effectively maintained during the drying process, ensuring that the final product retains its visual and nutritional qualities.

From an economic and operational perspective, hot air drying is also noted for its energy efficiency, particularly in large-scale production settings. The method is relatively cost-effective, providing a viable solution for industries looking to produce high-quality tomato powder with minimal nutrient loss. The controlled drying environment mitigates the risk of over-drying or nutrient degradation, making hot air drying a scientifically validated choice for tomato preservation.

2.10 Tomato powder fortified foods

Market research indicated a 40% increase in consumer interest in tomato powder, particularly for its health benefits and convenience (Adeoye et al., 2017).

The study Lavelli et al. (2001) examined the use of tomato powders to enhance food products' nutritional content and stability. Key findings highlighted that tomato powders effectively fortify foods with vitamins and antioxidants while improving texture and colour stability, making them valuable additives in food processing.

Mehta et al. (2018) demonstrated that integrating tomato powder into bread and muffins enhanced nutritional properties and achieved high consumer acceptance. Similarly, Ramya et al. (2023) found that tomato powder improved texture and shelf life in bakery products. L showed that incorporating tomato powder into pasta significantly boosted its nutritional value and consumer appeal. These studies collectively highlight the versatility and benefits of tomato powder as an additive in various food products.

Tomato powder is increasingly recognized as an effective thickener for tomato sauce, enhancing texture and flavour while maintaining nutritional quality (Donegà et al., 2015). Studies have shown that tomato powder, when rehydrated, provides a consistent and rich viscosity similar to that of fresh tomatoes, making it a viable alternative for thickening sauces.

2.11 Processing technique of tomato

Using whole tomatoes in food products retains all components, including nutrients like vitamins C and A, lycopene, and dietary fibre. Sujatha et al. (2023) reported that whole tomatoes contribute to a 20% higher fibre content in sauces. Also, the seeds and peel could introduce up to a 15% increase in bitterness and a gritty texture, which may not be desirable in all products.

Tomato pomace, comprising seeds, peel, and pulp, is rich in fibre and antioxidants. Szabo et al. (2018) found that adding pomace to bread increased fibre content by 30% and antioxidant activity by 25%. This study also noted that the high fibre content could make products denser, with a potential 10% increase in chewiness, which might be less favourable for certain consumers.

Tomato seeds and peel are particularly rich in bioactive compounds. Choe et al. (2021) highlighted that seeds contribute to a 40% higher essential fatty acid content, while the peel

boosts lycopene levels by 50%. Removing seeds and peel results in a smoother texture and milder flavour. Kim et al. (2016) reported a 25% reduction in bitterness and a 30% improvement in texture smoothness in processed tomato products.

In the commercial production of tomato products, the peel and seeds are often discarded to create a more homogeneous and firm texture in products like sauces and pastes. However, this practice significantly reduces the nutritional content of the final product. Research indicates that removing tomato peel and seeds can reduce key antioxidants, such as lycopene and total phenolic content (TPC). Specifically, lycopene content can decrease from approximately 65 µg/g to 39 µg/g, while TPC may drop from 120 µg/g to 78 µg/g. Additionally, removing these components results in a loss of essential nutrients like Vitamin C, which can decrease by around 20 mg per 100 g, and potassium, which can be reduced by 50 mg per 100 g.

The processing waste of tomato sauce industries includes a significant chunk of pomace, including seed, peels, fibrous parts, and pulp residues. After drying the processing waste, researchers recovered about 510.6 mg/ kg of lycopene, 95.6 mg/ kg of beta-carotene and 1229.5 mg of Gallic acid equivalent/kg (GAE/kg) of total phenolic compounds (Nour et al., 2018).

Researchers are exploring ways to repurpose these discarded tomato seeds and peels to address this nutritional loss. They can be reintroduced into food products as a value-added ingredient by processing them into a fine powder. This approach not only enhances the nutritional profile of the final product restoring some of the lost antioxidants and nutrients but also promotes sustainable practices by reducing food waste in the industrial processing of tomatoes. Incorporating this powder into various food products could potentially restore or even enhance the health benefits originally offered by the whole tomato, offering a more nutritionally balanced product without compromising texture or consumer appeal.

Blanching is a widely utilized pre-processing technique that involves briefly boiling tomatoes and rapid cooling. This method is employed to inactivate enzymes responsible for spoilage, thereby enhancing the shelf life of tomatoes. Urbonaviciene et al. (2012) have demonstrated that blanching effectively preserves tomatoes' color, texture, and nutritional quality, particularly ensuring the retention of crucial nutrients such as Vitamin C and carotenoids, including lycopene. The process also facilitates easier peeling, which is advantageous for

subsequent processing into products like sauces and pastes. The studies indicated that blanched tomatoes retain approximately 85% of their initial lycopene content, making them a preferred option in food processing industries aiming to maintain nutritional value during storage and processing.

On the other hand, unblanched tomatoes retain all their raw nutrients, including heat-sensitive compounds that may degrade during blanching. Calligaris et al. (2002) highlighted that while unblanched tomatoes initially preserve higher levels of certain nutrients like Vitamin C, they are more prone to enzymatic spoilage, accelerating the degradation of their colour, texture, and flavour over time. Unblanched tomatoes also pose challenges in processing, such as difficulties in peeling and a greater risk of microbial contamination during storage. These factors contribute to a shorter shelf life and potentially lower product quality in the long term.

2.12 Impact of storage on raw tomato

Sensory evaluations revealed that deterioration in texture and flavour became noticeable after two weeks, negatively influencing consumer acceptance. Maintaining favourable sensory attributes during storage was highlighted as crucial for consumer satisfaction and influenced purchasing decisions. The researchers also identified specific tomato varieties associated with different resistance to physical and chemical changes during storage.

The Lisiewska & Kmiecik (2000) study assessed how the duration of storage at ambient temperature affected the nutritional content of tomatoes, focusing mainly on lycopene and vitamin C. It was found that while lycopene content initially increased during the first week of storage, it declined sharply after that, whereas vitamin C levels decreased steadily from the onset.

In a longitudinal study of vitamin C content in various tomato varieties, vitamin C concentration decreased significantly from an initial average of 23 mg per 100 g to 16 mg after three months. The decline was not uniform, with the most stable variety decreasing from 20 mg to 15 mg per 100 gm, and the least stable variety from 25 mg to 12.5 mg (Carter & Doherty et al., 2020).

Research focused on the impact of cold storage on cherry tomatoes showed an increase in antioxidant activity from 1.9 mmol Trolox equivalent/100 g to 2.2 mmol by the second week, then a decline to 1.8 mmol by the fourth week. Similarly, total polyphenolic content rose initially but fell by the storage period's end (Vallverdú-Queralt et al., 2011).

The Sualeh et al. (2016) study explored how different storage temperatures and humidity levels affected the ripening process and the incidence of chilling injuries in raw tomatoes. The researchers found that lower temperatures significantly slowed the ripening process but increased the susceptibility to chilling injuries. The optimal storage conditions were identified as 12°C and 85% relative humidity, which effectively balanced the delay in ripening with minimal chilling injuries.

2.13 Impact of storage on tomato-derived products

Research explored how different processing techniques affect the sensory and textural properties of tomato products, such as sauces and pastes. Their analysis indicated that processing techniques like emulsification and homogenization significantly influence the texture and flavour profile, affecting consumer preferences. This study highlighted a significant reduction in water-soluble vitamins and antioxidants but increased concentration of certain minerals like potassium and magnesium.

The Smith et al. (2019) study meticulously measured the degradation in colour and texture of tomato paste stored under varying conditions. Researchers quantified a reduction in colour intensity from 14.5 to 10.2 Hunter units, indicating a 29.7% decrease, and a decrease in firmness from 65 Newtons to 48.75 Newtons, representing a 25% reduction. Additionally, pH levels slightly increased from 4.1 to 4.3, reflecting a subtle change in acidity over six months. Optimal storage at 4°C significantly preserved these qualities, maintaining over 90% of the original colour, texture, and acidity levels.

In their research, Lee & Kim et al. (2020) focused on the nutritional degradation in canned tomatoes during storage. They observed a decrease in vitamin C content from 20 mg/100g to 10 mg/100g, and a reduction in total antioxidant capacity from 5 mmol Trolox Equivalents/100g to 4 mmol TE/100g, reflecting losses of 50% and 20%, respectively. Furthermore, the soluble solids content (Brix) decreased from 5.5 to 4.8, a decrease of 12.7%, indicating a deterioration of flavour intensity.

Thompson et al. (2021) focused on lycopene content and its stability under temperature variations. They documented a decrease in lycopene content from 25 mg per 100 grams to 17.5 mg per 100 grams at 25°C, a 30% loss, compared to a minimal reduction to 22.5 mg per 100 grams, a 10% loss at 4°C over six months. Furthermore, acidity changes were monitored, showing a slight increase from pH 4.2 to pH 4.5 at higher temperatures, which could

influence nutrient stability and taste. Cooler temperatures effectively minimized these biochemical changes, preserving the nutritional and sensory properties of the sauce.

Garcia & Fernandez (2017) explored the microbial dynamics in tomato juice. They found significant increases in total microbial counts from 500 CFU/ml to 800 CFU/ml within two months under non-refrigerated conditions, representing a 60% increase. They also measured an increase in yeast and mold counts, which more than doubled under the same conditions, underscoring the need for stringent storage conditions to ensure safety and quality.

The Lee, H., & Kim, J. (2021) study examined the effects of various preservatives on the shelf life and safety of tomato products. The study revealed that natural preservatives like citric acid and ascorbic acid helped maintain color and texture while effectively inhibiting microbial growth. They recommended that future research focus on exploring combinations of natural preservatives to enhance the efficacy and consumer acceptance of preserved tomato products.

This study involved the preparation of tomato sauce using traditional fermentation methods. The researchers inoculated the sauce with two strains of probiotic bacteria and monitored the biochemical changes over six months. The fermented tomato sauce demonstrated a significant increase in lactic acid concentration, from 0.5% initially to 2.1% at the end of six months. The pH of the sauce decreased from 4.5 to 3.8, enhancing its microbial stability. Probiotic counts remained stable at 10^8 CFU/ml throughout the storage period, significantly higher than the therapeutic threshold of 10^6 CFU/ml typically recommended for probiotic efficacy Z. Wang et al. (2022).

2.14 Lycopene isomerization

Takehara et al. (2014) investigated the impact of industrial processing methods, such as canning and aseptic processing, on lycopene isomerization in tomato products using spectrophotometry, mass spectrometry, and nuclear magnetic resonance (NMR) spectroscopy. Spectrophotometry detected a significant increase in cis-lycopene content, from 0.5 µg/g in fresh tomatoes to 1.5 µg/g in canned products. Nuclear Magnetic Resonance (NMR) Spectroscopy provided detailed spectral shifts, illustrating the transformation from trans to cis forms with notable changes at the carbon double bond locations. Despite the increase in bioavailable cis forms, the overall lycopene content in canned products showed a

decrease from 5.0 µg/g in fresh to 4.5 µg/g, highlighting a loss in total lycopene content during processing.

According to Hackett et al. (2004), the accelerated isomerization and structural changes in refrigerated conditions could impact the antioxidant effectiveness and bioavailability of lycopene. Differential Scanning Calorimetry (DSC) revealed a decrease in the melting point of lycopene, suggesting structural changes. Specifically, the melting point dropped from 176°C in raw tomatoes to 171°C after four weeks of refrigeration. High-Performance Liquid Chromatography (HPLC) analysis found that cis-lycopene in refrigerated tomatoes rose from 0.4 µg/g to 1.0 µg/g, while it only increased slightly from 0.5 µg/g to 0.6 µg/g in tomatoes stored at room temperature. Concurrently, the total lycopene content in refrigerated tomatoes decreased from 5.25 µg/g to 4.85 µg/g, whereas it remained more stable in room temperature stored tomatoes, indicating less degradation at ambient conditions.

2.15 Coating to reduce post-harvest loss

Tomato coating has been extensively studied as a method to reduce post-harvest losses, which are a significant issue in the agricultural sector. Various researchers have investigated different coating materials and techniques to enhance the shelf life of tomatoes and reduce spoilage during storage and transportation.

The researchers concluded that nanotechnology-based coatings could effectively reduce tomato post-harvest losses. Recent studies have investigated using nanomaterials in coatings to enhance the preservation of tomatoes. For example, Mahajan et al. (2021) explored nanoemulsions incorporating essential oils as a coating material for tomatoes. The study found that nanoemulsion coatings significantly inhibited microbial growth and delayed the ripening process, leading to an extended shelf life of tomatoes. The researchers concluded that nanotechnology-based coatings could effectively reduce tomato post-harvest losses.

Similarly, Meena et al. (2020) examined using silver nanoparticles in biopolymer-based tomato coatings. Their findings demonstrated that the incorporation of silver nanoparticles enhanced the antimicrobial properties of the coatings, which in turn reduced decay and extended the storage life of tomatoes.

Biopolymer-based coatings have gained attention for their environmental sustainability and effectiveness in reducing post-harvest losses. Khwaldia et al. (2010) investigated using pectin-based edible coatings infused with natural antioxidants for tomato preservation.

Cold plasma technology is an emerging non-thermal method for extending the shelf life of fresh produce. Recent research by Misra et al. (2014) evaluated the effectiveness of cold plasma treatment in reducing microbial load and delaying tomato ripening. Their findings indicated that cold plasma reduced microbial contamination and helped maintain tomatoes' visual and nutritional quality during storage. Selcuk et al. (2008) also supported the potential of reduced microbial contamination and helped maintain the visual and nutritional quality of cold plasma as a novel method for improving the post-harvest management of tomatoes.

2.16 Tomato-value added products

Tomatoes are consumed in various way; they can be eaten raw in salads, cooked in dishes, or processed into products like sauces, juices, ketchup, and canned goods. The versatility of tomatoes makes them a staple in diverse culinary traditions. According to industry reports, fresh consumption accounts for approximately 30% of tomato usage, while 70% is processed commercially.

The processing of tomatoes into various products is a significant industry, especially in countries with large-scale production. Processed tomato products include canned tomatoes, tomato sauce, ketchup, and paste, staples in households worldwide. This sector not only extends the shelf life of tomatoes but also enhances their economic value, providing stability in price and supply throughout the year.

2.17 Instant Food products

The instant food products market is rapidly growing due to increasing consumer demand for convenient, ready-to-eat meals. This growth is driven by busy lifestyles, rising disposable incomes, and urbanization. The market is expected to continue expanding, with a Compound Annual Growth Rate (CAGR) of around 6% to 7% in the coming years, driven by innovation in product offerings and the increasing need for convenience foods. Several studies indicate that consumers increasingly seek products that align with their health goals, such as low-calorie, high-protein options. Additionally, the demand for plant-based instant foods has surged, reflecting broader dietary trends toward vegetarian and vegan diets. The sustainability of instant food production is another area of growing interest.

The market for commercially available instant food products has grown significantly, driven by the demand for ready-to-eat and easy-to-prepare meal options. Popular products in this category include instant noodles, soups, rice, oatmeal, mashed potatoes, and pasta, all of

which require minimal preparation, often just the addition of hot water. These products are widely commercialized, catering to busy consumers who seek convenience without compromising on variety and taste.

Instant food products offer several advantages:

1. **Convenience:** 70% of consumers choose instant foods for their time-saving benefits, requiring minimal preparation.
2. **Nutritional Enhancement:** Fortified instant foods have seen a 15% increase in market share, with added vitamins, minerals, and proteins to meet health-conscious demands.
3. **Market Growth:** The global instant food market is projected to grow at a CAGR of 6.5% over the next five years, driven by consumer demand for convenient, nutritious options.
4. **Extended Shelf Life:** Instant foods are often dehydrated or processed to extend their shelf life, making them ideal for long-term storage without refrigeration.
5. **Portability:** Instant foods are typically lightweight and packaged for easy transport, making them convenient for on-the-go consumption, especially outdoor activities and travel.
6. **Cost-Effectiveness:** Instant foods are generally less expensive than fresh or frozen alternatives due to mass production and reduced spoilage, providing an affordable meal option.
7. **Versatility:** Instant food products come in various flavors and types, catering to diverse consumer preferences, including dietary restrictions like gluten-free or vegan options.
8. **Waste Reduction:** By offering pre-measured portions, instant foods help reduce food waste, as consumers prepare only what they need.

Recent studies have led to significant advancements across a variety of products. These innovations, which include fortification with essential nutrients and the use of natural ingredients, reflect the evolving landscape of instant foods aimed at meeting health-conscious consumer needs. Mehta et al. (2018) investigated the integration of natural ingredients like vegetable powders into instant food formulations, finding that these additions improved flavor and nutritional value. Similarly, Ramya et al. (2023) explored novel processing techniques, such as extrusion and freeze-drying, to develop instant foods with enhanced texture and prolonged shelf life.

The specific developments and findings in instant food products:

- ◆ Instant Noodles: Researchers fortified instant noodles with iron and vitamin B12, enhancing nutritional content and improving consumer satisfaction.
- ◆ Instant Oatmeal: High-protein instant oatmeal was developed, improving satiety and nutritional profile, making it a preferred choice for health-conscious consumers.
- ◆ Instant Soup: Sodium reduction in instant soups maintained flavor quality, and consumer preference remained strong, highlighting the effectiveness of natural seasoning alternatives.
- ◆ Instant Rice: Fortified instant rice addressed micronutrient deficiencies effectively, with noticeable improvements in public health outcomes in target populations.
- ◆ Instant Pasta: Tomato powder-enriched instant pasta significantly boosted lycopene content and antioxidant activity, contributing to enhanced nutritional value.
- ◆ Instant Mashed Potatoes: Dietary fiber and calcium fortification improved the health benefits of instant mashed potatoes, offering a nutritious alternative to traditional options.
- ◆ Instant Coffee: Incorporating green coffee bean extracts in instant coffee increases antioxidant levels, benefiting consumer health through reduced oxidative stress.
- ◆ Instant Pancake Mix: Gluten-free pancake mix formulations maintained high consumer acceptance, with no significant compromise on texture or taste.
- ◆ Instant Smoothie Mix: Freeze-drying fruits preserve a high level of vitamins, making the instant smoothie mix a nutritious and convenient option for health-conscious consumers.
- ◆ Instant Ramen: Air-dried instant ramen reduces unhealthy fats, offering a healthier alternative with minimal changes to flavor and texture, maintaining consumer satisfaction.

Despite the wide variety of other tomato products, there are no commercially available instant tomato-based sauce powders. This study focused on developing a formulation for powdered instant tomato sauce, addressing a gap in the market. Commercial tomato sauces typically discard the seeds and peel, significantly reducing nutrient and antioxidant content. In contrast, this study used whole tomatoes to prepare the instant powder, ensuring that the final product retains higher levels of nutrients and antioxidants, offering a more nutritious alternative to traditional commercial sauces.

Moreover, the current study underscores the significant potential of developing instant tomato sauce powder using tomato puree and whole tomatoes, particularly in addressing post-harvest losses and meeting growing consumer demand for convenient and ready-to-eat products. By converting tomato processing waste (seed and peel) into a valuable ingredient, this research promotes sustainability and enhances the final product's nutritional profile. The study focuses on the physicochemical properties, bioactive compounds, and consumer acceptance of the reconstituted sauce, which comprehensively evaluates its commercial viability. The findings contribute to the expanding market for instant food products, offering a solution that is lightweight, space-saving, and has an extended shelf life, making it a practical choice for consumers and the food industry.

CHAPTER III

MATERIALS AND METHODS

3.1 Raw Materials Collection

Tomatoes (*Lycopersicon esculentum*) were purchased from Gabura Bazaar in Dinajpur which is renowned as one of the largest tomato markets in Bangladesh. The variety was selected based on several aspects: red colour, which indicates high lycopene concentration, pH above 4.2 for optimal lycopene stability during storage and a total soluble solid (TSS) above 4% to ensure maximum yield. The salt, sugar and spices (garlic, onion and red chili) were obtained from local markets and other ingredients, including maltodextrin, Xanthan gum and preservatives (Citric acid, Sodium benzoate, Acetic acid and Silicon dioxide), were purchased from commercial suppliers.

3.2 Commercial tomato sauce

Commercial tomato sauce was purchased from a grocery shop in Dinajpur. The brand was chosen due to its vast market share and high consumer demand, ensuring that the selected product is representative of popular consumer preferences.

3.3 Chemicals and reagents

Sodium hydroxide (NaOH), gallic acid ($C_6H_2(OH)_3CO_2H$), phenolphthalein ($C_{20}H_{14}O_4$), citric acid ($C_6H_8O_7$), sodium benzoate (C_6H_5COONa), acetic acid (CH_3COOH), xanthan gum, silicon dioxide (SiO_2), acetone (C_3H_6O), sodium sulfite (Na_2SO_3), petroleum ether (C_6H_{14}), hexane (C_6H_{14}), ethanol (C_2H_5OH), butylated hydroxytoluene (BHT, $C_{15}H_{22}O$), sodium carbonate (Na_2CO_3), methanol (CH_3OH), sodium bicarbonate ($NaHCO_3$), 2,6-dichloroindophenol ($C_{12}H_7Cl_2NO_2$), metaphosphoric acid (H_3PO_4), Eosin-Methylene Blue Agar, Salmonella Shigella Agar, Potato dextrose agar, and Nutrient agar.

3.4 Preparation of sample

3.4.1 Powder preparation

The raw tomatoes were sorted, graded, and washed before processing. For instant tomato sauce powder (ITSP-P1), the tomatoes were blanched at 80°C for 3 minutes and then blended to obtain the pulp. In the case of instant tomato sauce powder (ITSP-P2), the tomatoes were blanched in the same manner, after which the peel and seeds were removed before blending the tomatoes into puree. The subsequent processing steps after blending were consistent for

both samples. The next step involved concentrating the pulp at 85⁰C where preservatives (Citric acid 0.3%, Sodium benzoate 0.03%, Acetic acid 0.3% wb), spices paste (Onion 3%, garlic 0.3%, chili 0.08% and salt 0.2% wb) and stabilizer (Xanthan gum 0.3% wb) was eventually added. The concentration process was maintained for 25 minutes, yielding a final total soluble solids (TSS) content of 28%. At the end of the concentration, 8 % wb Maltodextrin was mixed. The final step was to dry the concentrated formulation using a hot air cabinet dryer initially at 75⁰ C for 3 hours, followed by 65⁰C for 7 hours, ensuring optimal moisture removal. The resultant dried product was ground into a fine powder, and then 8% db sugar and 0.8% db silicon dioxide (SiO₂) were thoroughly mixed into the final products.

3.4.2 Packaging and storage

The samples were weighed and packed in a polyethylene laminated aluminum foil package. These packages were then stored at a controlled temperature of 28⁰ C.

3.4.3 Reconstituted tomato sauce

The sauce was prepared by adding normal water to instant tomato sauce powder (ITSP) at a 2:1 and mixed.

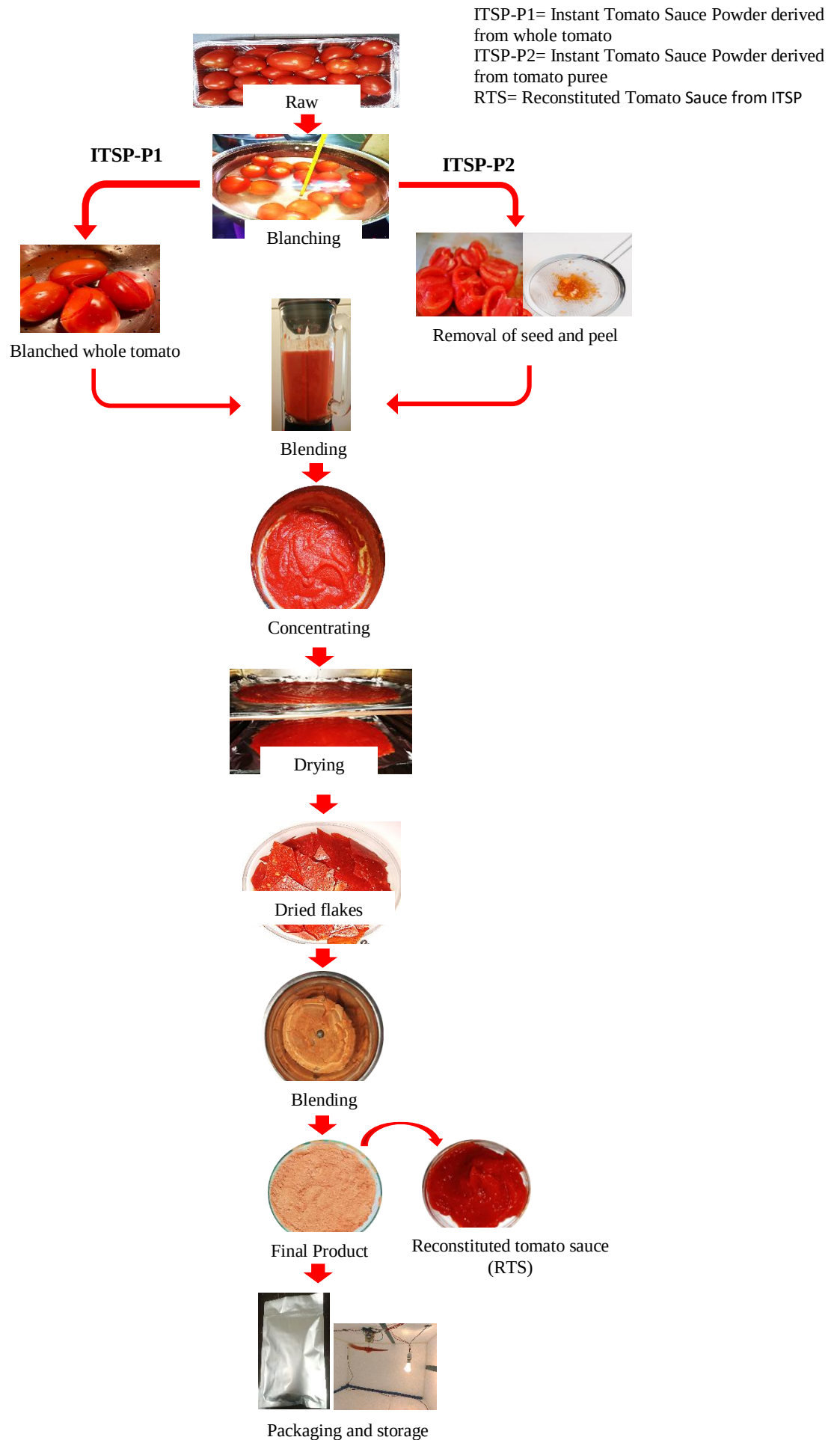


Figure 1: Flowchart of sample preparation procedure

3.5 Powder yield of instant tomato sauce powder (ITSP)

The yield percentage of instant tomato sauce powder (ITSP) was calculated for each sample by dividing the amount of final powder by the amount of concentrated pulp including all ingredients used.

$$\% \text{ Yield} = \frac{\text{Weight of dried final powder}}{\text{Weight of concentrated pulp including ingredients}} \times 100$$

3.6 Powder characteristics of Instant Tomato Sauce Powder (ITSP)

3.6.1 Moisture content

The moisture content of the powder was determined using a moisture analyzer (Model XY-105 MW). A sample of the powder was placed in the moisture analyzer pan, and the instrument was set to measure the moisture content by heating the sample until a constant weight was achieved. The final moisture content was displayed as a percentage, representing the amount of water in the powder relative to its total mass.

3.6.2 Water activity

Water activity (a_w) of the powder was measured using a water activity meter (Model LabSwift-aw, Novasina AG, Switzerland). A sample of the powder was placed in the sample chamber of the water activity meter, where it was allowed to equilibrate. The instrument then measured the water activity, which represents the ratio of the vapor pressure of water in the sample to the vapor pressure of pure water at the same temperature.

3.6.3 Solubility

The solubility of the powder was determined using a modified method from (Eastman & Moore, 1984) and (Santhalakshmy et al., 2015). 1 gram of powdered sample was blended with 100ml of distilled water in a blender running at high speed (1500 rpm) for five minutes. Then the solution was centrifuged at a speed of 3000 rpm for 5 min and allowed to settle completely for 30 min. 25 mL aliquots of the supernatant were transferred to pre-weighed petri dishes and dried in an oven at 105 °C for 5 h. The solubility was calculated by following the equation

$$\% \text{ solubility} = \left[\frac{\text{weight of solid in 25ml} \times 4}{\text{Weight of sample} \times \left(\frac{100 - \text{moisture content}}{100} \right)} \right] \times 100$$

3.6.4 Flowability

The bulk density (ρ_B) and tap density (ρ_T) of the powder were measured as mass-to-volume ratios in grams per cubic centimetre (g/cm^3), following the method of (Abdullah & Geldart, 1999) and (Santhalakshmy et al., 2015). To determine ρ_B , a 100 mL graduated cylinder was gently filled with the powder without compaction, and the mass and volume were recorded. For ρ_T , the same cylinder was manually tapped by raising it to a height of approximately 6.5 cm and dropping it onto a hard surface at 30 taps per minute. This process was continued until the volume stabilized, ensuring maximum packing. The flowability of the powder was then calculated as the Carr Index (CI) using the formula:

$$\text{Flowability (CI \%)} = 100 [(\rho_T - \rho_B) / \rho_T]$$

Carr index (CI%) value with correspondent flow characters:

Flow character	CI%
Excellent/very free flow	≤ 10
good/free flow	11-15
Fair	16-20
Passable	21-25
Poor/cohesive	26-31
Very poor/very cohesive	32-37
Very, very poor/Approx. non-flow	> 38

3.6.5 Wettability

Wettability was determined following the method of Kyaw Hla & Hoge Kamp (1999) by measuring the time required for 1 g of bulk powder to completely submerge in 400 mL of distilled water at 25°C. The powder was gently sprinkled onto the water surface without agitation, and the time until full submersion was recorded, expressed in seconds.

3.7 Rheological behavior of reconstituted tomato sauce (RTS)

The rheological behaviour was determined as a function of viscosity versus speed (Bousmina et al., 1999). The viscosity of both reconstituted tomato sauce (RTS) and commercial tomato sauce was measured using a Brookfield Viscometer (Digital Viscometer BDV-9S, BIOBASE). Samples were equilibrated to 25°C before measurement. An LV-4 spindle was

used, and the viscometer operated at 6, 12, 30 and 60 rpm respectively. 80 gm sample was placed in a 100 mL beaker, and each data were measured at 10 second intervals.

3.8 Physicochemical Characteristics of Reconstituted Tomato Sauce (RTS)

Before physicochemical analysis, the instant tomato sauce powder was reconstituted into the sauce.

3.8.1 pH

A digital pH meter (Jenco 6177M Benchtop Digital pH meter, USA) was used to determine the pH value of the sample. 10 ml reconstituted tomato sauce samples were taken in a 50 ml beaker. Then the electrode of the pH meter was dipped in the beaker. The reading was taken when the value was stable on the display of the pH meter. Previously the meter was calibrated with two known buffer solutions (pH 4 and pH 7).

3.8.2 TSS

Total soluble solids (TSS) were determined using a refractometer (HI-96801, Italy) expressed in %brix. Distilled water was used to tare the refractometer. After that, sample spread on the sample chamber and the reading was taken.

3.8.3 Titratable acidity

Sadler & Murphy (2010) outlined a method for determining titratable acidity, wherein 1 g of the samples were accurately weighed and dissolved in 20 mL of distilled water. The solution was then titrated with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as an indicator until a persistent pink endpoint was reached. The titratable acidity was calculated as the percentage of citric acid equivalent, based on the volume of NaOH used for neutralization. The results were expressed as %, following the standard procedure established in their study.

$$\% \text{ Acidity} = \frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Acid factor}}{\text{Weight of sample}} \times 100\%$$

Where, Normality of NaOH = 0.1; Acid factor (Equivalent weight of citric acid) = 64.04 g/mol

3.8.4 Color of reconstituted tomato sauce

The color attributes of reconstituted tomato sauce samples were analyzed by a colorimeter (BIOBASE Colorimeter BCM-200, China) for L, a*, and b* values noted as lightness, redness, and yellowness respectively.

3.9 Bioactive compound analysis of reconstituted tomato sauce

Before bioactive analysis, the instant tomato sauce powder was reconstituted into sauce.

3.9.1 Total carotenoid

Mahmood et al. (2021) provided the basis for the determination of total carotenoid content. At first, 0.5 grams of the sample were taken and combined with 10 ml of acetone solution in a vortex mixer for 10 minutes. Then filtered it using Whatman No. 41 filter paper. After that, transfer the mixture into a separatory funnel, add 35 ml of petroleum ether and 5 ml of distilled water, and then add a pinch of anhydrous sodium sulfite (Na_2SO_3). After separating the layers, dispose of the lower layer and keep the colored upper layer. Then a UV-vis spectrophotometer to measure the absorbance of this layer at 450 nm. The following equation was used to calculate the total carotenoids

$$\text{Total carotenoids } (\mu\text{g/g}) = (A \times V \times 10^6) / (A_{1\%}^{\epsilon} \times W)$$

Where, A= Absorbance at 450nm; V=Volume of extract in litre; $A_{1\%}^{\epsilon}$ = Dilution factor (2592); W= weight of sample in gram

3.9.2 Lycopene

Fish et al. (2002) method was used to determine the lycopene content. The first step was to combine 0.5 g of the sample with 5 mL of acetone (containing 0.05% butylated hydroxytoluene, or BHT), 5 mL of 95% ethanol, and 10 mL of hexane. The mixture was vortexed for 10 minutes before 3 mL of water was added. The solution was then left to remain at room temperature for 15 minutes to facilitate phase separation. The absorbance of the top layer was recorded at 503 nm using a Shaanxi UV-1800 UV-Vis spectrophotometer. The lycopene content was calculated with the equation:

$$\text{Lycopene Content } (\mu\text{g/g}) = \frac{(X \times A_{503} \times 3.12)}{Y}$$

Where, X = Amount of hexane (mL); Y = Weight of sample (gm); A_{503} = absorbance at 503 nm; 3.12= extinction co-efficient

3.9.3 Total phenolic content

The total phenolic content (TPC) was determined using a modified method based on Rizvi et al. (2023). 1 gram of the sauce sample was extracted with 10 mL of methanol, vortexed for 3 minutes, and filtered through Whatman No. 1 paper. A 0.5 mL aliquot of the extract was mixed with 0.5 mL of Folin-Ciocalteu's reagent, followed by the addition of 1 mL of 7.5%

sodium carbonate solution and 8 mL of distilled water. The mixture was vortexed, left to stand in the dark for 35 minutes, and then the absorbance was measured at 765 nm using a UV-1800 spectrophotometer (Shaanxi, China). TPC was calculated using a gallic acid standard curve, with results expressed as mg GAE/100gm.

3.9.4 Vitamin C

A modified method from Nielsen (2017) was used to analyze the vitamin C content of the samples. The procedure began by adding 1 gram of the material to a conical flask, followed by 10 milliliters of a meta-acetic acid solution (3% metaphosphoric acid and 8% acetic acid in distilled water). The mixture was then quickly shaken to ensure thorough mixing. Titration was performed using a solution of 0.021% sodium bicarbonate and 0.025% 2,6-dichloroindophenol in distilled water. The titration was stopped when a light pink color persisted for at least 5 seconds. The volume of indophenol solution used was determined by recording the initial and final readings on the burette. Then, the concentration of ascorbic acid was determined by applying the following formula:

$$\text{mg ascorbic acid/100g} = \{(X-B) \times (F/E) \times (V/Y)\} \times 100$$

Where, X=mL for sample titration; B=average mL for sample blank titration; F=mg of ascorbic acid equivalent to 1.0mL indophenol standard solution. E=mL assayed; V=volume of initial assay solution; Y=volume of sample

3.10 Microbial Analysis

Microbial analysis followed the method of Chauhan & Jindal (2020). A 2 g sample was homogenized with 20 mL of distilled water, filtered, and serially diluted (10^{-1} to 10^{-5}). For total bacterial count, 1 mL of the diluted sample was inoculated on Nutrient Agar and incubated at 37°C for 24 hours. The presence of pathogenic bacteria, *Escherichia coli* and *Salmonella* were identified using Eosin-Methylene Blue Agar and Salmonella Shigella Agar respectively incubated at 37°C for 48 hours. For mold and yeast counts, the samples were serially diluted with 0.1% peptone and plated on Potato Dextrose Agar, which was further incubated at 30°C for 3-5 days. Microbial analyses were conducted at the 0th and 6th months of storage.

3.11 Consumer acceptability

Thirty consumer panelists were selected from the University community. Consumer panelists were 43% male and 57% female, age ranged from 18 to 35. Samples were randomly presented to the panelists. Consumer Panelists were facilitated to rinse their mouths with tap water between sample evaluations. Consumers who participated had no repulsion to foods or the ingredients used in each sample. Consumers were invited to evaluate reconstituted tomato sauces according to a 9 point hedonic scale of 9 “like extremely” to 1 “dislike extremely”. For comparison, commercial tomato sauce also evaluated, though these differed significantly from the reconstituted tomato sauce samples in terms of processing, manufacturing, and preparation methods (Yang & Lee, 2018).

3.12 Statistical analysis

A study of statistical significance was carried out using SPSS for Windows, version 26.0. The significance level was established at $P < 0.05$ and a one-way analysis of variance (ANOVA) was used. Post hoc mean comparisons were conducted using Duncan's multiple range test. Additionally, the dataset underwent further analysis using a online software MetaboAnalyst 6.0 (<https://www.metaboanalyst.ca/MetaboAnalyst.xhtml>) to perform partial least squares discriminant analysis (PLS-DA) and to generate Variable Importance in Projection (VIP) scores. The statistical analysis of the single factor required a number of critical processes, the first of which was uploading and verifying the data file for completeness and accuracy. Next, autoscaling was applied, which involves mean-centering and dividing each variable by its standard deviation to ensure consistent data scaling. Finally, the dataset was normalized to prepare it for subsequent analyses.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Powder yield

The yield percentages for the Instant tomato sauce powder derived from whole tomato (ITSP-P1) and tomato puree (ITSP-P2) were 19% and 16%, respectively. According to Sarkar & Kaul. (2014), seeds and peels in tomatoes increase the dry matter content, leading to a higher product yield. Moreover, the higher water content in the puree leads to greater mass loss, resulting in a lower yield for ITSP-P2.

4.2 Powder characteristics

Table 1 represents moisture content (%) and water activity, and Table 2 represents changes in solubility, flowability and solubility during six months of Instant Tomato Sauce Powder (ITSP) storage.

Table 1: Change in moisture content (%) and water activity during storage of Instant Tomato Sauce Powder (ITSP-P)

Samples	Moisture Content				Water Activity			
	0	2	4	6	0	2	4	6
P1	^A 5.72±0.010 ^{ab}	^A 5.09±0.01 ^b	^A 6.91±0.04 ^a	^A 6.98±0.294 ^a	^A 0.31±0.01 ^b	^A 0.32±0.01 ^{ab}	^A 0.38±0.02 ^{ab}	^A 0.40±0.03 ^a
P2	^A 4.61±0.09 ^a	^A 4.37±0.09 ^a	^B 4.30±0.01 ^a	^B 4.14±0.365 ^a	^B 0.28±0.04 ^c	^B 0.28±0.04 ^b	^B 0.28±0.09 ^b	^B 0.31±0.03 ^a

All results are expressed as Mean ± Standard deviation,

^{a-c} different superscript letters within a row indicate significant differences among the same samples during storage at $P < 0.05$ level.

^{A-B} different superscript letters within a column indicate significant differences between the samples at the same storage time at $P < 0.05$ level.

P1 = Instant tomato sauce powder derived from whole tomatoes; P2= Instant tomato sauce powder derived from tomato puree

4.2.1 Moisture content (%) and water activity

Table 1 displays the changes in the moisture content and water activity of instant tomato sauce powder (ITSP) during storage. Instant sauce powder derived from whole tomatoes (ITSP-P1) had a higher moisture content and water activity than instant tomato sauce powder derived from tomato puree (ITSP-P2) throughout the storage period. The higher moisture content in ITSP-P1 could be attributed to the presence of seeds and peel, which have been shown to contribute to higher water retention in tomato by-products (seed and peel) during drying and storage. Studies have demonstrated that tomato by-products, such as seeds and peel, naturally contain higher moisture content, which enhances their ability to absorb and retain moisture (Karthika et al., 2016; Knoblich et al., 2005). The lower moisture content and stable water activity in ITSP-P2 were likely due to its more uniform texture and efficient drying process. During storage, both powders gain moisture content and water activity. The ITSP-P1 sample exhibited a 21.03 % increase in moisture content (mc) and a 29.03 % increase in water activity (aw), whereas the ITSP-P2 sample also demonstrated an 11.35 % increase in moisture content and a 10.72 % increase in water activity. This indicates that ITSP-P1 had an increased moisture content and water activity retention as seeds and peel in the whole tomato powder may change the particle size and hygroscopicity, making it better at absorbing water (Lavelli et al., 2013; Vinha et al., 2014).

Table 2: Changes in solubility, flowability and solubility in Instant Tomato Sauce Powder (ITSP-P) during storage

Samples	Solubility (%)		Flowability Carr Index (CI) (%)		Wettability (sec)	
	0	6	0	6	0	6
P1	^B 88.66±0.01 ^a	^B 85.3±0.07 ^b	^B 18.7±0.002 ^a	^B 19.6±0.00 ^a	^A 19±0.00 ^b	^A 22±1.00 ^a
P2	^A 92.09±0.012 ^a	^A 88.21±0.1 ^b	^A 21.95±0.007 ^a	^A 21.95±0.01 ^a	^B 15±0.00 ^b	^B 18±0.00 ^a

All results are expressed as Mean ± Standard deviation,

^{a-b} different superscript letters within a row indicate significant differences among the same samples during storage at $P < 0.05$ level.

^{A-B} different superscript letters within a column indicate significant differences between the samples at the same storage time at $P < 0.05$ level.

P1 = Instant tomato sauce powder derived from whole tomatoes; P2= Instant tomato sauce powder derived from tomato puree

4.2.2 Solubility

The total solubility of instant tomato sauce powder derived from whole tomato (ITSP-P1) was found to be significantly higher than that of instant tomato sauce powder derived from tomato puree (ITSP-P2) throughout the storage period (Table 2). The solubility of ITSP-P1 ranged from 88.66 to 85.5%, while ITSP-P2 was from 92.09 to 88.21%. Tomato puree, characterized by its homogeneous composition and higher concentration of soluble sugars and organic acids, demonstrates greater solubility in water. Conversely, whole tomato powder contains a more complex insoluble matrix with fibres, adversely affecting its solubility (Castoldi et al., 2015). Both powders decreased significantly after six months of storage. The resultant decrease may be due to the oxidative denaturation of chemicals and increased hydrophobicity (Ji et al., 2021). Also, prolonged storage may cause structural changes in the interaction of polysaccharides, such as xanthan gum with other components, reducing its surface area and limits interaction with water (Goula & Adamopoulos, 2008).

4.2.3 Flowability

The flowability of instant tomato sauce powder derived from whole tomato (ITSP-P1) ranged from 18.7% to 19.6% over six months, indicating that its flow was good (Table 2). In contrast, the instant tomato sauce powder derived from tomato puree (ITSP-P2) had a flowability of 21.95%, which remained unchanged throughout the storage period, indicating a fair flow property range. The Carr Index, which measures flow properties, suggests that a higher index corresponds to lower flowability (Carr, 1965). ITSP-P1 showed higher flowability than ITSP-P2 throughout the last storage period. According to Sousa et al. (2008), the fibrous tomato seed and peel powder improved flow qualities by preventing moisture-induced clumping and enhanced bulkiness. During storage, the increase in moisture content over time slightly affected the flowability of ITSP-P1, whereas ITSP-P2 remained unchanged. By the end of the storage period, both powders maintained a passable range of flowability.

4.2.4 Wettability

Instant tomato sauce powder derived from whole tomato (ITSP-P1) had a lower wettability than instant tomato sauce powder derived from tomato puree (ITSP-P2). The wettability of ITSP-P1 and ITSP-P2 ranged from 19 to 22 seconds and 15 to 18 seconds

during storage. Whole tomatoes contain hydrophobic chemicals, such as tomato seed-oil, peel-cutin which reduce wettability by forming a water-absorption barrier (Eller et al., 2010; López-Casado et al., 2007). The fibrous texture of the peel and seed also caused particles to clump together, making them less dispersible in water. The ITSP-P2 had a homogeneous nature with reduced moisture content, resulting in higher wettability. Both powders exhibited increased wettability over the storage period as their moisture content and water activity increased, as Baharoğlu et al. (2012) claimed.

4.3 Rheological behaviour of reconstituted tomato sauce (RTS)

Figure 2 represents the rheological behavior as a function of viscosity with speed. Among the samples, the whole tomato-based sauce (RTS-S1) consistently demonstrated the highest viscosity at all speeds, followed by the puree-based sauce (RTS-S2). The fibrous seed and peels interact with polysaccharides (xanthan gum), reinforcing the hydrocolloid matrix and increasing resistance to flow (Sahin & Ozdemir, 2004). The commercial sauce shows lower viscosity than the reconstituted sauces, primarily because of mechanical homogenization during industrial processing, whereas the reconstituted sauces were derived from powdered formulations. The viscosity of all samples decreased with increasing rotational speed, demonstrating the typical pseudo-plastic behavior of non-Newtonian fluid (Chhabra, 2010). The hydrocolloid matrix, including polysaccharides, protein and other ionic compounds, progressively breaks down with increased rotational speed and subsequently reduces viscosity (Wyatt & Liberatore, 2009). This characteristic is vital for sauces, allowing them to stay thick at rest while becoming more fluid during mixing, pouring, or consumption.

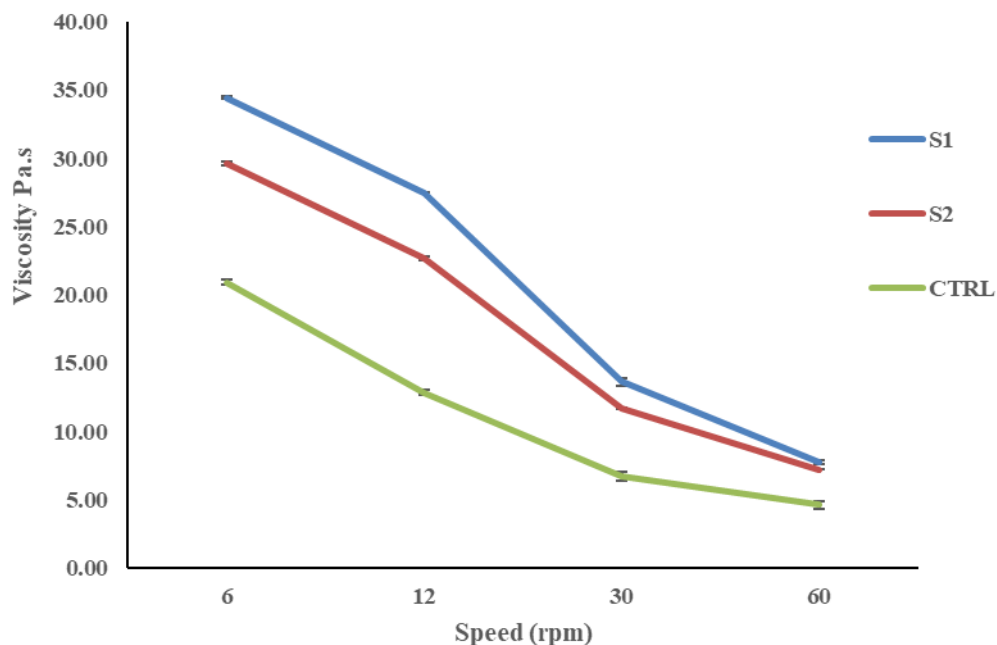


Figure 2: Rheological behavior as a function of viscosity of reconstituted tomato sauces (RTS-S)

RTS-S1= Reconstituted Tomato Sauce from ITSP-P1; RTS-S2 = Reconstituted Tomato Sauce from ITSP-P2
 ITSP-P1= Instant Tomato Sauce Powder derived from Whole tomato; ITSP-P2 =Instant Tomato Sauce Powder Derived from Tomato puree

4.4 Physicochemical characteristics of reconstituted tomato sauce (RTS)

Table 3 shows the changes in TSS, pH and titratable acidity, and Table 4 represents changes in colour of reconstituted tomato sauce during storage.

Table 3: Changes in TSS, pH and titratable acidity of Reconstituted Tomato Sauce (RTS-S) during storage

Samples	TSS (%)				pH				Titratable acidity (%)			
	0	2	4	6	0	2	4	6	0	2	4	6
S1	^A 34.57±0.67 ^a	^B 32.00±0.01 ^b	^B 30.60±0.00 ^c	^B 28.59±0.15 ^d	^A 4.00±0.01 ^a	^A 3.93±0.01 ^{ab}	^A 3.86±0.06 ^b	^A 3.68±0.01 ^c	^A 0.80±0.08 ^b	^B 0.92±0.06 ^b	^B 1.18±0.05 ^a	^C 1.22±0.00 ^a
S2	^B 33.27±0.15 ^a	^C 29.87±0.12 ^b	^C 28.53±0.15 ^c	^C 27.10±0.17 ^d	^B 3.75±0.01 ^a	^B 3.72±0.04 ^{ab}	^B 3.68±0.02 ^b	^B 3.51±0.01 ^c	^A 0.91±0.08 ^c	^A 1.16±0.06 ^b	^B 1.31±0.05 ^b	^B 1.50±0.05 ^a
CTRL	^A 34.43±0.21 ^a	^A 34.50±0.01 ^a	^A 34.00±0.02 ^b	^A 34.10±0.02 ^b	^C 34.54±0.03 ^a	^C 3.55±0.02 ^a	^B 3.53±0.01 ^a	^C 3.41±0.01 ^b	^A 0.92±0.06 ^c	^A 1.12±0.08 ^b	^A 1.57±0.05 ^a	^A 1.63±0.05 ^a

All results are expressed as Mean ± Standard Deviation,

^{a-d} different letters within a row indicate significant differences among the same samples during storage at $P < 0.05$ level.

^{A-C} different letters within a column indicate significant differences among the samples at the same storage time at $P < 0.05$ level.

S1 = Reconstituted tomato sauce from ITSP-P1 ; S2= Reconstituted tomato sauce from ITSP-P2 ; CTRL = Commercial tomato sauce

ITSP-P1= Instant tomato sauce powder derived from whole tomato; ITSP-P2= Instant tomato sauce powder derived from tomato puree

4.4.1 TSS % Brix

Table 3 represents the changes in Total Soluble Solids (TSS) of the Reconstituted Tomato Sauce (RTS) during storage. Control (commercial) tomato sauce had the highest TSS values (34.50-35.28 %Brix) throughout the storage period, followed by reconstituted tomato sauce from ITSP-P1 (RTS-S1) ranged from 34.70-30.81 % Brix and reconstituted tomato sauce from ITSP-P-2 (RTS-S2) ranged from 33.27-28.23 % Brix. The higher TSS values in commercial tomato sauce are probably a result of its distinctive composition, which includes a higher sugar content. The total soluble solids (TSS) of whole-tomato based RTS-S1 were consistently higher than those of tomato-puree based RTS-S2 during storage, possibly due to seed and peel dry content. According to Suthar et al. (2022), tomato waste containing polysaccharides such as cellulose and pectin had a higher retention capacity for moisture and sugars. The total soluble solids in both reconstituted sauces gradually decreased throughout the storage, probably due to the degradation of natural organic acids and sugars with time (Asikin et al., 2014; Chawafambira & Maramba, 2022). In contrast, commercial tomato sauce exhibited slight changes during the storage period. These fluctuations were likely due to preservatives, stabilizers, and other additives that slow down the degradation of soluble solids.

4.4.2 pH and acidity

The Reconstituted Tomato Sauce from ITSP-P1 (RTS-S1) exhibited a higher pH and lower acidity (pH:4.00-3.68; acidity: 0.80-1.22%) compared to reconstituted tomato sauce from ITSP-P2 (RTS-S2) (pH: 3.75-3.51; acidity: 0.91%-1.50%) and commercial tomato sauce (pH: 3.54-3.41; acidity: 0.92-1.63%) in Table 3. Valdez-Morales et al., (2014) studied tomato puree had less acidity. The pH of commercial tomato sauces significantly differed from that of reconstituted tomato sauce samples due to the formulation and processing variance including, addition of various acids and preservatives at different levels. During the storage time, the pH of all samples varied, with a decrease towards the end and an increase in acidity. The continuous metabolic reactions that occur at different rates during storage lead to increased acidity as organic acids accumulate while basic compounds decompose, driving pH alterations (Liu et al., 2010).

Table 4: Changes in colour of reconstituted tomato sauce (RTS-S) during storage

Samples	L				a*				b*			
	0	2	4	6	0	2	4	6	0	2	4	6
S1	^A 26.52±0.21 ^b	^A 28.84±0.65 ^b	^A 28.93±2.48 ^b	^A 32.95±0.18 ^a	^A 7.38±0.06 ^a	^A 7.27±0.05 ^a	^A 7.11±0.05 ^b	^A 6.83±0.04 ^c	^A 6.40±0.22 ^d	^B 7.15±0.09 ^c	^A 9.32±0.23 ^b	^A 10.38±0.11 ^a
S2	^B 25.19±0.31 ^c	^A 29.63±0.76 ^b	^A 29.59±0.71 ^b	^A 33.14±0.86 ^a	^C 6.62±0.07 ^a	^C 6.33±0.09 ^b	^C 6.08±0.04 ^c	^C 5.87±0.04 ^d	^A 6.37±0.38 ^d	^A 7.92±0.21 ^c	^A 8.81±0.26 ^b	^{AB} 9.86±0.39 ^a
CTRL	^B 25.16±0.55 ^b	^A 29.74±0.12 ^a	^A 28.27±2.15 ^a	^B 29.35±0.25 ^a	^B 7.15±0.04 ^a	^B 6.96±0.09 ^b	^B 6.37±0.07 ^c	^B 6.32±0.08 ^c	^B 5.57±0.28 ^c	^A 7.72±0.25 ^b	^A 8.94±0.03 ^a	^B 9.16±0.63 ^a

All results are expressed as Mean ± Standard Deviation,

^{a-d} different letters within a row indicate significant differences among the same samples during storage at $P < 0.05$ level.

^{A-C} different letters within a column indicate significant differences among the samples at the same storage time at $P < 0.05$ level.

S1 = Reconstituted tomato sauce from ITSP-P1 ; S2= Reconstituted tomato sauce from ITSP-P2 ; CTRL = Commercial tomato sauce

ITSP-P1= Instant tomato sauce powder derived from whole tomato; ITSP-P2= Instant tomato sauce powder derived from tomato puree

4.4.3 Colour

Table 4 represents changes in colour during storage in reconstituted tomato sauce samples from ITSP (RTS). The L, a*, and b* values were higher in Reconstituted Tomato Sauce from ITSP-P1 (RTS-S1) as compared to Reconstituted Tomato Sauce from ITSP-P2 (RTS-S2) and commercial tomato sauce at the initial days of storage. Lycopene, which is plentiful in tomato peel, was probably the cause of the greater colour values in whole-tomato-based sauce sample RTS-S1. Albanese et al. (2014) and Kiralan & Ketenoglu (2022) revealed that the incorporation of tomato pomace powder significantly affected the colour of tomato sauce. Commercial tomato sauces often used artificial colourants, which might have affected the colour reading, as indicated in the labelling. The oxidation of lycopene and carotenoid pigment resulted in a decrease in a* and an increased L value during storage. A further change during storage was the isomerization of lycopene from its trans to its cis form (S. Srivastava & Srivastava, 2015). The increase in b* value was likely caused by the Maillard reaction, which occurs when sugar reacts with amino acids in tomato powder, similarly claimed by Yildiz & Baysal., (2007). In addition, the physicochemical properties of the samples, such as pH and acidity, also affected the colour during storage (Holcroft & Kader, 1999).

4.5 Changes in bioactive compound of reconstituted tomato sauce (RTS) during storage

Changes in the bioactive compound of reconstituted tomato sauces during storage are represented in Figure 3.

4.5.1 Total carotenoid and lycopene

The total carotenoid and lycopene content of reconstituted tomato sauce derived from ITSP-P1 (RTS-S1) and reconstituted tomato sauce from ITSP-P2 (RTS-S2) remained substantially greater than that of commercial tomato sauce throughout the storage period (Fig. 3). The commercial product probably had less tomato puree and more artificial flavourings and colors, which indicate less carotenoids and lycopene. RTS-S1 exhibited higher levels of carotenoids and lycopene content compared to RTS-S2. The difference was primarily due to the whole tomato peel, a rich source of carotenoids and lycopene (Sarkar & Kaul, 2014). The total carotenoid and lycopene content of both reconstituted sauce samples gradually decreased over storage. This reduction was because of the oxidative degradation and isomerization of these compounds, as carotenoids and lycopene are highly sensitive to heat

and light (S. Srivastava & Srivastava, 2015). Although, Kubola & Siriamornpun (2011) reported that dried tomato peel retained lycopene better than puree powder during storage. In contrast, the commercial tomato sauce sample exhibited significant fluctuations in carotenoid and lycopene content but was visually stable compared to reconstituted tomato sauces. The unique formulation and packaging of the commercial sauce sample might have influenced its stability.

4.5.2 Total phenolic content

The Reconstituted Tomato Sauce from ITSP-P1 (RTS-S1) had a higher total phenolic content (TPC) than reconstituted tomato sauce from ITSP-P2 (RTS-S2) (Fig. 3). This is because tomato pomace powder typically showed a higher total phenolic content than tomato puree powder (Martínez-Valverde et al., 2002; Nour et al., 2018). Furthermore, Navarro-González et al. (2011) revealed that tomato peel fiber is a rich source of phenolic content. Both reconstituted tomato sauces show a higher TPC than commercial tomato sauce, which could be attributed to variations in the formulation used to prepare the commercial sauce. Furthermore, the commercial tomato sauce featured artificial color and flavor, whereas the reconstituted tomato sauce lacked these additives. All samples showed a progressive decrease in total phenolic concentration during the period. Oxidation, storage conditions, and drying methods can cause degradation of the total phenolic content (Georgé et al., 2011). The commercial sample decline rate remained consistent across the storage time, owing to variations in the packing material, method of processing, and amount of ingredients utilized.

4.5.3 Vitamin C

Initially, Reconstituted Tomato Sauce from ITSP-P1 (RTS-S1) had more vitamin C than Reconstituted Tomato Sauce from ITSP-P2 (RTS-S2) and commercial tomato sauce after storage (Fig. 3). This could be attributed to the higher concentration of bioactive compounds in the whole tomato sauce, such as polyphenols and carotenoids (Georgé et al., 2011; Vinha et al., 2014). The commercial sauce showed lower vitamin C levels as the formulations differed. The levels of vitamin C in the RTS-S1 drastically decreased in the initial period of storage due to oxidation and then remained partially stable. This stability could be attributed to the protein and polysaccharides of peel that may build a complex chemical interaction with vitamin C. Yin et al. (2022) indicated that protein, polysaccharide, and lipid emulsions encapsulate ascorbic acid, protecting it from oxidation and degradation. Vitamin C levels in

RTS-S2 decreased significantly throughout the storage. However, initial vitamin C content in commercial products was lower than in reconstituted tomato sauces due to differences in formulation and preparation methods. On the other hand, the commercial tomato sauce showed only slight changes in vitamin C content during storage likely due to acid regulators or other additives that may help stabilize the product.

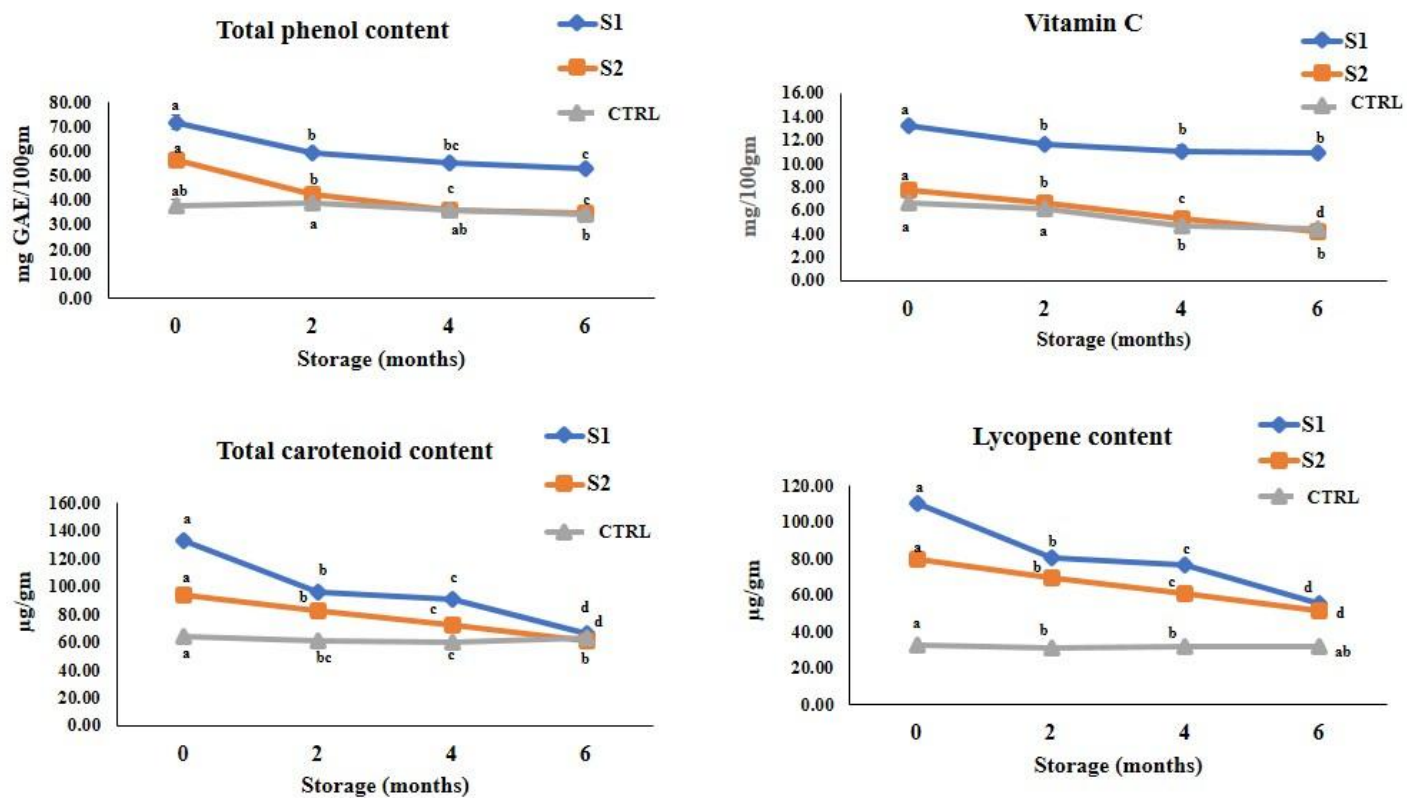


Figure 3 : Changes in bioactive compounds of Reconstituted Tomato Sauce (RTS-S) during storage

a-d different letters indicate significant differences among the same samples during storage at $P < 0.05$ level.

RTS-S1= Reconstituted Tomato Sauce from ITSP-P1; RTS-S2 = Reconstituted Tomato Sauce from ITSP-P2 ; CTRL= Commercial tomato sauce
 ITSP-P1 = Instant Tomato Sauce Powder derived from Whole tomato; ITSP-P2 =Instant Tomato Sauce Powder Derived from Tomato pure

4.6 Microbial analysis

Total bacteria, yeast and mold were not detected throughout the storage period. Also there was no presence of pathogenic bacteria- *Escherichia coli* and *Salmonella*.

4.7 Multivariate analysis of the physicochemical, colour, and antioxidants of reconstituted tomato sauces (RTS)

Partial Least Squares Discriminant Analysis (PLS-DA) was utilized to investigate the physicochemical properties, color attributes, and antioxidant levels of reconstituted sauces prepared (RTS) over time. Figure 4A shows that the first three PCs accounted for 93.1% of the total variation. PC1 was responsible for 29.2%, PC2 for 20.7%, and PC3 for 43.2%. The high proportion of explained variance indicates that three components successfully captured the variations among the samples. The results showed three distinct groups: S1, S2, and CTRL. The samples appear to display varying concentrations of physicochemical qualities, color, and antioxidant content, as indicated by this separation. Figure 4B displays the results of identifying the important variables affecting sample differentiation using the Variable Importance in Projection (VIP) score. Total soluble solids (TSS), lycopene content, a*, and pH were the main variables that distinguished the samples. Other critical factors were the total carotenoids, acidity, L value, total phenols, b* value, and vitamin C.

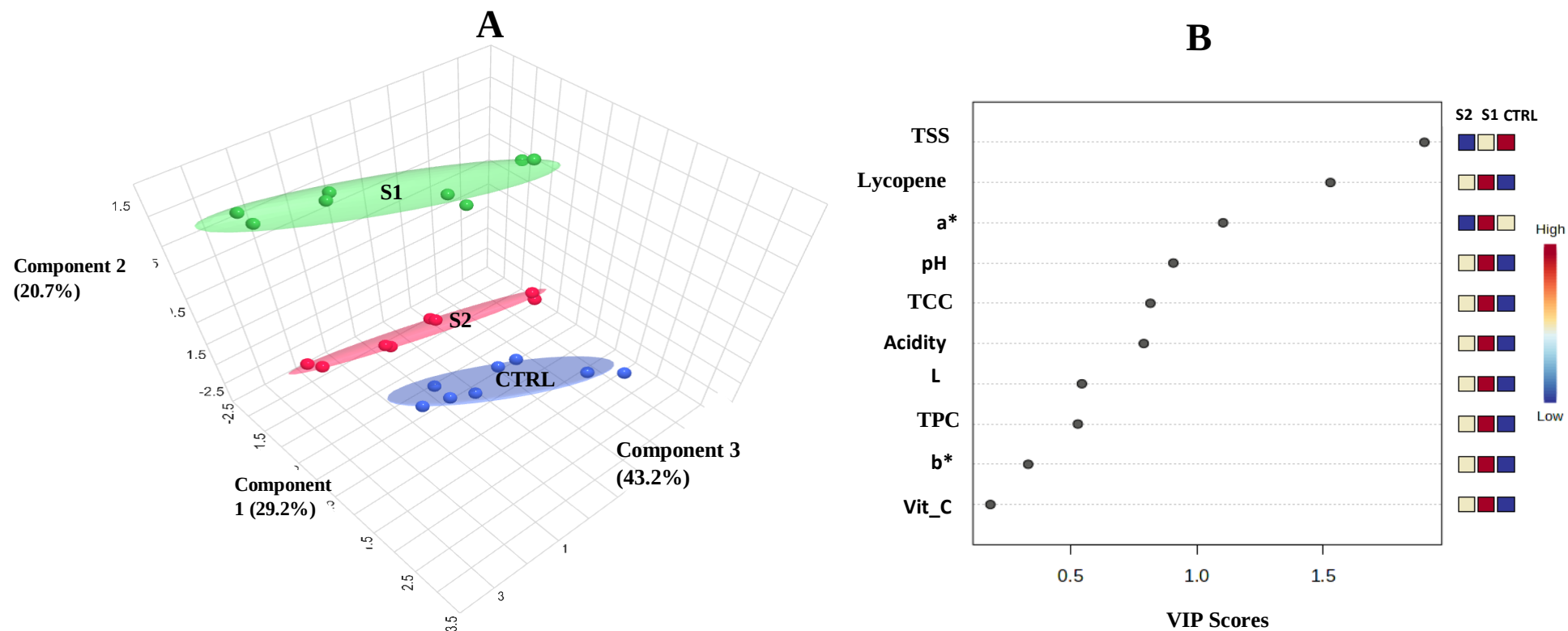


Figure 4 : PLS-DA (A), and VIP scores (B) of Reconstituted Tomato Sauces (RTS-S)

S1 = Reconstituted tomato sauce from ITSP-P1 ; S2= Reconstituted tomato sauce from ITSP-P2 ; CTRL = Commercial tomato sauce
 ITSP-P1= Instant tomato sauce powder derived from whole tomato; ITSP-P2= Instant tomato sauce powder derived from tomato puree

4.8 Consumer acceptability of reconstituted tomato sauce (RTS)

Figure 5 represents the frequency of consumer acceptability on 9-point hedonic scale of reconstituted tomato sauces from ITSP-P1 (RTS-S1), reconstituted tomato sauce from ITSP-2 (RTS-S2) and commercial tomato sauce as control sample. The whole tomato-based sauce RTS-S1 showed the highest frequency response 46.785% for score 7 (like moderately), while the highest hedonic rating was 8 with 15.625 % response. The tomato puree-based sauce RTS-S2 got the highest 43.75% response at a score of 8 (Like very much) with a 3.125% response of 9 (like extremely) score. This is a clear indication that RTS-S2 got the higher liking-response while the only difference between the reconstituted sauces was the presence of seed and peel. The peel and seed part might be responsible for the uneven texture influence the acceptability. Among the samples, commercial tomato sauce had the highest response of 50 % of the consumers who scored 9 (like extremely). Meanwhile, only 3.125 % gave 9 score for RTS-S2 and no response for sample RTS-S1. Although it is generally considered that commercial food products have high response as habitually consumed food has a higher acceptability even after using hurdle sensory evaluation (Garber Jr et al., 2003; Imm et al., 2011).

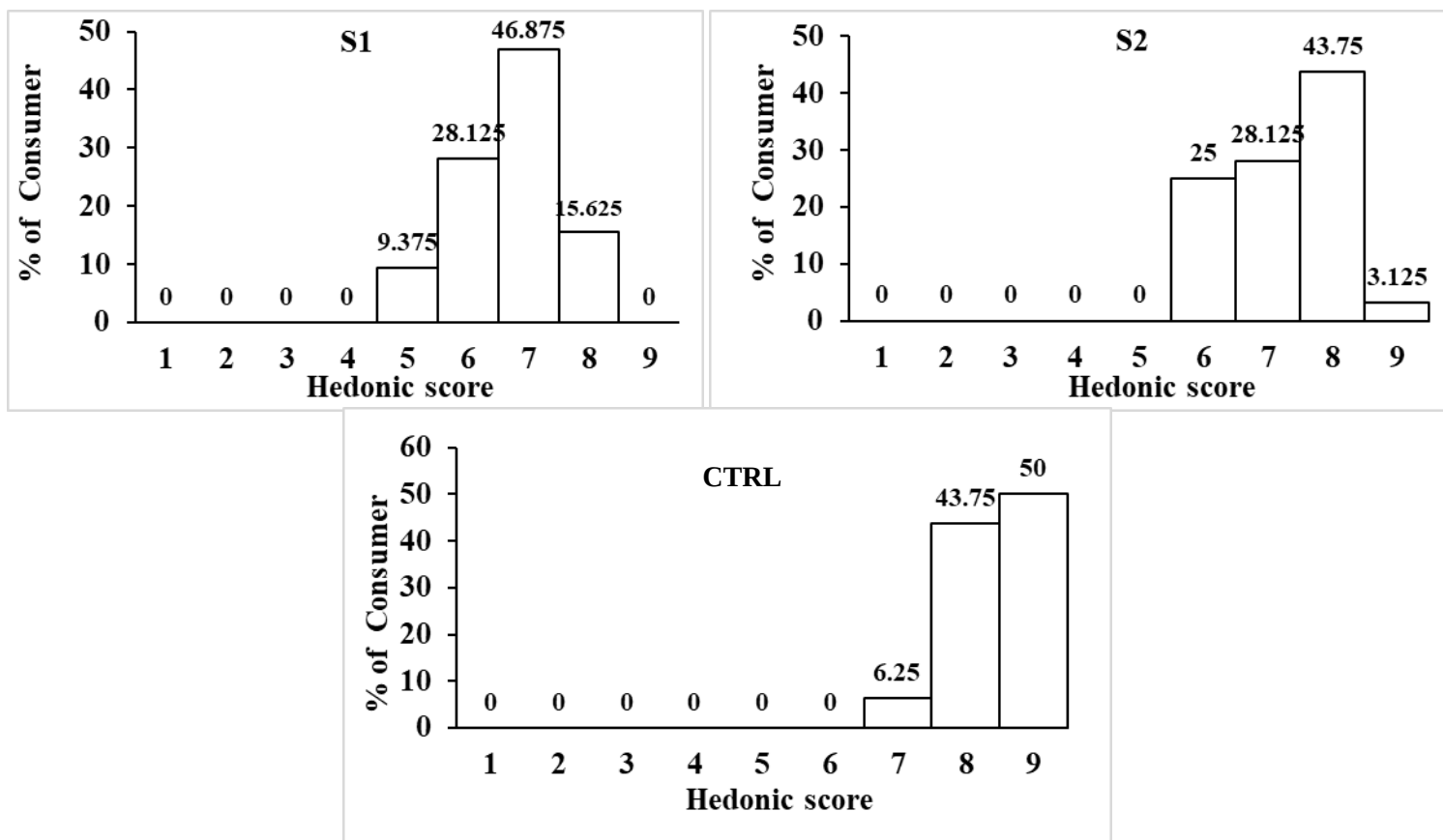


Figure 5: Consumer Acceptability of Reconstituted Tomato Sauces (RTS)

9-point hedonic scale was presented as verbal description where 1 = dislike extremely, 2= dislike very much, 3= dislike moderately, 4= dislike slightly, 5= neither like or dislike, 6= like slightly, 7= like moderately, 8= like very much, 9=like extremely

S1 = Reconstituted tomato sauce from ITSP-P1; S2= Reconstituted tomato sauce from ITSP-P2; CTRL = Commercial tomato sauce
 ITSP-P1=Instant tomato sauce powder derived from whole tomato; ITSP-P2= Instant tomato sauce powder derived from tomato puree

CHAPTER V

CONCLUSION

The current investigation results revealed that instant tomato sauce powder could be successfully prepared from whole tomato and tomato puree using hot air drying. Instant tomato sauce powder derived from whole tomato showed higher moisture content, water activity and wettability, while solubility and flowability were higher in powder derived from tomato puree. The reconstituted sauce maintained a commercial sauce like, rheological behavior, and physicochemical characteristics. All parameters perceived changes over time. The whole tomato-based reconstituted tomato sauce had higher bioactive compound compared to the puree-based sauce which further degraded over time. Moreover, no microbial presence was found during storage period. The puree-based sauce scored the highest acceptability, likely due to its smooth and consistent texture that enhances the overall mouth feel. This study introduces a viable substitute for the existing tomato sauces in market. More research is required to assess the effectiveness of drying techniques in minimizing possible nutrient loss.

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APPENDICES

APPENDIX A: CHANGES IN POWDER CHARACTERISTICS OF INSTANT TOMATO SAUCE POWDER (ITSP-S) DURING SIX MONTH OF STORAGE

Changes in moisture content and water activity:

Sample	Moisture content %				Water Activity			
	0	2	4	6	0	2	4	6
S1	5.57	5.41	6.91	6.9	0.32	0.33	0.36	0.42
	4.15	4.47	6.92	6.92	0.31	0.33	0.37	0.43
S2	4.46	4.32	3.76	4.56	0.27	0.28	0.27	0.3
	4.44	4.27	3.74	4.72	0.28	0.27	0.28	0.32

Changes in solubility, flowability and wettability:

Sample	Solubility (%)		Wettability		Flowability CARR Index (%)	
	0	6	0	6	0	6
S1	88.67	85	19	22	18.09	19.60
	88.64	88.06	19	20	18.68	19.59
S2	92.09	85.66	15	18	21.39	21.96
	92.12	88.34	15	19	21.36	21.94

APPENDICES

APPENDIX B: RHEOLOGICAL BEHAVIOR OF RECONSTITUTED TOMATO SAUCE (RTS)

Speed (rpm)	Viscosity (Pa.s)								
	S1			S2			CTRL		
6	34.379	34.479	34.5	29.504	29.551	29.803	20.852	20.729	21.07
12	27.489	27.489	27.49	22.827	22.609	22.599	12.708	12.874	12.765
30	13.456	13.992	13.4	11.665	11.72	11.678	6.268	6.95	7.064
60	7.832	7.832	7.5	7.2027	7.1855	7.185.5	4.976	4.556	4.292

APPENDICES

APPENDIX C: CHANGES IN PHYSICOCHEMICAL CHARACTERISTICS OF RECONSTITUTED TOMATO SAUCE DURING STORAGE

Changes in TSS, pH and acidity

Storage (months)	pH			Acidity%			TSS % Brix		
	S1	S2	CTRL	S1	S2	CTRL	S1	S2	CTRL
0	4.01	3.74	3.52	0.88	0.85	0.75	35.3	33.3	34.6
	3.99	3.76	3.56	0.96	0.96	0.85	34.4	33.1	34.2
2	3.93	3.69	3.56	1.07	1.20	0.88	32	30	34.51
	3.92	3.74	3.53	1.17	1.12	0.96	32.01	29.8	34.5
4	3.92	3.66	3.54	1.54	1.28	1.22	30.6	28.7	34.01
	3.8	3.69	3.52	1.60	1.34	1.15	30.6	28.5	34
6	3.68	3.52	3.41	1.60	1.47	1.22	28.5	27.3	34.1
	3.67	3.5	3.4	1.66	1.54	1.22	28.5	27	34.12

Changes in Colour

Storage (months)	L			a*			b*		
	S1	S2	CTRL	S1	S2	CTRL	S1	S2	CTRL
0	26.23	24.76	24.52	7.46	6.63	7.2	6.68	6.9	5.63
	26.67	25.41	25.86	7.34	6.71	7.1	6.13	6.1	5.87
	26.67	25.41	25.11	7.34	6.53	7.14	6.39	6.1	5.2
2	27.99	28.73	29.91	7.27	6.45	7.07	7.26	7.72	7.39
	28.95	29.58	29.65	7.33	6.31	6.97	7.13	7.84	7.8
	29.58	30.58	29.67	7.2	6.24	6.85	7.05	8.21	7.98
4	31.37	30.16	25.22	7.17	6.13	6.43	8.99	9.01	8.92
	29.88	28.59	29.79	7.11	6.03	6.4	9.45	8.97	8.98
	25.53	30.02	29.79	7.05	6.09	6.27	9.51	8.44	8.92
6	32.7	34.22	29.7	6.87	5.87	6.43	10.31	9.91	8.26
	33.14	33.08	29.25	6.83	5.81	6.23	10.29	9.36	9.59
	33	32.11	29.11	6.78	5.92	6.29	10.54	10.31	9.62

APPENDICES

APPENDIX D: CHANGES IN BIOACTIVE COMPOUND OF RECONSTITUTED TOMATO SAUCE (RTS)

Storage (months)	Total carotenoid (µg/gm)			Lycopene (µg/gm)			Vitamin C (mg/100gm)			TPC (mg GAE/100gm)		
	S1	S2	CTRL	S1	S2	CTRL	S1	S2	CTRL	S1	S2	CTRL
0	133.71	94.45	65.86	110.61	79.88	33.07	13.02	7.51	6.68	69.51	56.57	39.42
	132.98	94.61	63.16	110.5	79.15	32.97	13.44	7.81	6.51	73.72	55.6	36.18
2	96	82.55	61.14	80.21	69.91	31.64	11.45	6.51	6.24	59.81	42.07	39.42
	96.01	82.23	60.27	80.27	69.6	31.32	11.7	6.72	6.12	58.19	42.49	37.86
4	91.29	72.4	60.27	76.05	60.81	32.32	10.69	5.19	4.36	55.51	35.86	35.92
	89.68	72.18	60.21	76.55	60.38	31.95	11.4	5.36	4.9	55.22	35.53	35.59
6	65.48	60.12	62.57	55.49	51.76	32.88	10.92	4.12	4.38	53.66	35.21	35.15
	66.13	61.81	62.24	55.44	51.51	31.95	10.88	4.31	4.34	52.04	34.89	33.5

APPENDICES

ADDENDIX E: CONSUMER ACCEPTABILITY RATING ON HEDONIC SCALE OF RECONSTITUTED TOMATO SAUCE (RTS)

Consumer	S1	S2	CTRL
1	6	7	8
2	7	7.5	8
3	7	8.5	9
4	8	8	9
5	6	8	8
6	7	7.5	8
7	7	8	9
8	6	7	8
9	8	8.5	8.5
10	7	8	9
11	6	7	9
12	6	8	9
13	6	6.5	8
14	7	6	9
15	7	7	9
16	7.5	6	8
17	7	7	9
18	7	6	8
19	8	7	9
20	7	7	7
21	8	7	9
22	6	6	8
23	7	8	9
24	7	7.5	8.5
25	7	7	8
26	7	8	9
27	7	8	9