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FDRE TECHNICAL & VOCATIONAL TRAINING INSTITUTE

FDRE TECHNICAL AND VOCATIONAL TRAINING INSTITUTE

SCHOOL OF GRADUATE STUDIES

EFFECT OF CARROT-ORANGE BLENDING RATIO AND COOKING TEMPERATURE ON PHYSICOCHEMICAL AND SENSORY PROPERTIES OF COMPOSITE JAM

BY

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JULY, 2026

ADDIS ABABA, ETHIOPIA

EFFECT OF CARROT-ORANGE BLENDING RATIO AND COOKING TEMPERATURE ON PHYSICOCHEMICAL AND SENSORY PROPERTIES OF COMPOSITE JAM

THESIS SUBMITTED TO FDRE TECHNICAL AND VOCATIONAL TRAINING INSTITUTE FACULTY OF AGRO-PROCESSING TECHNOLOGY DEPARTMENT OF FOOD PROCESSING TECHNOLOGY

IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER SCIENCE IN FRUIT AND VEGETABLE PROCESSING TECHNOLOGY (MSc.)

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DECLARATION OF THE AUTHOR

I hereby declare that the work which is being presented in this thesis entitled “effect of carrot-orange blending ratio and cooking temperature on physicochemical and sensory properties of composite jam” is my original work carried out under the supervision of Dr. Tilahun Abera. It has not been submitted for to any degree of any other university/institute and all source of materials used for this thesis are duly acknowledged

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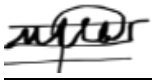
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ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
AlCl3	Aluminum Chloride
ANOVA	Analysis of variance
BR	Blending Ratio
CRD	Completely Randomized Design
FAO	Food and Agricultural organization
GAE	Gallic Acid Equivalent
gm	Gram
H2SO4	Sulphuric Acid
HCL	Hydrochloric Acid
HSD	Honestly Significant Difference
LSD	Least Significant Difference
N	Normality
Na2CO3	Sodium Carbonate
Na2CO3	Sodium Carbonate
NaNO2	Sodium Nitrite
NaOH	Sodium Hydroxide
mPa.s	Milli Pascal-Second
ppm	Parts Per Million
QE	Quercetin Equivalent
SD	Standard Deviation
TSS	Total Soluble Solid
USDA	United State Department of Agriculture
UV	Ultraviolet
W	Weight

ABSTRACT

The study was conducted to develop composite jam from carrot and orange. This study investigated how different carrot-orange blending ratios and cooking temperatures affected the physicochemical and sensory properties of composite jam. A 5×2 factorial Completely Randomized Design (CRD) examined four blending ratios carrot to orange pulp (90:10, 80:20, 75:25, and 25:75) and two cooking temperatures (90 °C and 105 °C) along with control (100% carrot pulp). The results showed that both blending ratio and cooking temperature significantly influenced the quality of the jam. Physicochemical properties, phytochemical constituents, mineral composition and sensory properties analyses were conducted. Moisture content ranged from 34.75% to 38.85%, crude protein 0.62% to 1.11%, crude fat 0.55% to 1.12%, crude fiber 2.08% to 2.91%, ash content 0.25% to 0.34%, carbohydrate 55.69% to 60.27%, Vitamin C 1.11 to 9.73 mg/100g, TA 0.18% to 0.72%, pH 3.48 to 4.17, TSS 61.15 °Brix to 65.25 °Brix and viscosity ranged from 81.99 to 86.20 mPa.s. Phenolics, flavonoids, tannins, sodium, potassium and calcium ranged from 53.24 to 90.13 mg GAE/100g, 92.35 to 118.85 mg QE/100g, 0.42 to 1.19 mg/100g, 1.67 to 10.09 mg/100g, 202.99 to 217.02 mg/100g, 20.13 to 27.04 mg/100g respectively. The result suggest that composite jam developed from 25% of carrot pulp and 75% of orange pulp cooked at 90 °C was a feasible and nutritious value-added product, and that can have enhanced nutritional value, and consumer acceptance, and reduced fruit and vegetable wastage.

***Keywords**: Blending Ratio, Carrot, Composite jam, Cooking Temperature, Orange, Physicochemical Properties, Sensory Acceptability.*

TABLE OF CONTENTS page

DECLARATION OF THE AUTHOR II

APPROVAL SHEET III

ACKNOWLEDGMENT IV

ACRONYMS AND ABBREVIATIONS V

ABSTRACT VI

LIST OF TABLES XII

LIST OF FIGURES XIII

LIST OF TABLE IN THE APPENDIX XIV

LIST OF FIGURE IN THE APPENDIX XV

CHAPTER ONE 1

INTRODUCTION 1

1.1 Background of the Study 1

1.2 Statement of Problems 2

1.3 Objectives 4

1.3.1 General objective 4

1.3.2 Specific objectives 4

1.4 Research Questions of the Study 4

1.5 Hypothesis of the Study 4

1.6 Significance of the Study 5

1.7 Scope of the Study 5

1.8 Limitations of the Study 5

CHAPTER TWO 6

LITERATURE REVIEW 6

2.1 Overview Carrot 6

2.1.1 Nutritional Composition of Carrot 6

2.1.2 Carrot Processing 7
2.2 Orange Fruits 7
2.2.1 Nutritional Composition of Orange Fruit 8
2.2.2 Orange Processing 9
2.3 Overview of Jam and Its Preparation 9
2.3.1 Ingredients of the Jam 9
2.3.2 Jam Production Steps 12
2.4 Factors Affecting Jam Preparation 13
2.4.1. Blending Ratio 13
2.4.2 Composition 13
2.4.3 Sensory Quality 14
2.4.4 Cooking Temperature 14
2.4.5 Nutrient Retention 14
2.4.6 Acceptability 15
2.5 Quality Parameters of Jam 15
2.5.1 Physicochemical Properties of Composite Jam 15
2.5.2 Phytochemical Constituents of Composite Jam. 18
2.5.3 Minerals Content of Composite Jam 18
2.5.4 Sensory Properties of Composite Jam 19
CHAPTER THREE 21
MATERIALS AND METHODS 21
3.1 Location of the Study 21
3.2 Raw Material Collection and Preparation 21
3.2.1 Raw Material Collection 21
3.2.2 Raw Materials Preparation 21
3.3 Preparation of Composite Jam 23

3.4 Experimental Design 25
3.5 Physicochemical Analysis of Composite Jam 26
3.5.1 Determination of Moisture Content 26
3.5.2 Determination of Crude Protein 26
3.5.3 Ash Content 27
3.5.4 Determination of Crude Fat 27
3.5.5 Determination of Crude Fiber 28
3.5.6 Determination of Carbohydrates 28
3.5.7 Determination of Vitamin C 29
3.5.8 Measurement of pH 29
3.5.9 Determination of Titratable Acidity 29
3.5.10 Determination of Total Soluble Solids 30
3.5.11 Determination of Viscosity 30
3.6 Phytochemical Constituent Analysis of Composite Jam 30
3.6.1 Determination of Total Phenolic Content 30
3.6.2 Determination of Total Flavonoid Content 30
3.6.3 Determination of Total Tannin Content 31
3.7 Mineral Analysis of Composite Jam 31
3.8 Sensory Evaluation of Composite Jam 31
3.9 Statistical Analysis 32
CHAPTER FOUR 33
RESULTS AND DISCUSSION 33
4.1 Physicochemical Properties of Composite Jam 33
4.1.1 Moisture Content 33
4.1.2 Crude Protein Content 33
4.1.3 Crude Fat Content 34

4.1.4 Crude Fiber Content 34
4.1.5 Ash Content 35
4.1.6 Carbohydrate Content 35
4.1.7 Vitamin C 36
4.1.8 Titrable Acidity 36
4.1.9 pH Value 37
4.1.10 Total Soluble Solids 37
4.1.11 Viscosity 38
4.2 Phytochemical Constituents of Composite Jam 41
4.2.1 Phenolic Content 41
4.2.2 Flavonoids Content 41
4.2.3 Tannins Content 42
4.3 Minerals Composition of Composite Jam 44
4.3.1 Sodium Content 44
4.3.2 Potassium Content 44
4.3.3 Calcium Content 45
4.4 Sensory Analysis Result of Composite Jam 47
4.4.1 Color 47
4.4.2 Aroma 47
4.4.3 Taste 48
4.4.4 Texture 48
4.4.5 Flavor 49
4.4.6 Spreadability 49
4.4.7 Overall Acceptability 50
CHAPTER FIVE 45
CONCLUSION AND RECOMMENDATION 45

5.1 Conclusion……...… 45

5.2 Recommendation.....46

6. REFERENCES 47

7. APPENDIX.....59

LIST OF TABLES

Table page

Table 1: Nutritional value of 100g of orange fruit.....8

Table 2: Treatment combination of composite jam.....25

Table 3.1: The interaction effect of blending ratio and cooking temperature on physicochemical properties of composite jam.....39

Table 3.2: The interaction effect of blending ratio and cooking temperature on physicochemical properties of composite jam.....40

Table 4: The interaction effect of blending ratio and cooking temperature on Phytochemical Constituents of composite jam.....43

Table 5: The interaction effect of blending ratios and cooking temperatures on minerals composition of composite jam.....46

Table 6: The interaction effect of blending ratio and cooking temperature on sensory properties of composite jam.....44

LIST OF FIGURES

Figures Pages

Figure 1: Flow chart for preparation carrot pulp. 22

Figure 2: Flow chart for preparation of orange pulp.....22

Figure 3: Flow chart for preparation of composite jam. 24

LIST OF TABLE IN THE APPENDIX

Appendix Table 1: Summary ANOVA of Physicochemical Properties of Composite Jam 59

Appendix Table 2: Summary ANOVA of Phytochemical Constituents of Composite Jam 64

Appendix Table 3: Summary ANOVA of Minerals Composition in Composite Jam 66

Appendix Table 4: Summary ANOVA of Sensory Properties of Composite Jam 67

Appendix Table 5: Sensory Evaluation Format Sheet 71

LIST OF FIGURE IN THE APPENDIX

Appendix Figure 1: Raw material for composite jam preparation 72

Appendix Figure 2: Carrot pulp preparation.....72

Appendix Figure 3: Orange pulp preparation 72

Appendix figure 4: Lemon juice (citric acid) preparation 72

Appendix Figure 5: Weight pulp for composite jam formulation 73

Appendix Figure 6: Cooking of composite jam.....73

Appendix Figure 7: Sterilization of glass bottles and composite jam 73

Appendix Figure 8: composite jam products and stored in refrigerator 73

Appendix figure 9: pH and TSS determination of composite jam.....74

Appendix Figure 10: TA determination of composite jam.....74

Appendix Figure 11: vitamin C analysis of composite jam.....75

Appendix Figure 12: fiber analysis of composite jam 75

Appendix Figure 13: Moisture and Ash analysis of composite jam 75

Appendix Figure 14: sensory evaluation of composite jam.....76

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Jam is a semi-solid food type made of boiling fruits or vegetables by adding sugar, pectin and citric acid (Mukhopadhayay and Chatterjee 2023). Sugar makes jams sweeter and acts as a natural preservative by binding the water in the jam and stopping microbial growth (Alsuhaibani and Al-Kuraieef 2018). Pectin always added in order to assist jam gel at the proper pH, sugar levels and facilitate the creation of pectin-pectin linkages (A. Sharma *et al*. 2026) . Acid serves a variety of purposes such as; acidifier, pH regulator and preservation (Pokharel 2024) .

Jam is regarded as ways to preserve food (Das 2023). Its manufacturing process prolongs the shelf life of the jam by lowering the fruit's moisture content and reduce postharvest loss. Consumers and academics are becoming more interested in natural antioxidants, particularly those found in fruits and vegetables, because epidemiological studies show that frequent use of these antioxidants is linked to a lower risk of cancer and cardiovascular disease (Indumathi *et al*. 2014).

Previous research has investigated the development of jam using various combinations of fruits with carrot. Apple and carrot, for instance, have been researched for their physicochemical and sensory qualities (Ullah *et al*. 2018). Research had focused on blending ratios and storage effects on quality but, not investigated how different processing condition like cooking temperatures affect product quality and nutrient retention. Similarly, blends of Carrots with Sweet Potato (Krivokapić, Pejatović, and Perović 2020), Papaya with carrot (Das 2023) and Carrot blends with cucumber Timothy *et al*. (2019) have been investigated to improve nutritional value and consumer acceptability. Previous studies focused on blending ratios which affect both physicochemical composition and sensory acceptability of the jams. The research found optimal proportions for carrot--papaya jams while, the carrot--cucumber jams needed to study multiple blending levels together with their rheological properties under constant cooking conditions. There is a notable lack of investigation into how cooking temperature variations affect quality and they did not investigate blending ratios and cooking

temperatures together to understand their effects on jam properties. Through the inhibition of enzymes and the inactivation of microorganisms, thermal processing is used to increase the shelf life of vegetable jams. However, the thermal treatments frequently result in significant adverse effects, such as the loss of nutritional compounds, a decrease in biological activities, and changes to color, flavor and texture (Riganakos *et al*. 2017). Moreover, they were unable to develop the jam using carrots and other citrus fruits, such as oranges, which had different nutrients and enhanced the spreadability, acidity and unflavored of the carrots that oranges help mask the characteristic earthy aroma and flavor of carrots, which originate from volatile compounds such as terpenoids.

Therefore, the study aims to fill these gaps by evaluate how cooking temperature and blending ratio affect the quality of carrot-orange composite jam.

1.2 Statement of Problems

Post-harvest loss is one of the major challenges affecting of food security and global hunger in many countries (Elik *et al*. 2019). Elik *et al.* 2019 reported the maximum level of fruit and vegetable losses reaches 50%, which means that the reduction of fruit and vegetable loss and waste stands as the main challenge for achieving sustainable food supply for the entire global population in upcoming years. Around 20-50% losses are occurring in developing country like sub-Saharan countries (Hailu and Derbew 2015).

Ethiopia suffers from high post-harvest losses that determine food security and nutrition (Mintesnot 2016). However, the country's produce large quantities of production (Banjaw 20 17). Rahiel *et al*. (2018) indicated that that nearly 30 % vegetables are lost after harvest due to lack of adequate postharvest technology. In Ethiopia, carrot cultivation is expanding rapidly due to increasing demand in urban and peri-urban markets. Recent estimates indicate that total production has reached 12,345.8 metric tons cultivated on approximately 2,215 hectares (Bareke *et al*. 2025) . However, about 11.74% postharvest loss has been reported by (Yeshiwas and Tadele 2021). Ethiopia produced approximately 53.3 thousand metric tons of oranges in 2024. Although production has fluctuated over the years due to diseases, limited improved planting materials, and management constraints, orange remains an important fruit crop for income generation, nutrition, and domestic consumption. The extent of fruit loss for orange is 12.6 percent (Gosa, Aga, and Geleta 2019) . These losses lead to significant food and economic

waste and exacerbate food insecurity in Ethiopia (Etefa, Forsido, and Kebede 2022). Economic losses in Ethiopia by reducing the quantity and quality of marketable produce, lowering farmers' incomes, increasing marketing costs and limiting the availability of raw materials for agro-processing industries.

Processing of fruits and vegetables into value added products like jam has been seen as an effective way to reduce post-harvest losses and at the same time improve how products are used and their market worth. Halder *et al.* (2024) noted that technologies for fruit processing can greatly lower waste and make shelf life longer. However, the quality of jam and similar spreads is strongly shaped by processing conditions such as cooking heat and the mixing proportion.

At the same time, today's consumers want foods that give good nutrition, natural taste and bright colour and that keep okay on the shelf, as Augustin *et al*. (2016). So using fruits and vegetables that are local and often ignored, by making jam which has high soluble solids content and a low water activity, which inhibit the growth of spoilage microorganisms, a way to make healthy, nutritious foods and reduce losses after harvest. Mixing carrot pulp with orange pulp to make jam better balance of sweetness, acidity and aroma than other citrus fruits, because carrot brings lots of carotenoids, minerals and dietary fiber while orange adds vitamin C, organic acids, antioxidants and those pleasant flavor compounds.

Therefore, the present research work was conducted to prepare a value added product from carrot and orange fruit and study the influence of blending ratios of carrot-orange and cooking temperature on composite jam.

1.3 Objectives

1.3.1 General objective

- The aim of this study is to determine the effect of carrot-orange blending ratio and cooking temperature on the physicochemical and sensory properties of composite jam.

1.3.2 Specific objectives

The specific objectives of this study are:

- To determine how different blending ratios of carrot-orange with various cooking temperatures would affect the physicochemical characteristics of composite jam
- To evaluate how different blending ratios of carrot-orange with various cooking temperatures would affect the sensory characteristics of composite jam
- To determine how different blending ratios of carrot-orange with various cooking temperatures would affect the phytochemical constituent of composite jam
- To determine how different blending ratios of carrot-orange with various cooking temperatures would affect the mineral composition of composite jam

1.4 Research Questions of the Study

1. How do the blending ratios of carrot-orange with various cooking temperatures affect the physicochemical properties of composite jam?

2. How do different blending ratios of carrot-orange with various cooking temperatures affect the organoleptic properties of composite jam?

3. How do different blending ratios of carrot-orange with various cooking temperatures affect the phytochemical constituents of composite jam?

4. How do different blending ratios of carrot-orange with various cooking temperatures affect the minerals composition of composite jam?

1.5 Hypothesis of the Study

Null hypothesis (H0): Blending ratios of carrot-orange and Cooking temperatures have no significant effect on the physicochemical and sensory properties the composite jam.

Alternative hypothesis (H1): Different blending ratios of carrot-orange with various cooking temperatures have significant effect on physicochemical and sensory properties of composite jam.

1.6 Significance of the Study

The study providing macro and micro nutrients including vitamins, proteins, carbohydrates and bioactive chemicals that support growth, energy production and general health protection (Organization and others 2020; Ramya and Patel 2019). It increase distribution of value added products within local products and creates sustainable income streams through product range expansion (Yahia, Fonseca, and Kitinoja 2019). And also, practical benefits which enabled small and medium-scale processors, entrepreneurs and extension workers to produce jams with desired taste quality and nutritional value and chemical properties (Mushtaq and Goswami 2025). The study providing information and knowledge of fruit-vegetable jam technology by establishing formulation ratio and thermal processing condition (Mushtaq and Goswami 2025).

1.7 Scope of the Study

The thesis work focused on preparation of the composite jam from carrot and orange, and determined the effect of carrot-orange blending ratios and cooking temperature on physiochemical and sensory qualities of composite jam.

1.8 Limitations of the Study

- The research limited to examined the specific aspects of jam mentioned above and did not extended to other types of composite because the findings are applicable only to carrot–orange composite jam
- The study was conducted using a specific cooking temperature and blending ratio, which limited the general findings and did not consider any other interaction effect with parameters like cooking time and ingredients during process due to limitations in time, and the need to maintain a manageable experimental design
- Shelf-life and storage stability of composite jam were not investigated because the study focused on product development and the immediate assessment of physicochemical, phytochemical, mineral and sensory properties after processing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview Carrot

Carrot (*Daucus carota L*.) is a widely cultivated root vegetable which belongs to the Apiaceae family because of its nutritional value and economic value and health value (Bashir *et al*. 2021). The plant originated in Central Asia, but now grows throughout temperate and subtropical regions around the world. It serves as an essential horticultural crop in China and India and Ethiopia, because it helps secure food supplies and generates income for those nations. In addition, it providing exceptional nutritional benefits, because it essential for vision and immune health and general health (Nagraj *et al*. 2020). The food contains essential nutrients, which include vitamin C, dietary fiber and potassium, together with antioxidants that help prevent chronic illnesses. The nutritional profile of carrot enables it to function as a vital defender against vitamin deficiencies which affect developing nations. The carrot serves as an essential edible root which consumers use fresh while food processing industries utilize it to deliver essential vitamins and minerals and dietary fiber to people throughout the globe.

2.1.1 Nutritional Composition of Carrot

The nutrient-loaded root vegetable carrot provides both essential macronutrients and beneficial plant compounds. The item has a standard proximate composition which contains 84% to 95% of moisture, 0.6% to 2.0% protein, 0.2% to 0.7% fat, 9.58% to 10.6% carbohydrates and 0.6% to 2.9% dietary fiber according to described by (H. K. Sharma 2018). The carbohydrate content of the sample was 9.58g/100 g, protein content 0.93g/100 g, fiber content 2.80g/100 g and the vitamin C content 5.9mg /100 g according to described by (Raees-ul and Prasad 2015). Carrots provide multiple nutrients while serving as a major antioxidant source which contains phenolic compounds that have total phenolic content between 10.5 and 267.1 mg/100 g with purple carrot varieties showing maximum concentration of these compounds according to described by (Raees-ul and Prasad 2015).

2.1.2 Carrot Processing

The first step in carrots processing which need to be maintained as their most important requirement is washing (Mazza 2021). The carrots washed to remove all dirt, mud and all other materials which were collected during the harvesting process. The industrial-grade washing machines use their brushes and water jets to scrub the carrots, while they remove all outer layer contaminants.

Conversa *et al*. (2021) indicated that carrot quality is impacted differentially by various peeling techniques. When carrot roots are peeled, the epidermis and certain sub-epidermal tissues are removed, transforming the roots from entire to ready-to-use forms for further handling (Edelenbos 2015). In comparison to unpeeled roots, peeling also increases respiration rate. Additionally, more severe peeling techniques result in a greater loss of ascorbic acid, and the roots' look and color are noted (Kenny and O'Beirne 2010).

Finally, Pulping of carrot into a uniform after pretreatment (Peters 2019). This process removes coarse fibers from the products, which are key to getting perfect jam production.

2.2 Orange Fruits

Orange belongs to the *Rutaceae* family, is the most widely cultivated citrus fruit which people consume throughout the world (Etebu and Nwauzoma 2014). It originating from Southeast Asia and become a crucial element of the global fruit market, because of their unique scent, hydrating juice and their ability to thrive in both subtropical and tropical regions (Schwartz *et al.* 2016).

In Ethiopia, the citrus industry, particularly orange production, plays a vital role in the national economy and the horticultural sector (Dagnew and Belew 2011). For Ethiopian smallholders and commercial state farms, oranges represent a high-value commodity that serves both the domestic fresh market and the juice processing industry. However, similar to carrots, the orange sector faces challenges such as seasonal gluts, where an oversupply during peak harvest leads to significant price drops and waste due to the lack of advanced cold chain infrastructure. The high market demand for oranges is met with delivery challenges, because the fruit has a short shelf life and experiences post-harvest fungal decay and transportation-related mechanical damage (Ravi Chandra 2021). The process of making composite jam from these fruits serves as an efficient method to prolong their storage duration (Shinwari and Rao 2018).

2.2.1 Nutritional Composition of Orange Fruit

The orange contains highest nutritional value through its outstanding Vitamin C (ascorbic acid) content which functions as a strong water-soluble antioxidant (Kujawińska *et al*. 2022). It also contains organic acids including citric acid and malic acid. These acids give the fruit its distinct sour flavor which serves an essential function in food processing (Walker and Famiani 2018). large quantity of dietary fiber, especially pectin, which exists in high amounts within the fruit pulp and the white albedo layer Angor (2023),which serves as a natural gelling agent by existing as a complex carbohydrate and bioactive compounds in orange fruit.

Table 1: Nutritional value of 100g of orange fruit

Component	Composition
Protein	0.94 g
Fat	0.12g
Water	86.75g
Fiber	2.4 g
Vitamin C	53.2mg
Potassium	181mg
Calcium	40mg

Reference: (Rawal *et al.* 2023)

2.2.2 Orange Processing

The first step of orange processing involves sorting, cleaning, and sanitization (Aky\ild\iz, Dundar Kirit, and A\ugçam 2024). The inspection of fruits leads to the removal of infected items which have both fungal infections and mechanical bruising and insect damage, because even a small amount of spoiled fruit can compromise the flavor and microbial safety of the entire batch.

Then, peeling process of differs from the processing method of carrots, because whole carrots can be processed, while oranges require their skin to be removed to prevent bitter taste (Pagán, Ibarz, and Pagán 2005). The fruit's components can transfer their bitter taste to the jam when they enter the pulp. The fruit undergoes halving before being processed through reaming or through mechanical juice sacs extraction to produce high-quality composite jam.

The final step in preparing orange pulp for jam production is quality standardization and pre-treatment (Jacob and Gomez 2024). The pulp TSS measurement together with pH assessment at this point in time serves as essential data needed to create the final jam recipe. Pulp serves as the acidic and aromatic component of the composite jam, providing the chemical environment necessary for the pectin in the carrot-orange mixture to form a stable gel during the subsequent cooking process (Jolie and Hendrickx 2010).

2.3 Overview of Jam and Its Preparation

Composite jam functions prepare from multiple fruit and vegetable pulps which undergo cooking with sweeteners and pectin and acid (Kapoor 2021). It used to exist as single-fruit products, but contemporary food science now uses composite or blended preserves to enhance nutritional value and sensory variety of food items.

2.3.1 Ingredients of the Jam

2.3.1.1 Fruit and Vegetable

Cosme *et al*. (2022) indicated that fruits and vegetables are rich sources of vitamins, minerals, phytochemicals, dietary fibers, vitamin C, vitamin E, carotenoids and polyphenols. Depending on the variety, maturity level and storage circumstances, the fruits used in the production also have an impact on the gelling process. The fruit's pectin content, sugar and acid content, mineral content, and other fruit-specific components are the most crucial elements. Fruit

enzymes break down the fruit's natural pectin as it ripens, making the pulp softer. Optimal ripeness, full fruity flavor, variety-specific color, no blemishes (spots, bruises), adequate consistency (form solidity) and soluble solids content in accordance with quality standards, and perfect hygienic condition of raw materials and packaging are the most crucial quality criteria for fruits used.

2.3.1.2 Sugar

Sugar contributes gelling qualities and color retardation, which helps preserve the color of fruit goods by drawing and retaining water (Cosme *et al*. 2022). One of the primary ingredients in jams, jellies, and marmalades, sugars have a significant impact on the shelf life of these goods due to their soluble solids content. Taste, flavor, consistency and coloration are all provided simultaneously. Jams are frequently made with refined sugar or white sugar. Additional sugar must be added to the finished product in order to achieve the necessary sugar content of 65 to 68%. A portion of the sucrose is inverted during heating. The pH level, temperature and boiling duration all affect this desired chemical process, which is the breaking of sucrose into glucose and fructose by binding water. Invert sugar inhibits the sucrose in the final product from crystallizing.

2.3.1.3 Citric Acid

Citric acid is the primary ingredient in jam production (Saad *et al*. 2021). Fruit processing uses acid for a variety of purposes including acidification, pH regulation, flavoring, preservation, gelling and coagulation (Sinha *et al.* 2012). The process of making jam requires fruits with higher acid content than what naturally occurs in low-acid fruit varieties. The pH of jam (optimum pH 3.2 to 3.44) products depends on organic acids which function as their primary acidifying agents to reach the optimal gel formation pH. Gel elasticity increases and the gels become hard and brittle if the acid value is too high. The gel structures become extremely soft when the acid value is low. Many fruits naturally contain citric acid. It dissolves readily in water and is crystalline. Although it is stronger than lactic acid, citric acid is weaker than tartaric acid. Citric acid has a naturally tart and pleasing flavor. It is also recommended to add this acid in a 50% aqueous solution. Fruit acids are often added to the cooking batch near the end of the cooking process. This avoids pre-gelling, which could happen if the cooking batch's temperature falls below the predetermined level as a result of the sugar or pectin solution being

blended in. An excessively long processing time can result in pre-gelation following the addition of acid, even if all parameters are optimized and the temperature is higher than the setting temperature.

2.3.1.4 Pectin

Fruits naturally contain pectin, which can be extracted and used in food processing to create the distinctive gel in jams and jellies (Cherian *et al*. 2024). The type of fruit, its level of ripeness, its species and its development stages all affect how much pectin it contains. When compared to completely ripe fruit, it is higher in under-ripe fruit. Citrus, apples and beet fruits are among the fruits from which pectin's are extracted for use in the commercial production of jams and jellies. It is necessary for the production of jam, because it functions as a gelling agent, which means that when the pectin chains come together, they form a network that eventually turns into a gel.

2.3.1.5 Interaction Effect of Ingredients

The quality of jam depends on the interaction among fruit, sugar, pectin and acid rather than on the individual ingredients alone (Chalchisa *et al*. 2022). Pectin forms the gel structure, sugar binds free water and increases soluble solids, while acid lowers the pH to the optimum range (approximately 3.0–3.5), enabling pectin molecules to form a stable three-dimensional gel network (Said, Olawuyi, and Lee 2023). A proper balance among these components is essential for achieving the desired texture, consistency, flavor, color and shelf stability of jam (Shinwari and Rao 2020). If the sugar or acid concentration is too low, the gel becomes weak or fails to form, whereas excessive acidity can produce a hard and brittle gel. Fruit composition also influences these interactions because different fruits vary in their natural pectin, sugar, acid, moisture, and fiber contents.

In composite jams blending fruits with complementary characteristics can improve both nutritional and sensory quality (Rana *et al.* 2021). Furthermore, cooking facilitates the interaction of these ingredients by dissolving sugar, activating pectin, and concentrating soluble solids, although excessive heating may degrade pectin and heat-sensitive nutrients (Sui *et al*. 2025).

2.3.2 Jam Production Steps

The basic steps for the making of jam include the preparation of fruit, boiling, filling, and packaging.

2.3.2.1 Fruit and Vegetable Preparation

The optimum state of fruit and vegetable ripeness serves as the first requirement for jam production, because it needs fruits to meet the standard (Sinha *et al*. 2012). The correct method for cleaning fruits involves using water to remove all the dirt that has become attached to the fruit surface (Akyildiz and A\ugçam 2014).

2.3.2.2 Pulp Preparation

The fruit undergoes mechanical breaking at the factory to produce its base material for making jam. The prepared fruit undergoes crushing or pulping to produce a complete uniform puree. The commercial processes require pulp pre-heating through blanching to achieve tissue softening while enzyme inactivation prevents both browning and off-flavours from developing (H. K. Sharma 2018).

2.3.2.3 Boiling

Boiling dissolves sugar and creates a gel through sugar-acid-pectin combination. The fruit shows different behavior when sugar syrup cooks it because of its specific fruit type (Zaitoun, Ghanem, and Harphoush 2018). The process needs boiling time to be short because extended boiling time results in flavor loss and color change and pectin hydrolysis (Ismail and Revathi 2006). Different methods exist to determine the final point of the jam. The first, involves putting some of the jam in a cup of water; if the water's color does not change and the drop settles as solid substance at the cup's bottom, the jam has reached its end point. The second method, requires a refractometer which functions as a digital instrument to assess the complete soluble solid content of a product; the jam reaches its readiness stage when it achieves a measurement between 60 and 68ºBrix.

2.3.2.4 Test Spreadability

The process begins with boiling which uses a spoon or wooden ladle to extract a small jam portion (Devi *et al*. 2015). The extracted portion is then allowed to fall from its position. The product has reached its final stage, when it falls as sheets or flakes instead of flowing as a continuous stream of syrup. The process will continue to boil until the sheet test shows positive results.

2.3.2.5 Filling and Packaging

The hygienic storage of jam requires its distribution in hermetically sealed containers which protect against soil, bacteria, and gas particles according to described by (Sethi, Choudhary, and Kumar 2025). The glass packaging of jams and jellies provides an attractive presentation which enables extended storage after product opening (Cunha *et al*. 2020). The containers need water cleaning or inverted air cleaner cleaning procedures before their filling process. The container was warmed to stop the hot product from entering and shattering the glass. The containers require pre-filling heating, because it protects against spoilage, while allowing hot product entry into containers (Saravacos and Kostaropoulos 2015).

2.3.2.6 Storing

Store the composite jam after packaging and labeling at four degree Celsius in a cool, dry and dark environment (Egan 2016).

2.4 Factors Affecting Jam Preparation

2.4.1. Blending Ratio

Leul *et a*l. (2026) reported that the strawberry fruit blending ratio was taken into consideration in study as an input component that had a less substantial impact on the final jam's vitamin C content. Rather than the blending ratio of the strawberry fruit content, this could be caused by the significant degradation of vitamin C that takes place during thermal processing.

2.4.2 Composition

The composition of jam is influenced by raw material proportions and processing conditions, particularly blending ratio and cooking temperature (Leul *et al*. 2026). These factors determine key physicochemical properties such as total soluble solids, pH, moisture content, ash and bioactive compounds including vitamins and phenolics. Fruit-vegetable combinations

contribute differently to the nutritional and chemical composition; for example, some provide higher vitamin C while others contribute dietary fiber and carotenoids (Yahia, Maldonado Celis, and Svendsen 2017). Therefore, formulation significantly determines the final chemical and nutritional composition of jam (Wasihun *et al.* 2023)

2.4.3 Sensory Quality

Sensory quality refers to consumer-perceived attributes such as taste, aroma, color, texture and overall acceptability (Symmank 2018). It is strongly influenced by both blending ratio and processing conditions, which determine the balance of sweetness and acidity, flavor intensity, spreadability and visual appeal of the jam. Formulation enhances sensory attributes by improving flavor harmony and texture consistency, whereas poor formulation or excessive processing may lead to undesirable taste, darkened color, or weak gel structure (Kirtil 2025)

2.4.4 Cooking Temperature

The most important aspects of manufacturing fruit jam are cooking temperature (Leul *et al.* 2026). Vitamins and minerals can be depleted by high processing temperatures. A reduction in pH, vitamin loss, total phenolics, antioxidant activity and anthocyanins can also result from high processing and storage temperatures. On other hand, raising the processing temperature increases the fruit jam's total soluble solids (TSS). The impact of processing temperatures on the total soluble solids (TSS) of smooth cayenne pineapple jam manufacture was investigated by (Chalchisa *et al*. 2022). The created cactus pear and strawberry fruit blended jam has varying TSS values due to the interaction of the blending ratio with cooking temperature and time, which may have an impact on the jam's physicochemical composition and sensory qualities.

2.4.5 Nutrient Retention

Nutrient retention in jam is influenced mainly by heat exposure during processing and the nature of the raw materials used (Shinwari and Rao 2018). Heat-sensitive nutrients such as vitamin C, phenolic compounds and some antioxidants tend to degrade during cooking, at higher temperatures and longer processing times. Blending fruits with complementary nutritional profiles can partially compensate for nutrient losses, but excessive thermal processing remains the primary cause of nutrient degradation in jam products (Dar *et al.* 2022).

2.4.6 Acceptability

Acceptability refers to the overall consumer preference for a food product based on sensory evaluation (Sharif *et al*. 2017). It is determined by the combined effects of composition, processing conditions, and sensory attributes such as taste, aroma, color and texture. In jam production, blending ratios and appropriate cooking temperatures improve acceptability by enhancing flavor balance, gel consistency, and appearance (Garg *et al*. 2019).

2.5 Quality Parameters of Jam

2.5.1 Physicochemical Properties of Composite Jam

Rana *et al*. (2021) study tested the moisture content of mixed fruit jam which used different coconut and pineapple pulp ratios and produced results that ranged from 26.78% to 29.15%. The product exhibits different shelf stability and water activity characteristics because the heating process duration determines the extent of water removal which results in nutrient concentration (Syamaladevi *et al*. 2016). According to the proximate analysis, the moisture content of the jam and marmalade samples varied between 23.29% and 45.21% and 24.92% and 49.02%, with pineapple having the lowest moisture content and guava having the highest (Emelike and Akusu 2019).

The crude protein value of the pineapple-carrots jam samples ranged from 0.11% to 0.48% those reported by (Nkansah 2022). Timothy *et al*. (2019) reported the protein content of carrot-cucumber jam sweetened with honey ranged from 1.32% to 1.94%. The protein content of jackfruit jam and pineapple jam and raw jackfruit amounted to 1.3% and 0.46% and 0.19% and 1.12% respectively (Neupane 2025).

Naeem *et al*. (2017) reported that traditional jam has very little fat ranges from 0.01% to 0.44%. The pineapple-carrot jam samples' crude fat content from 5.29% to 10.67%, affected the food's overall physical characteristics, including flavor, texture and mouthfeel (Nkansah 2022) . The observed differences in composite jams arise from variations in raw material composition, processing operations, and analytical techniques. Elevated fat levels in these jams can influence key quality characteristics, such as texture, mouthfeel, and flavor. In contrast, traditional jams typically have low fat content, although different ingredients and methods can lead to variations in fat levels.

According to Chukwu *et.al* (2022), the ash contents of the composite jams prepared from orange, apple, and date powder ranged from 0.67% to 1.00%. In contrast, the ash content of carrots and pineapples ranged from 0.60 to 0.8% (Nkansah 2022) . Chalchisa *et al*. (2022) reported that grape, apricot, blueberry and strawberry jams have 0.18, 0.25, 0.12 and 0.23 g/100 g of ash contents respectively, while the pineapple jam's ash contents ranged from 0.166 to 0.387%. The jam samples from the various formulas differed significantly ($p < 0.05$). The study indicated that single-fruit products have lower mineral content compared to composite jam products, attributed to variations in raw material composition, ingredient quantities and processing methods.

Hassan *et al. (*2024) reported that the crude fiber content of F. benghalensis fruit jam when aloe Vera gel added ranged from 1.73% to 1.87%. The findings demonstrated that the crude fiber contents of F. benghalensis fruit jam were unaffected by the inclusion of aloe Vera gel, but the crude fiber contents of strawberry jam with various fruit blends varied between 0.42 and 0.64% (Hassan *et al*. 2024).

The carbohydrate content of varied jam samples ranged from 53.64% to 75.87% with PJ (pineapple jam) having the highest value and GJ (guava jam) having the lowest. According to recommendations, the marmalade samples' carbohydrate values ranged from 50.03% to 74.19%, with PM (pineapple marmalade) and GM (guava marmalade) having the highest and lowest values, respectively (Emelike and Akusu 2019).

According Alokun-Adesanya and Adebisi (2020) the results, sample AA, BB and CC had higher levels of vitamin C (10.13 mg/100g, 11.00 mg/100g, and 11.23 mg/100mg) respectively than the control jam (9.82 mg/100g). The fact that the samples were made from various fruits could be one of these characteristics. The sample with apple, orange and date has the highest vitamin C concentration, despite the fact that there isn't much of a difference. This could be due to the combination of different fruits in the jam, as dates only carry a little amount of vitamin C

Oluchi *et al*. (2024) reported that Apple jam had a pH of 3.91, while orange jam had a pH of 3.15. The average pH values for African bush mango and pineapple ranged from 4.85 to 5.55. The pH of the jam samples was within the acid range, with JAM4 (60:40 African bush mango

and pineapple) having the lowest value (4.85) and JAM2 (90:10 African bush mango and pineapple) having the highest value (5.55).

According to Garg *et al*. (2019) the nutritionally enriched jam made from blends of Indian blackberry and other Fruits has a TSS concentration between 64.33 and 66.67º Brix. The concentration of sugar and dissolved nutrients is represented by total soluble solids (TSS), which is typically expressed in degrees Brix (S. Sharma, Sirisomboon, and Pornchaloempong 2020) . The amount of TSS changed when orange peel was added to orange jam. Specifically, TSS values for TP (traditional pectin) jam varied from 63.03 to 63.55 °Brix at 15 °C and 63.03 to 64.89 °Brix at 30 °C. For orange peel jam, TSS values varied from 65.11 to 65.23 °Brix at 15 °C and 65.11 to 66.33 °Brix at 30 °C Sicari *et al*. (2020). Additionally, the concentration of sugar and pectin caused substantial ($p<0.05$) changes in the total soluble solids (TSS) of the pineapple jams. The TSS of the jam was found to have an increasing value as the sugar concentration rose (Chalchisa *et al*. 2022).

According to Oluchi *et al*. (2024) the titratable acidity of Africa bush mango jam revealed that the jam samples differed significantly ($P\leq0.05$) varied between 0.47 to 1.24 ml/g. However, the total Titrable acidity of honey-sweetened jam made from blends of carrot and cucumber ranged from 0.18 to 0.6 (Timothy *et al*. 2019) . According to Garg *et al*. (2019), all of the samples had titratable acidity levels between 1.00 and 1.64. The proportion of malic acid was used to express the titratable acidity of a nutritionally enhanced jam made from blends of Indian blackberries and other fruits. The titratable acidity of orange jam was higher (0.21) than that of apple jam (0.065).

Timothy *et al*. (2019) analyzed that carrot-cucumber jam sweetened with honey at ratios of 100:0 (435.35-477.15 mpa/s), 90:10 (504.60-517.00 mpa/s) and 82:20 (411.60-497.65 mpa/s) at lower spindle speeds of 12 rpm. As time, spindle speed and the amount of carrots in the jam samples dropped, the viscosities of the carrot-cucumber jam generally decreased. Additionally, the viscosity of jam production from blends of banana, pineapple, and watermelon pulp ranged from 45.00-129.00 pa/sec at 50 °C (Awolu *et al*. 2018). The research indicated that spindle speed and temperature influenced viscosity, with higher shear rates and temperatures leading to reduced viscosity measurements. Furthermore, raw material selection, blending ratios and

processing methods, particularly the fiber-water-gel component ratio, were critical in determining jam viscosity.

2.5.2 Phytochemical Constituents of Composite Jam.

According to Kamiloglu *et al*. (2015), preparing black carrot jam and marmalade considerably reduced the total phenolic content from 89.2% to 90.5%. Additionally, the purple carrot puree-fortified strawberry jam's total phenol content ranged from 114.5 to 212.5 mg/100g (ALI *et.al* 2014). The addition of phenolic-rich carrot puree enhances the antioxidant capacity of jam by counteracting processing losses of phenolic compounds caused by thermal processing.

Elsayed *et al*. (2021) total flavonoids in orange sweet potato jams range from 0.42 to 0.72 g/g dried extract. T3 (potato, carrot, and pumpkin) had the highest flavonoid values, while control had the lowest values (0.42). Orange jam had a flavonoid concentration of 0.06 mg GAE/g, but apple jam had a level of 0.32 mg GAE/g. The changes occur, because of different natural flavonoid compositions found in the raw materials, which interact with the processing conditions.

The tannins content of C.parchycarpa jam was 0.61 mg/100g, while in C. lepidota jam was 3.5 according to reported by (Okudu and Ene-Obong 2015). The two fruit species differ in their tannin composition, which are polyphenolic compounds contributing to astringent taste and antioxidant properties. C. lepidota jam has higher tannin content, leading to a more pronounced astringent flavor and enhanced health benefits. The study indicated that varying fruit types produce distinct tannin levels, influencing the sensory characteristics and nutritional value of jam.

2.5.3 Minerals Content of Composite Jam

Nwosu *et al. (2014) reported that* the jam products' sodium contents varied from 1.98 to 2.57 mg/100g. The composite jam made from 50% African star apple and 50% pineapple pulp had the lowest value (1.98 mg/100g), whereas the control sample (jam made from 100% African star apple pulp) had the highest value (2.57 mg/100g). The high percentage of African star apple pulp used to prepare the goods may be the cause of the mixed jam samples' decreased sodium level. This suggested that pineapple is a poor sodium supplier.

According to Awolu *et al*.(2018) potassium concentration in functional jam made from banana, pineapple and watermelon pulp blends ranged from 59.50-80.77 mg/100 g. Nwosu *et al*. (2014)

also reported the potassium contents jam samples' from star apple and pineapple ranged from 46.24 to 89.31 mg/100g. The composite jam made from 50% African star apple and 50% pineapple pulps had the highest calcium level (89.31 mg/100g), while the control (jam made from 100% African star apple pulp) had the lowest value (46.24 mg/100g). The potassium content (59.50 to 80.77 mg/100g) reported for jam made from mixes of banana, pineapple, and watermelon pulp was lower than the values (46.24 to 89.31 mg/100g) achieved in this investigation. The outcome shown that as more pineapple pulp was added, the potassium level of the composite jam products rose.

According to Nwosu *et al*. (2014) the jam products from African star apple and pineapple contained calcium level varied from 32.67 to 44.32 mg/100g. The calcium content of the samples varied significantly ($p<0.05$). The sample made from 50% African star apple and 50% pineapple pulps had the highest calcium level (44.32 mg/100g), whereas the control (jam made from 100% African star apple pulp) had the lowest value (32.67 mg/100g). The high calcium concentration of the pineapple fruit used to prepare the product may be the cause of the sample's observed rise in calcium content.

2.5.4 Sensory Properties of Composite Jam

Nwosu *et al*. (2014) reported the color of jam was ranged from 6.10 to 7.75. Mixed fruit jam developed from 50% African star apple and 50% pineapple pulps got the best score (7.75), whereas the control (jam made with 100% African star apple pulp) had the lowest score (6.10). The addition of pineapple pulp to the goods may be the cause of the composite jams' brighter color as compared to the control.

Nwosu *et al*. (2014) also reported the taste of jam ranged from 5.85 to 7.55. The control had the lowest value (5.85), whereas the composite jam made from 50% African star apple and 50% pineapple pulps had the best value (7.55). Since pineapple fruit is recognized for its sweetness and acidity, adding more pineapple pulp to the items improved the jam samples' taste preference.

According to O R Adegbanke (2025) pawpaw, apple, banana and orange blended fruit jam in terms of aroma, AO1 (6.40) and AR2 (6.25) led, while OM8 (5.95) trailed behind suggesting that the aromatic profile is influenced by the fruit composition The analysis indicated a discernible pattern despite groups not reaching statistical significance ($p > 0.05$). Higher aroma

scores in AO1 and AR2 are attributed to their balanced composition with orange, which generates potent volatile aromatic compounds. In contrast, OM8 has a lower aroma score due to reduced orange content, diminishing citrus aroma strength. Overall, the research underscores that the fruit composition, particularly aromatic fruits like orange, is crucial in defining the aroma profile of composite jam.

Nwosu *et al*.(2014) reported that the jam samples' texture scores varied from 5.75 to 7.40. Mixed fruit jam made from 50% African star apple and 50% pineapple pulps got the highest score (7.40), whereas the control sample had the lowest value (5.75). The results indicated that the samples' textures differed significantly ($p<0.05$). When more pineapple pulp was added to the goods, the composite jams' texture score increased.

Spreadability scores for pawpaw, apple, banana, and orange blended fruit jam show that A0I (7.25) and AR2 (6.50) performed well which may have an impact on the jam's consistency (O R Adegbanke 2025). The study highlights that the superior spreadability of AO1 is due to its balanced fruit composition, leading to an optimal pectin-sugar-acid interaction and a smooth gel structure. In contrast, AR2 and OM8 recorded lower scores due to formulation imbalances, where increased apple content results in firmness and higher pawpaw content adds excess moisture, weakening gel strength.

Overall acceptability of pawpaw, apple, banana, and orange blended fruit jam show a preference for AO1 (7.65), indicating that customers prefer a well-balanced fruit combination. According to O R Adegbanke (2025), OM8 has the lowest acceptance score (6.40), which may make it less popular. This is consistent with the lower scores for appearance, texture, scent, taste, and spreadability. People preferred AO1 jam due to its superior fruit composition, offering an appealing taste, visual attractiveness and ideal texture. In contrast, OM8 received lower acceptance due to its inadequate sensory characteristics, such as appearance, aroma, taste, texture, and spreadability. The overall acceptance of a product relies on the harmonious functioning of all these sensory attributes.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of the Study

Raw materials preparation, composite jam development, sensory evaluation, pH Value and total soluble solid determination were conducted at the agro-processing laboratory of the Federal Technical and Vocational Training Institute. Physicochemical analyses, phytochemic al constituent determination and mineral compositions analyses were carried out at the laboratories of Addis Ababa Science and Technology University (ASTU) and Addis Ababa University (AAU) respectively.

3.2 Raw Material Collection and Preparation

3.2.1 Raw Material Collection

Carrots (*Daucus carota L*.) and Oranges (*Citrus sinensis*) were obtained from Awash Melkessa Agricultural Research Center. Other ingredients used for jam preparation, including granulated sugar, pectin powder (commercial pectin) was used to ensure uniform gel formation, stable texture, and reproducible product quality across treatments and lemon (to extract citric acid) which used as an additional acid source to standardize acidity during jam formulation were purchased from local markets in Addis Ababa.

3.2.2 Raw Materials Preparation

The preparation of the samples was carried out following procedure. The carrots (*Daucus carota L*.) were selected based on uniform maturity, firmness, and absence of physical defects such as bruises, cracks, or decay, since maturity level significantly affects their chemical composition, including sugar content, carotenoid concentration, fiber content, and moisture level, which in turn influences the quality of the final jam. Only fresh, mature carrots with acceptable firmness and bright orange color were selected. The carrot were then thoroughly washed with potable tap water to remove soil, dust and other external contaminants (Das 2023). Subsequently, the bruised upper and lower portions were trimmed off. The cleaned carrots were than peeled with slicer. After peeling, the carrots were grated using grater to obtain a smooth and homogenous pulp.

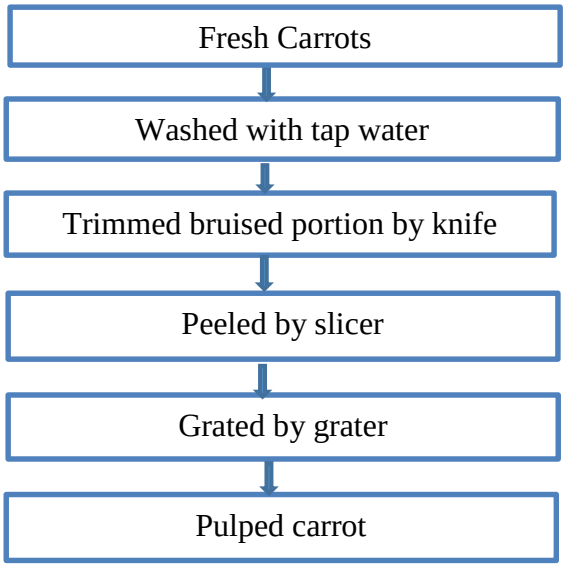


Figure 1: Flow chart for preparation carrot pulp (Das 2023).

The Oranges fruit (*Citrus sinensis*) were sorted based on uniform maturity, color and absence of physical defects**,** since fruit maturity significantly affects sugar content, acidity, pectin level, and overall quality of the final product. Only fully ripe oranges with acceptable firmness and uniform orange color were selected. The fruits were then washed with clean tape water (Makanjuola and Alokun 2019). The fruits were than manually peeled. The inedible portion and the seeds were removed using a clean table knife. Subsequently, the edible portions were pulped to obtain a uniform orange pulp suitable for blending.

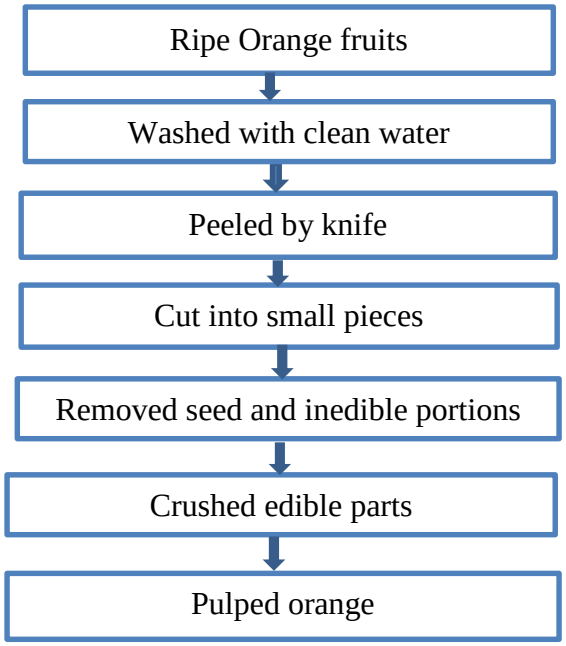


Figure 2: Flow chart for preparation of orange pulp (Makanjuola and Alokun 2019).

3.3 Preparation of Composite Jam

The composite jam was prepared following procedures described by (Rahman and Moshiur 2018). For each treatment, 1 kg of blended pulp was formulated according to the specified carrot-orange ratios of 90:10, 80:20, 75:25 and 25:75 as reported by (Nkansah 2022). A control treatment consists of 100% carrot pulp was also included.

The blended pulp was transferred into a stainless steel vessel. The mixture was subsequently heated at cooking temperatures of 90°C and 105°C following method described by (Chalchisa *et al*. 2022). 90 °C represents a mild heat treatment**,** used to minimize destruction of heat-sensitive nutrients such as vitamin C, phenolics, and natural color pigments while still allowing partial concentration of soluble solids. 105 °C represents a higher traditional jam cooking temperature, commonly associated with reaching final gel formation conditions and sufficient moisture evaporation for preservation. During the cooking, sugar in a 1:1 ratio, 3.5 g of pectin powder and 1.75 ml of citric acid were added into mixture (Rozan 2017). The product was stirred continuously to obtain a homogeneous gel consistency. After reaching the desired consistency, the jam was filled into sterilized glass jars with minimal headspace. The endpoint of cooking was determined using standard jam processing indicators, mainly the attainment of approximately 65 °Brix total soluble solids (TSS) measured with a refractometer, which is the conventional endpoint for proper gel formation and preservation. In addition, the consistency of the jam was checked using the sheeting or drop test, where the product forms a thick sheet or drops slowly from a spoon instead of flowing freely, indicating adequate concentration. These combined methods ensured that the jam reached the standard endpoint required for proper texture, stability, and quality. The filled jars were sealed, sterilized and stored at 4°C for subsequent analysis.

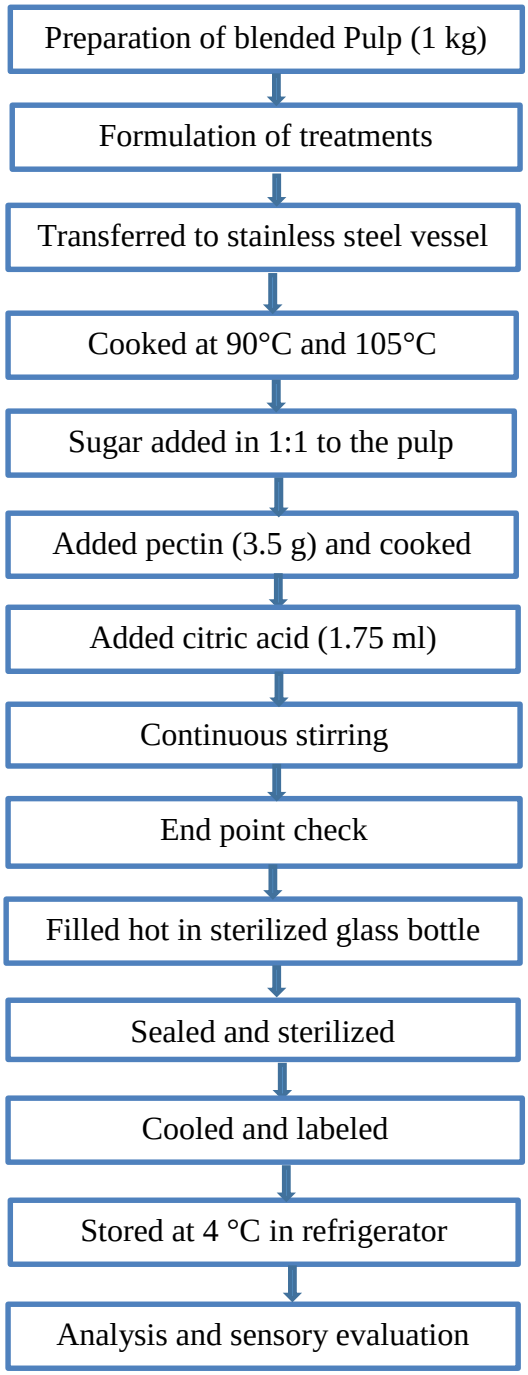


Figure 3: Flow chart for preparation of composite jam (Rahman and Moshiur 2018).

3.4 Experimental Design

The study used 5×2 factorial experimental design arranged in a Completely Randomized Design (CRD). The two independent variables were the blending ratios and cooking temperatures. Blending ratio consisted of four levels: 90:10, 80:20, 75:25 and 25:75 carrot-orange as reported by Nkansah (2022), while cooking temperature comprised two levels: 90°C and 105°C following (Chalchisa *et al.* 2022). In addition, a control treatment containing of 100% carrot pulp was processed at both temperatures, resulting in a total of ten treatment combinations. Each treatment was conducted in triplicate to ensure statistical reliability and experimental accuracy. The dependent variables measured were physicochemical, phytochemical constituent, minerals composition and sensory properties of composite jam.

Table 2: Treatment combination of composite jam

	Cooking Temperature (Factor 2)	
Blending Ratio (Factor 1)	90°C (T1)	105°C (T2)
C0 (100)	C0T1	C0T2
BR1 (90:10)	BR1T1	BR1T2
BR2 (80:20)	BR2T1	BR2T2
BR3 (75:25)	BR3T1	BR3T2
BR4 (25:75)	BR4T1	BR4T2

Where, C0=control (100% carrot pulp)

BR1= 90% carrot pulp + 10% orange pulp

BR2= 80% carrot pulp + 20% orange pulp

BR3= 75% carrot pulp + 25% orange pulp

BR4=25% carrot pulp and 75% orange pulp

3.5 Physicochemical Analysis of Composite Jam

3.5.1 Determination of Moisture Content

The moisture content of composite jam samples were measured using oven-drying method described by (Das 2023) . Five grams of each jam sample was weighed into a petri dish and dried in a hot air oven for 24 hours at 105°C until the weight remained constant, indicate complete removal of free water. The dried the samples were placed in a desiccator to cool for fifteen minutes before final weighing. Moisture content was calculated based on loss in weight loss in relation to the initial sample's weight.

$$\text{Moisture Content (\%)} = \frac{W1-W2}{W1-W} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

W = weighted of petridish, g

W1 = weighted of petridish + sample, g and

W2 = weighted of petridish + dry sample in oven, g

3.5.2 Determination of Crude Protein

Crude protein of composite jam samples were determined using the Kjeldahl method described by Das (2023), which based on quantification of total nitrogen. 0.8 g of jam sample was digested with concentrated sulfuric acid in a fume chamber until a clear digest was produced. The digest was then neutralized with sodium hydroxide and distilled into a 4% boric acid solution containing mixed indicators, namely methyl red and bromocresor green. The resulting distillate was titrated against 0.1N hydrochloric acid (HCl). The crude protein content of composite jam was calculated by multiplying determined nitrogen content by a conversion factor of 6.25.

Nitrogen (%) = HCl in L × N HCl (0.1N) × 14.00 x 100/Ws

Where:

VHCl = volume of HCl in L

NHCl = normality of HCl (used often is 0.1N).

Ws = sample weight on a dry matter basis and

14.00 is the molecular weight of nitrogen.

$$\text{Crude Protein (\%)} = \text{Nitrogen (\%)}\ x\ 6.25(\text{1 ml of 0.1N HCl}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

3.5.3 Ash Content

Ash content of composite jam samples were, which representing the total inorganic mineral residue was, determined using dry ashing method described by (Friday *et al*. 2021). 5 g jam sample was weighed and placed in an empty crucible. The sample was initially pre-ashing the sample on a hot plate until was charring occurred and then transferred into muffle furnace maintained at 550°C in a for five hours until a white ash was obtained. After ashing, the crucible cooled in the desiccator and weighed. The ash was calculated using the formula below:

$$\text{Ash Content (\%)} = \frac{W2-W3}{W2-W1} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where,

W1 = Weighted of empty crucible.

W2 = Weighted of crucible + weighted of sample before ashing.

W3 = Weighted of crucible + weighted of sample after ashing.

3.5.4 Determination of Crude Fat

The crude fat content of composite jam samples were determined using the Soxhlet extraction method described by (Das 2023). The extraction flask was carefully weighed before 2 g of the material was added to the extraction thimble and carefully placed in the extractor. After connecting the extraction flask to the extractor with the thimble, 25 milliliters of n-hexane were introduced to the extractor. The flask was heated on a heating mantle for six hours while the extractor was attached to the condenser. The heat causes the solvent to evaporate, and the condenser causes it to condense. Drop by drop, the condensed solvent is added to the thimble. Food fat is eliminated by the solvent. After that, the flask was carefully taken out.

After adding the extract to a conical flask, the solvent was heated until it evaporated. weighed following desiccator cooling.

The crude fat content was calculated as follows:

$$\text{Crude Fat}(\%) = \frac{\text{weight of extracted fat(g)}}{\text{weight of original sample(g)}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3.5.5 Determination of Crude Fiber

After crude fat determination, 2 g of dried, fat free residue was weighted accurately and moved into the conical flask (Nkansah 2022). In a beaker 200 mL dilute sulphuric acid (1.25%) was taken and boiled 30 min on the hot plate. Then the sample was filtered with muslin cloth and washed with hot water until the washing was no longer acid to litmus. The entire residues were transferred in the same beaker. Then 200 mL of NaOH (1.25%) was added to the beaker and boiled 30 min. Filtered the residue with muslin cloth and the residue was washed thoroughly with boiling water till free from alkali and again washed with 95% ethanol. The residue in a crucible was transferred to an oven dryer which temperature was maintained at 105˚C and kept there the sample overnight for drying. Then removed the crucible and kept it in the desiccator for cooling. Then the sample was weighed to the crucible with residue. The crucible and its contents were transferred in a muffle furnace and ignited at 600˚C for 2 hours. Finally, the crucible was removed and cooled in desiccators. Then, the ash was weighed.

Crude fiber in the composite jam was calculated as follows.

$$\text{Crude Fiber } (\%) = \frac{\text{A} - \text{B}}{C} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

A is the weight of crucible with dry residue (g),

B is the weight of crucible with ash (g) and

C is the weight of sample (g).

3.5.6 Determination of Carbohydrates

Carbohydrate content was determined by differenced according the method described by (Friday *et al*. 2021). The percentage of carbohydrate was calculated by subtracting the cumulative percentages of moisture, crude protein, crude fat, ash, and crude fiber from 100.

$$\text{Carbohydrate } (\%) = 100 - (\%\ \text{Moisture} + \%\ \text{Fat} + \%\ \text{Protein} + \%\ \text{fiber} + \%\ \text{Ash}. (6)$$

3.5.7 Determination of Vitamin C

The vitamin C content of composite jam samples were determined using titration method described by (Chalchisa *et al*. 2022). Thirty grams of samples were weight and blended with an equal weight of 6% meta-phosphoric acid for 3–4 minutes. The homogenized mixture was then filtered and Ten ml of filtrate transfer into a conical flask. The solution was immediately titrated against standard 2, 6-dichlorophenol indophenols dye solution until faint pink color was observed.

The ascorbic acid concentration was determined according to the following.

$$\text{Ascorbic acid } \left(\frac{\text{mg}}{100}g\right) = \frac{v \times t}{w} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where, v = volume of dye used in titration against an aliquant diluted sample,

t = value of standardized dye,

w = weight of the sample

3.5.8 Measurement of pH

The pH of the composite jam samples were determined using a pH meter following described by (Tadele, Abera, and Dereje 2022). 5 g of jam sample was dissolved in 25 mL of distilled water and transferred into a beaker. Prior to measurement, the pH meter was calibrated using standard buffer solutions of pH 4.0 and 7.0. The electrode of calibrated pH meter was then immersed into the samples solution and pH value was recorded. After each measurement, the electrode was rinsed with distilled before proceeding the next sample to avoid cross contamination.

3.5.9 Determination of Titratable Acidity

Titratable acidity (TA) of composite jam sample were determined according to the method described by (Tadele, Abera, and Dereje 2022). 10 grams of jam sample was dissolved in 250 milliliters of distilled water to obtain dilution solution. The solution then titrated against standardized 0.1N sodium hydroxide (NaOH) solution using phenolphthalein (2-3 drops) as indicator until the light pink color obtained. The titratable acidity was calculated as following:

$$\text{TA (\%)} = \frac{\text{Titre x Normality of alkali x meq wt. of citric acid}}{\text{Volume of taken sample}} \times 100 \ldots\ldots\ldots\ldots (7)$$

3.5.10 Determination of Total Soluble Solids

Total soluble solids (TSS) of composite jam samples were determined using a hand refractometer according to official method described by (Tadele, Abera, and Dereje 2022). Prior to sample measurement, the refractometer was calibrated using distilled by placing few drops on the prism surface and adjusting the instrument to zero. Calibration readings were through the eyepieces with refractometer direct toward the light source and the point at which on the boundary line between of the shaded and unshaded area intersected the scale was noted. For determination TSS, drop of the sample jam was placed on the prism surface and reading was recorded as ^{0}Brix.

3.5.11 Determination of Viscosity

Viscosity of composite jam samples were determined using a digital viscometer (Adindu-Linus *et al*. 2024). 200 ml of the jam was poured into a 250 ml volumetric flask. The viscosity in mPa/s was measured at 60 rpm using spindle 2.

3.6 Phytochemical Constituent Analysis of Composite Jam

3.6.1 Determination of Total Phenolic Content

The total phenolic content of composite jam samples were determined by spectrophotometric method (Chalchisa *et a*l. 2022). In brief, 1 mL of methanol 80% fruit extract was mixed with 1 mL of Folin-Ciocalteau phenol reagent and incubated for 5 min at room temperature (25°C) (State the temp). After 5 minutes added 10 milliliters of 7% Na2CO3 solution to the mixture which he then brought to 13 milliliters through the addition of distilled water. The sample remained in the dark for a 90-minute period before the 750 nanometer absorbance measurement. Determined total phenolic content by extrapolating from the calibration curve which they created using Gallic acid solution at concentrations between 20 and 100 micrograms per milliliter and reported the result in micrograms per milliliter per gram of dried extract.

3.6.2 Determination of Total Flavonoid Content

The total flavonoid content of composite jam samples were determined using method described by (Chalchisa *et al*. 2022). 1 mL of 80% methanolic extract was mixed with 4 mL of distilled water by addition of 0.30 mL of 10% a NaNO2 solution. After a 5-minute 0.30 mL 10% of

AlCl3 solution was added, followed by 2 mL of 5% NaOH solution. The mixture was mixed was mixed thoroughly and absorbance was measured immediately at 510 nm against the blank solution using spectrophotometer.

3.6.3 Determination of Total Tannin Content

The tannin content of jam sample was determined by using the method described by (Chalchisa *et al.* 2022). 1 gram of sample mixed with 10 mL of 1% HCl dissolved in methanol. The mixture was subjected to mechanical shaking for 24 hours at room temperature (25°C) and centrifuged at 1000 rpm for 5 minutes. 1 mL of supernatant was transferred into separate tubes and mixed with 5 mL of vanillin-HCL reagent. into a separate test tube. After incubation for 20 minutes, the absorbance of solution was measured measurement at 500 nm using a spectrophotometer. Finally calculated total tannin content quantified standard curve which they constructed from tannic acid measurements ranging from 20 to 100 µg/ml.

3.7 Mineral Analysis of Composite Jam

1 g of each composite jam samples were transferred into 100 mL round-bottom flask, followed by addition of Five milliliters of perchloric acid. The mixture was heated over an electric heater in a fume room until it turned colorless. The diluted samples were reserved for additional research after the solutions were diluted with distilled water to the 10 mL level. Concentrations of Ca, K, and Na were determining using an atomic absorption spectrophotometer (AAS) according to described by (Friday *et al*. 2021).

3.8 Sensory Evaluation of Composite Jam

The sensory properties of the jam samples were evaluated by 45 semi-trained panelists select from Federal Technical and Vocational Training Institute. The panelists evaluated composite jam attributes including color, aroma, taste, texture, flavor, spreadability and overall acceptability using a 9-point hedonic scale where, 9= like extremely, 8= like very much, 7= like moderately, 6= like slightly, 5= neither like nor dislike, 4= dislike slightly, 3= dislike moderately, 2= dislike very much and 1= dislike extremely. The samples were presented to the panelists in coded (three-digit number) white plastic cups with plastic teaspoons at room temperature and arranged in randomized order to minimize bias during evaluation. A cup of

potable water was provided to the panelist to rinse mouth between successive sample evaluations.

3.9 Statistical Analysis

The data collected from the physicochemical, antioxidant activity, mineral and sensory analyses were subjected to two-way analysis of variance (ANOVA) using Minitab software (version 19.1). The ANOVA was performed to evaluate the main effects of the blending ratio and cooking temperature, as well as their interaction effects on the quality attributes of the jam. The least significant difference (LSD) test at a 95% confidence level ($p \leq 0.05$) was used to determine significant differences between the mean values. The results were presented as mean values ± standard deviation to provide a clear scientific interpretation of the findings.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Physicochemical Properties of Composite Jam

4.1.1 Moisture Content

As shown in table 3.1 below, the moisture content of composite jam decreased from 38.85±0.09% to 34.75±0.07%. There were highly significant ($p<0.01$) differences in moisture content among the treatments. The highest moisture content value (38.85%) was recorded in C0T1 which contained 100% carrot pulp cooked 90 ^{o}C, whereas the lowest value (34.75%) was recorded in BR3T2 which contained 75% carrot pulp plus 25% orange pulp cooked at 105 ^{o}C. The decrease in moisture content at higher cooking temperature occurred because prolonged heating time leads to increased evaporation and water loss from the food. Increasing the orange pulp decrease the moisture content of composite, however when the orange pulp highly incorporated the moisture content of jam was increased. The moisture content obtained in present study were within range of 23.93%-49.57% reported by O R Adegbanke (2025) for jam produced from pawpaw, apple, banana and orange Fruit. However, the values were lower than 77% moisture content reported by Jan *et al*. (2022) for apricot jam. The variations result from differences in their raw material composition, their blending ratio and their processing conditions. Reducing moisture content of food can be used increase the shelf stability by slowing microbial growth.

4.1.2 Crude Protein Content

According to table 3.1 below, the crude protein content of the composite jam samples increased from 0.62±0.02% to 1.11±0.01%. There were a significant ($p<0.05$) differences among the treatments. The highest protein content (1.11%) was recorded in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C while the lowest value (0.62) was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C. The decrease in protein content with a higher proportion of orange pulp is due to its comparatively lower protein contribution than carrot pulp. Conversely, high cooking temperatures decrease protein content, likely caused by thermal denaturation and the degradation of heat-sensitive amino acids. The protein value obtained in the present study were within the range of 0.26-8.58% reported by Awolu *et al*. (2018) for jam produced banana, pineapple and watermelon fruits. However, the

value were higher than 0.26-0.69 % reported by Adewole *et al.* (2022) for jam produced from apple and banana blends. The research demonstrated that cooking jam at moderate temperatures results in better protein preservation and enhanced nutritional value for composite jam.

4.1.3 Crude Fat Content

Crude fat content composite jam samples differed significantly ($p<0.05$) among treatments and decrease from 1.12±0.01% to 0.55±0.01% as shown in table 3.1 below. The highest fat content (1.12) was recorded in C0T2 which contained 100% carrot pulp cooked at 105 ^{o}C, whereas the lowest value (0.55%) in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C. The addition of orange pulp, which has a lower fat content than carrot pulp, led to a reduction in fat. Conversely, increased the cooking temperature increased the fat content of composite jam due concentration fat soluble content. The fat content obtained in present study were within range of 0.29-3.92% which reported by Awolu *et al.* (2018) for jam prepared from pineapple, banana and watermelon. However, the values were lower than 2.28 to 3.00% reported by Ogunlade and Oluwafemi (2021) for African star apple and pineapple blended jam. The low fat content of jam products is viewed as an excellent quality characteristic because it decreases the chances of rancidity, which helps to maintain flavor quality and prolong product storage time.

4.1.4 Crude Fiber Content

The crude Fiber content of composite jam ranged from 2.08±0.01% to 2.91±0.00%. There were significant ($p<0.05$) differences in fiber content among treatments (Table 3.1). The highest fiber content (2.91%) was recorded in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C, whereas the lowest value (2.08%) recorded in BR4T2 which 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C. The reduction in fiber content is mostly because plant cell walls components like cellulose and hemicellulose get broken down during the heat processing, kind of loosening everything up. Increased orange pulp incorporation decreased the fiber content of composite jam due to low fiber content than carrot. The crude fiber content obtained in present study were within range of 1.25-3.03% which reported by Awolu *et al*. (2018) for jam production from blends of banana, pineapple and watermelon Pulp. The values were higher than 0.42-0.64% reported by Hassan *et al*. (2024) for strawberry jam and the 0.16% reported

by Atta *et al*. (2021) for cashew apple jam. The higher fiber content obtained in current study indicates that blending carrot and orange pulp can enhance the nutritional content of jam product. Dietary fiber is an important nutritional component because it supports digestive function and enhances functional value of food product.

4.1.5 Ash Content

Table 3.1 below shows that the ash content of composite jam samples differed highly significant ($p<0.01$) and increased from 0.25±0.01% to 0.34±0.00%. The highest ash content value (0.34%) was recorded in C0T2 which contained 100% carrot pulp cooked at 105 ^{o}C, whereas the lowest value (0.25%.) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C. A decrease in ash content with added orange pulp implies it has fewer minerals compared to carrot pulp. Heat treatment during processing affects mineral content due to leaching and chemical interactions with heat. Higher ash content in products with more carrot indicates the naturally high mineral content in carrots. The obtained results in present study consistent with 0.166 to 0.387% reported by Chalchisa *et al*. (2022) for pineapple jam and the 0.27 to 0.39% reported by Awolu *et al.* (2018) for jam production from blends of banana, pineapple and watermelon Pulp. Desirable ash content suggests the presence of essential minerals that enhance the nutritive value of the composite jam.

4.1.6 Carbohydrate Content

The Carbohydrate content of composite jam samples increased from 55.69±0.08% to 60.27±0.08%. There were highly significant ($p<0.01$) differences in carbohydrates among treatments (Table 3.1). The highest carbohydrate content (60.27%) was recorded in BR3T2 which contained 75% carrot pulp plus 25% orange pulp 105 ^{o}C, whereas the lowest value (55.69%) was recorded in C0T1 which contained 100% carrot pulp cooked 90 ^{o}C. Higher cooking temperatures increase carbohydrate content by causing moisture loss and creating more soluble sugars. The orange pulp contributes natural sugars and soluble solids, enhancing the carbohydrate levels in blended jams. Water evaporation during cooking further concentrates these components, resulting in a final product with increased carbohydrate content. The carbohydrate content values obtained in present study were within the range of 50.03-75.87% reported by Emelike and Akusu (2019) for different jam and marmalade product. However, the values were higher than 36.84 to 44.22 % reported by Millicen, Bigson,

and Akwaah (2021) for jam prepared from blends of pineapple and baobab fruits pulp. The raw material composition, blending ratio and processing conditions of a product lead to different carbohydrate content level. A higher content of carbohydrates has an effect on sweet taste, the energy value of the system, gel formation, and preservation of jams.

4.1.7 Vitamin C

According to table 3.2 below, the vitamin C content of composite jam increased from 1.11±0.01 mg/100 g to 9.73±0.06 mg/100g. There were highly significant ($p<0.01$) differences among composite jam treatments. The highest vitamin C content (9.73 mg/100g) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C, whereas the lowest value (1.11 mg/100g) was in C0T2 which contained 100% carrot pulp cooked 105 ^{o}C. Higher amounts of orange pulp increase vitamin C content due to its higher ascorbic acid concentration compared to carrots. However, all treatments showed a decrease in vitamin C at elevated cooking temperatures due to thermal degradation and oxidation with destruction of vitamin C occurring with prolonged exposure to high temperatures and oxygen. The vitamin C values obtained in present study were comparable to those reported by Timothy *et al*. (2019) for carrot-cucumber jam, which ranged 0.65-4.35 mg/100g and by Naeem *et al*. (2017), who reported vitamin C values ranging from 2.40-5.67 mg/100g for various fruit jams. Higher value (BR4T1) vitamin C content observed in current study associated with the high ascorbic acid concentration in orange fruits. The preservation of vitamin C in food products is vital because it provides protection against oxidation while maintaining its nutritional value and assisting the body's immune defense and antioxidant functions.

4.1.8 Titrable Acidity

As shown in table 3.2 below, the titratable acidity of composite jam samples increased from 0.18±0.01% to 0.72±0.01%. There were significant ($p<0.05$) differences in (TA) among the treatments. The highest TA value (0.72%) was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp 105 ^{o}C, whereas lowest value (0.17%) was in C0T1 which contained 100% carrot pulp 90 ^{o}C. The increase in titratable acidity with more orange pulp is due to the high citric acid content in oranges. The rise in TA is mostly because organic acids, like citric and malic acids, get more concentrated while moisture is lost and the fruit tissues undergo thermal breakdown. The Titratable acidity obtained in present study were consistent with

finding of Oluchi *et al*. (2024) who reported titratable acidity values ranging from 0.47% to 1.24% for Africa bush mango jam and reported by Timothy *et al.* (2019), which ranged from 0.18 to 0.67, for jam produce from carrot and cucumber. However the highest value recorded in present study was higher than 0.49% reported by Pinandoyo, Siddiqui, and Garg (2019) for protein fortified papaya jam. The substantial increase in titratable acidity of jam-products significantly improves their flavor, gelation, microbial stability and keeping quality.

4.1.9 pH Value

The pH value of composite jam samples decreased from 4.17±0.03 to 3.48±0.04. There were a significant ($p<0.05$) differences among treatments (Table 3.2). The highest pH value (4.17) was recorded in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C, whereas the lowest pH value (3.48) was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C. The decrease in pH with increasing orange pulp is likely due to the high organic acid content of oranges, which reduces hydrogen ion concentration. The drop in pH seems connected with a higher buildup of organic acids and a reduced amount of water in the processing steps. Treatments with high acidity levels and high temperature used typically show lower pH measurements. The pH value obtained in this study were comparable to those reported by Chukwu *et al.* (2022) obtained in their research on orange-apple-date jam, which produced a pH range of 3.50 to 4.00. However, the values were lower than 5.02 to 5.67 those reported by Aruna and others (2017) for jam prepared from muskmelon. Chalchisa *et al.* (2022) reported the similar trend in pH reduction with incorporation of acidic fruit components in composite jam products. Lowering pH levels provides better preservation results, increased stability of gel products and reduced chance of microbial contamination.

4.1.10 Total Soluble Solids

Total soluble solids content of composite jam samples increased from 61.15±0.01°Brix to 65.25±0.07°Brix. There were highly significant ($p<0.01$) differences in TSS content among the treatments (Table 3.2). The highest TSS value (65.25°Brix) was recorded in BR3T2 which contained 75% carrot pulp plus 25% orange pulp cooked at 105 ^{o}C, whereas the lowest value (61.15) recorded in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C. The increase in cooking temperature leads to higher total soluble solids (TSS) due to moisture evaporation and the concentration of sugar and soluble solids during thermal processing. Blending jams with

orange pulp adds natural sugars and soluble compounds, enhancing the soluble solid content. Additionally, the heating process causes water loss, elevating the TSS in the final product. The TSS values obtained in present study were consistent with the finding of Okoye, Okoh, and Uke (2025) , who reported TSS values ranging from 61.17 to 68.23 Brix for African star apple and pineapple blended jam. However, the values were higher than 4.00^0Brix to 6.10^0Brix reported by Omolara R Adegbanke, Chukwu, and Liasu-Oni (2022) for composite jam produced from orange, apple and Date Powder. High TSS levels are crucial for jam production because they create sweet flavor, develop texture and protect against microbial growth while maintaining product shelf life.

4.1.11 Viscosity

As shown in table 3.2 below, the viscosity of the composite jam samples differed highly significant ($p<0.01$) among treatments and increased from 81.99±0.31 mPa.s to 86.20±0.08 mpa.s. The highest viscosity value (86.20 mPa.s) was recorded in BR2T2 which contained 80% carrot pulp plus 20% orange pulp cooked at 105 ^oC and BR3T1 which contained 75% carrot pulp plus 25% orange pulp cooked at 90 ^oC, whereas the lowest viscosity value (81.99 mPa.s) in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked 90 ^oC. The cooking temperature increases viscosity due to moisture loss, leading to higher concentrations of pectin and sugars, which improve gel formation and thicken jams. Increased the orange pulp increased the viscosity of composite, however highly increased orange incorporation decreased the viscosity. The viscosity values obtained in present study were comparable with 69 to 78 mPa.s reported by Ahmed *et al.* (2016) for sapodilla jam. The highest viscosity values observed in current study were due to higher pectin and fiber content of orange pulp and also cooking temperature. The viscosity of jam products serves as a key quality assessment because it affects their ability to spread and their textural properties and their mouthfeel and their general acceptance by consumers and their complete product quality.

Table 3.1: The interaction effect of blending ratio and cooking temperature on physicochemical properties of composite jam

Treatments	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
C0T1	38.85±0.09^{a}	1.11±0.01^{a}	1.11±0.01^{a}	2.91±0.00^{a}	0.32±0.00^{b}	55.69±0.08^{g}
C0T2	38.78±0.08^{a}	1.10±0.02^{a}	1.12±0.01^{a}	2.89±0.00^{b}	0.34±0.00^{a}	56.10±0.07^{f}
BR1T1	37.75±0.09^{bc}	1.10±0.00^{a}	1.10±0.00^{b}	2.87±0.00^{c}	0.31±0.00^{c}	56.87±0.09^{e}
BR1T2	37.69±0.06^{bc}	1.02±0.02^{b}	1.11±0.00^{ab}	2.85±0.01^{d}	0.32±0.01^{b}	57.00±0.06^{e}
BR2T1	36.46±0.08^{d}	1.00±0.00^{bc}	0.98±0.00^{c}	2.82±0.01^{e}	0.29±0.01^{d}	58.46±0.08^{d}
BR2T2	36.26±0.09^{d}	0.99±0.01^{bc}	0.99±0.00^{c}	2.81±0.00^{e}	0.30±0.00^{c}	58.65±0.11^{cd}
BR3T1	36.26±0.09^{d}	0.96±0.05^{c}	0.96±0.00^{d}	2.81±0.01^{e}	0.28±0.01^{d}	58.73±0.06^{bc}
BR3T2	34.75±0.07^{e}	0.95±0.01^{c}	0.97±0.01^{d}	2.79±0.01^{f}	0.29±0.00^{d}	60.27±0.08^{a}
BR4T1	37.89±0.04^{b}	0.66±0.02^{d}	0.55±0.01^{f}	2.09±0.01^{g}	0.25±0.01^{f}	58.56±0.06^{cd}
BR4T2	37.56±0.08^{c}	0.62±0.02^{d}	0.58±0.01^{e}	2.08±0.01^{g}	0.27±0.01^{e}	58.90±0.07^{b}
CV (%)	**0.20**	**1.66**	**0.63**	**0.19**	**2.47**	**0.14**
p-value	**0.000**	**0.027**	**0.017**	**0.025**	**0.006**	**0.000**

Notes: Values are expressed as mean ± standard deviation of triplicate determinations. Means within the same column followed by different superscript letters are significantly different at P ≤ 0.05 according to Tukey's HSD test. C0=100% carrot pulp (control), BR1= 90% carrot pulp +10% orange pulp, BR2=80% carrot pulp +20% orange pulp, BR3= 75% carrot pulp + 25% orange pulp, BR4=25% carrot pulp + 75% orange pulp, whereas T1=90 ^{o}C and T2=105 ^{o}C are cooking temperature.

Table 3.2: The interaction effect of blending ratio and cooking temperature on physicochemical properties of composite jam

Treatments	Vitamin C (mg/100g)	TA (%)	pH	TSS (°Brix)	Viscosity (mPa.s)
C0T1	1.29±0.02^{de}	0.18±0.01^{e}	4.17±0.03^{a}	61.15±0.09^{e}	84.93±0.13^{e}
C0T2	1.11±0.01^{f}	0.19±0.00^{e}	4.16±0.02^{a}	61.22±0.08^{e}	85.04±0.06^{de}
BR1T1	1.28±0.02d^{e}	0.20±0.01^{d}	4.13±0.04^{a}	62.25±0.09^{cd}	85.24±0.06^{de}
BR1T2	1.12±0.01^{f}	0.21±0.00^{cd}	4.12±0.03^{a}	62.31±0.06^{cd}	85.55±0.07^{cd}
BR2T1	1.33±0.04^{de}	0.22±0.00^{cd}	4.11±0.04^{a}	63.54±0.08^{b}	85.96±0.16^{bc}
BR2T2	1.25±0.03^{e}	0.23±0.00^{c}	3.99±0.03^{b}	63.74±0.09^{b}	86.20±0.08^{b}
BR3T1	1.44±0.05^{c}	0.23±0.01^{c}	3.97±0.02^{b}	63.74±0.09^{b}	86.20±0.08^{b}
BR3T2	1.36±0.03^{cd}	0.25±0.01^{b}	3.95±0.03^{b}	65.25±0.07^{a}	85.01±0.14^{a}
BR4T1	9.73±0.06^{a}	0.71±0.00^{a}	3.50±0.03^{c}	62.11±0.04^{d}	81.99±0.31^{f}
BR4T2	9.45±0.04^{b}	0.72±0.01^{a}	3.48±0.04^{c}	62.44±0.08^{c}	82.30±0.46^{f}
CV (%)	**1.67**	**2.78**	**0.77**	**0.12**	**0.19**
p-value	**0.000**	**0.028**	**0.040**	**0.000**	**0.000**

Notes: Values are expressed as mean ± standard deviation of triplicate determinations. Means within the same column followed by different superscript letters are significantly different at P ≤ 0.05 according to Tukey's HSD test. C0=100% carrot pulp (control), BR1= 90% carrot pulp +10% orange pulp, BR2=80% carrot pulp +20% orange pulp, BR3= 75% carrot pulp + 25% orange pulp, BR4=25% carrot pulp + 75% orange pulp, whereas T1=90 °C and T2=105 °C are cooking temperature.

4.2 Phytochemical Constituents of Composite Jam

4.2.1 Phenolic Content

As shown in table 4 below, the total phenolic content of composite jam samples increased from 53.24±0.10 mg GAE/100g to 90.13±0.20 mg GAE/100g. There were a significant ($p<0.05$) differences among composite jam treatments. The highest total phenolic content (90.13 mg GAE/100g) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C, whereas lowest value (53.24 mg GAE/100g) was recorded in C0T2 which contained 100% carrot pulp cooked 105 ^{o}C. The total phenolic content increases with higher proportions of pulp due to the presence of flavanones and phenolic acids. However, elevated cooking temperatures result in a decrease in phenolic content due to thermal degradation and oxidation, leading to polymerization and structural changes that reduce the detectability of these compounds. The total phenolic values obtained in present study were comparable with those reported by Kamiloglu *et al*. (2015) for black carrot jam, which ranged from 89.2-90.5 mg GAE/100g. The higher values observed in present study associated with the incorporation of orange pulp, which rich is rich in bioactive phenolic compounds. However, the values were lower than range of 132.9 to 218.9 mg GAE/100g reported by Kim *et. al* (2004) for jam prepared from cherry, plum and raspberry fruits, due to differences in raw materials composition and effect of elevated temperatures on phenolic stability. Phenolic compounds are essential because they provide antioxidant protection, enhancing nutritional value and functional characteristics of food items.

4.2.2 Flavonoids Content

The total flavonoid content of the composite jam samples showed significance difference ($p<0.05$) among treatments and increased from 92.35±0.13 mg QE/100g to 118.85±0.08 mg QE/100g (Table 4). The highest flavonoid content (118.85 mg QE/100g) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C, whereas the lowest value (92.35 mg QE/100g) was in C0T2 which contained 100% carrot pulp cooked at 105 ^{o}C. The increase in flavonoid levels in orange pulp clarifies the high citrus flavonoid content of oranges. However, cooking procedures diminish flavonoid levels due to the impact of heat and oxidizing elements, leading to thermal degradation that reduces their antioxidant capacity. The flavonoid values obtained in present study were higher than those reported by

Turgut, Tokgoz, and Glukcu (2021) for kumquat jams, which contained 37.71 mg CE/100 g. The higher flavonoid content observed in present study associated with incorporation of raw materials, which are rich in flavonoids. Flavonoids are crucial bioactive compounds known for their strong antioxidant effects, along with anti-inflammatory and antimicrobial properties, which improve the nutritional value and functionality of jam products.

4.2.3 Tannins Content

As shown in table 4 below, total tannin content composite jam samples differed significantly ($p<0.05$) among treatments and increased from 0.42±0.01 mg/100g to 1.19±0.01 mg/100g. The highest tannin content (1.19 mg/100g) was recorded in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C, whereas the lowest value (0.42 mg/100g) observed in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C. The decrease in tannin content with higher orange pulp proportions is due to oranges having lower tannin concentration than carrot pulp. Additionally, thermal degradation, oxidation and the formation of complex bonds during processing lead to reduced tannin levels as cooking temperature rises, causing chemical structure changes in tannins that lower their detectability. The tannins values obtained in present study were comparable to those reported by Okudu *et al*.(2015) for C. parchycarpa jam 0.61 mg/100 g. However, the values were lower than reported for C. lepidota jam, which contained 3.5 mg/100 g. The reduced tannin levels found in treatments that used more orange pulp result from the fact that citrus fruits naturally contain less tannins carrots. The preferred tannin range for jam production should be at moderate levels because excessive tannin content creates astringent flavors, while reduced tannin levels make flavors more appealing to consumers.

Table 4: The interaction effect of blending ratio and cooking temperature on Phytochemical Constituents of composite jam

Treatments	Phenolic (mg GAE/100g)	Flavonoid (mg QE/100g)	Tannin (mg/100g)
COT1	54.03±0.21^{e}	92.87±0.06^{d}	1.19±0.01^{a}
COT2	53.24±0.10^{f}	92.35±0.13^{e}	1.14±0.00^{bc}
BR1T1	54.65±0.26^{de}	93.22±0.12^{d}	1.17±0.00^{ab}
BR1T2	54.44±0.34^{de}	93.17±0.08^{d}	1.14±0.01^{bc}
BR2T1	54.76±0.04^{d}	93.87±0.06^{c}	1.13±0.01^{c}
BR2T2	54.54±0.05^{de}	93.68±0.08^{c}	1.06±0.01^{d}
BR3T1	56.60±0.33^{b}	93.93±0.05^{c}	1.08±0.01^{d}
BR3T2	55.66±0.28^{c}	93.75±0.28^{c}	0.98±0.01^{e}
BR4T1	90.13±0.20^{a}	118.85±0.08^{a}	0.49±0.03^{f}
BR4T2	89.80±0.01^{a}	118.43±0.26^{b}	0.42±0.01^{g}
CV (%)	**0.33**	**0.13**	**0.90**
p-Value	**0.027**	**0.022**	**0.016**

Notes: Values are expressed as mean ± standard deviation of triplicate determinations. Means within the same column followed by different superscript letters are significantly different at P ≤ 0.05 according to Tukey's HSD test. C0=100% carrot pulp (control), BR1= 90% carrot pulp +10% orange pulp, BR2=80% carrot pulp +20% orange pulp, BR3= 75% carrot pulp + 25% orange pulp, BR4=25% carrot pulp + 75% orange pulp, whereas T1=90 ºC and T2=105 ºC are cooking temperature.

4.3 Minerals Composition of Composite Jam

4.3.1 Sodium Content

Sodium content of the composite jam samples were highly significant ($p<0.01$) differences among treatments and decreased from 10.09±0.01 mg/100g to 1.67±0.01 mg/100g (table 5). The highest sodium content (10.09 mg/100g) was recorded in C0T2 which contained 100% carrot pulp cooked at 105 ^{o}C, while lowest value (1.67 mg/100g) was observed in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C. The reduction in sodium levels with more orange pulp is due to oranges having lower sodium concentrations than carrots. Cooking treatments raised sodium levels as higher temperatures caused moisture loss, concentrating the mineral components. This thermal processing reduces water content, leading to increased concentrations of soluble minerals in the final product. The lowest value obtained in present study was lower than reported by Bouchefra *et al*. (2023) for strawberry and grape jams, which contained 4.07 mg/100g and by Nwosu *et al*. (2014) for African star apple-pineapple jam, which ranged from 1.98-2.57 mg/100g. Sodium serves an essential function through its role in electrolyte balance and taste enhancement yet reduced sodium content improves both the nutritional value and consumer preference for jam products.

4.3.2 Potassium Content

As shown in table 5 below, the potassium content of the composite jam samples highly significant ($p<0.01$) differences among treatments and increased from 202.99±0.11 mg/100g to 217.02±0.20 mg/100g. The highest potassium content (217.02 mg/100g) was recorded in C0T2 which contained 100% carrot pulp cooked at 105 ^{o}C, whereas the lowest value (202.99 mg/100g) observed in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C. The increased use of orange pulp in the current formulation results in lower potassium levels in carrot pulp. Cooking treatments raised potassium levels as higher temperatures caused moisture loss, concentrating the mineral components. This thermal processing reduces water content, leading to increased concentrations of soluble minerals in the final product. The potassium values obtained in this study were higher than those reported by Awolu *et al*. (2018) for banana-pineapple-watermelon jam, which ranged from 59.50-80.77 mg/100g and by Nwosu *et al.* (2014) for African star apple-pineapple jam, which ranged from 46.24-89.31 mg/100g. The potassium values observed in current study were high, due to the naturally rich

potassium content of carrot pulp. Potassium serves as a vital mineral which maintains critical functions in nerve transmission, muscle performance, body fluid control, blood pressure management and thus enhances the nutritional value of mixed jam products.

4.3.3 Calcium Content

The calcium content of composite jam samples showed differed highly significant ($p<0.01$) among treatments and increased from 20.13±0.06 mg/100g to 27.41±0.08 mg/100g (table 5). The highest calcium content (27.41 mg/100g) was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C, whereas lowest value (20.13 mg/100g) was observed in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C. The increase in calcium content in processed foods is largely due to higher quantities of orange pulp, which is rich in calcium. The thermal processing reduces water content, leading to increased concentrations of minerals in the final product. While minerals generally remain stable under heat, prolonged exposure can change their extraction properties, resulting in noticeable increasing in detectable calcium amounts. The calcium values obtained in present study were higher than those reported by Prisacaru *et al*. (2025), who found calcium contents ranging from 6 to16 mg/100g for various fruit jams, due to naturally higher calcium content raw materials used in formulations. Calcium is essential for bone, teeth development, muscle function and it enhances the nutritional value.

Table 5: The interaction effect of blending ratios and cooking temperatures on minerals composition of composite jam

Treatments	Sodium(mg/100g)	Potassium(mg/100g)	Calcium(mg/100g)
C0T1	9.96±0.06^{b}	216.88±0.10^{ab}	20.13±0.06^{g}
C0T2	10.09±0.01^{a}	217.02±0.20^{a}	20.43±0.06^{f}
BR1T1	9.88±0.03^{cd}	216.68±0.02^{bc}	20.65±0.06^{e}
BR1T2	9.94±0.01^{bc}	216.89±0.02^{ab}	20.71±0.00^{e}
BR2T1	9.86±0.01^{d}	216.35±0.10^{de}	20.97±0.01^{d}
BR2T2	9.89±0.01^{cd}	216.60±0.08^{cd}	21.02±0.02^{cd}
BR3T1	9.83±0.01^{d}	216.11±0.01^{e}	21.11±0.03^{cd}
BR3T2	9.84±0.01^{d}	216.12±0.01^{e}	21.13±0.01^{c}
BR4T1	1.67±0.01^{e}	202.99±0.11^{f}	27.04±0.08^{b}
BR4T2	1.68±0.01^{e}	203.10±0.01^{f}	27.41±0.08^{a}
CV (%)	**0.39**	**0.03**	**0.19**
p-Value	**0.001**	**0.002**	**0.000**

***Notes**: Values are expressed as mean ± standard deviation of triplicate determinations. Means within the same column followed by different superscript letters are significantly different at* P *≤ 0.05 according to Tukey's HSD test. C0=100% carrot pulp(control), BR1= 90% carrot pulp +10% orange pulp, BR2=80% carrot pulp +20% orange pulp, BR3= 75% carrot pulp+25% orange pulp, BR4=25% carrot pulp+ 75% orange pulp whereas T1= 90 ºC and T2= 105 ºC are cooking temperature.*

4.4 Sensory Analysis Result of Composite Jam

4.4.1 Color

The color scores of composite jam samples showed significant differences ($p<0.05$) among treatments and ranged from 6.49±0.51 to 7.87±0.69 (table 6). The highest color value (7.87) was recorded in C0T1 which contained 100% carrot pulp cooked at 90 ^{o}C, whereas lowest was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C. Carrot-dominant treatments are preferred for their appealing bright orange color, attributed to natural carotenoid pigments. However, high cooking temperatures and increased orange pulp content may result in pigment degradation and browning, negatively affecting visual quality due to heat treatment, Maillard reactions, and carotenoid degradation. The color scores obtained in present study were align within those reported by Okoye, Okoh, and Uke (2025) for African star apple and pineapple blended jam, which ranged from 6.10 to 7.75. The sensory property of color plays a vital role because it affects how consumers first perceive products which determines their marketability and attractiveness for jam products.

4.4.2 Aroma

As shown in table 6, aroma of composite jam samples differed significantly ($p<0.05$) among treatments and increased from 5.20±0.73 to 7.49±0.59. The highest aroma value (7.49) was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C, whereas lowest value (5.20) was recorded in C0T1 which contained 100% carrot pulp cooked 90 ^{o}C. The increased acceptance of aroma with higher orange pulp usage is due to the presence of natural volatile aromatic compounds and essential oils in orange fruits. Cooking at a moderate temperature of 90°C preserves desirable aroma compounds, while excessive heat leads to the evaporation of volatile flavor substances. The aroma scores obtained in present study were higher than those reported by O R Adegbanke (2025) for jam prepared from pawpaw, apple, banana and orange fruits, which ranged from 5.95 to 6.40. The aromatic quality of orange pulp improved by the presence of volatile compounds which include limonene and terpenes and esters that produce the citrus scent. The aroma of food products is vital because it determines how consumers perceive the food and how much they want to eat and how they receive the entire sensory experience of the food.

4.4.3 Taste

The taste of the composite jam samples score showed highly significant differences ($p<0.01$) among and increased from 6.73±0.78 to 7.58±0.69 (Table 6). The highest taste value (7.58) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C, whereas the lowest value (6.73) was recorded in BR3T2 which contained 75% carrot pulp plus 25 % orange pulp cooked at 105 ^{o}C. The improved taste in is due to the balance of sweetness from carrot and slight acidity from orange pulp, creating a desirable sweet-sour flavor. However, excessive orange pulp increases acidity, negatively affecting taste preference. Additionally, higher cooking temperatures can alter the sugar-acid balance through degradation and concentration effects. The results obtained in present study were within the range reported by Ullah *et al*. (2018) for carrot and apple blended jam, which ranged from 6.1-8.20 and by Nwosu *et al*. (2014) for African star apple-pineapple jam, which ranged from 5.85-7.55. Taste determining consumer preference and hence repeated consumption of a certain item.

4.4.4 Texture

As shown in table 6, the texture value of the composite jam samples differed significantly ($p<0.05$) and ranged from 6.56±0.50 to 7.58±0.75. The highest texture value (7.58) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C, whereas the lowest value (6. 56) was recorded in BR1T2 and C0T2. The higher texture due to pectin content and moisture content, which contributes to gel formation through blending and cooking. Some treatments scored lower due to excessive heating that compromised pectin structure and altered gel texture. Additionally, high orange pulp content and acidic levels beyond the optimal stability range negatively affected the texture. The texture scores obtained in present study were comparable with those reported by Ullah *et al*. (2018) for carrot and apple jam, which ranged from 6.9-7.7 and by Nwosu *et al*. (2014) for African star apple-pineapple jam, which ranged from 5.75-7.40. The texture also determines the level of the perceptible, flavor or aroma interplay of the food.

4.4.5 Flavor

As shown table 6 the flavor value of the composite jam samples differed significance ($p<0.05$) and increased from 5.47±0.92 to 7.49±0.76. The highest flavor score (7.49) was recorded in BR4T2 which contained 25% carrot pulp plus 75% orange pulp cooked at 105 ^{o}C, while the lowest value (5.47) was recorded in C0T1 which contained 100% carrot pulp cooked 90 ^{o}C. Increasing orange pulp improves flavor acceptance due to volatile oils and citrus flavor compounds. Higher heating temperatures enhance sugar and flavor development, resulting in distinct flavors. However, overheating during processing can reduce volatile chemicals. The flavor scores obtained in present study were within the range reported by O R Adegbanke (2025) for various fruit jam products. Flavor serves as the primary sensory element which most affects consumer satisfaction, product selection and market acceptance of jam and other processed food items.

4.4.6 Spreadability

Spreadability of composite jam samples differed significantly ($p<0.05$) and ranged from 5.13±0.79 to 7.64±0.68 (Table 6). The highest spreadability value (7.64) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C, whereas the lowest value (5. 13) was recorded in C0T2 which contained 100% carrot pulp at 105 ^{o}C. The ability of orange-rich treatments to spread improved due to reduced viscosity and a softer gel structure resulting from higher acidity and moisture content. In contrast, carrot-dominant treatments had lower spreading ability due to higher viscosity and a firmer structure. Variations in cooking temperature influenced moisture levels and the pectin gel structure, impacting spreading capabilities. The spreadability scores obtained in present study were with those comparable reported by O R Adegbanke (2025) for jam from pawpaw, apple, banana, and orange fruits, which ranged jam from 6.50 to 7.25. The higher spreadability scores obtained because of lower viscosity and more fluid consistency. The spreadability of products serves as a key quality attribute which affects both application ease, texture assessment and total customer satisfaction.

4.4.7 Overall Acceptability

Table 6 shows that the overall acceptability value of composite jam differed highly significant ($p<0.01$) among treatments and increased from 6.12±0.27 to 7.29±0.26. The highest overall acceptability value (7.29) was recorded in BR4T1 which contained 25% carrot pulp plus 75% orange pulp cooked at 90 ^{o}C, whereas the lowest score (6.12) was recorded in C0T1 which contained 100% carrot pulp cooked 90 ^{o}C. The acceptability scores were higher at a lower cooking temperature of 90°C compared to 105°C, indicating better nutrient retention, reduced off-flavor development, and preservation of natural color and aroma compounds, leading to cumulative benefits. Increased the orange pulp increased the overall acceptability of composite jam. The overall acceptability score obtained in present study were comparable with reported by Ullah *et al.* (2018) for carrot and apple jam, which ranged from 6.8-8.0. The BR4T1 achieved highest overall acceptability because ratio created sensory characteristics which include improved aroma, flavor from orange volatiles, balanced sweetness and acidity, good texture and spreadability.

Table 6: The interaction effect of blending ratio and cooking temperature on sensory properties of composite jam

Treatments	Color	Aroma	Taste	Texture	Flavor	Spreadability	Overall acceptability
C0T1	7.87±0.69^{a}	5.20±0.73^{e}	6.87±0.73^{b}	6.58±0.50^{c}	5.47±0.92^{g}	5.44±0.76^{ef}	6.12±0.27^{f}
C0T2	7.13±0.79^{bc}	5.44±0.50^{de}	6.78±0.64^{b}	6.56±0.50^{c}	6.31±0.90^{ef}	5.13±0.79^{f}	6.23±0.34^{f}
BR1T1	7.38±0.61^{b}	5.62±0.61^{d}	7.11±0.71^{ab}	6.76±0.61^{bc}	6.29±0.73^{f}	5.71±0.79^{e}	6.48±0.32^{e}
BR1T2	7.09±0.73^{bc}	6.12±0.73^{c}	6.96±0.71^{b}	6.56±0.50^{c}	6.67±0.83^{cdef}	5.62±0.75^{e}	6.51±0.35^{e}
BR2T1	7.04±0.74^{bc}	6.53±0.50^{bc}	7.04±0.64^{b}	7.02±0.62^{b}	6.38±0.81^{def}	6.36±0.61^{d}	6.73±0.28^{d}
BR2T2	6.87±0.73^{cd}	6.71±0.66^{b}	6.84±0.67^{b}	6.98±0.66^{bc}	6.84±0.74^{cde}	6.31±0.51^{d}	6.76±0.30^{d}
BR3T1	7.04±0.79^{bc}	7.38±0.49^{a}	7.11±0.88^{ab}	7.11±0.71^{b}	6.89±0.83^{bcd}	7.38±0.81^{ab}	7.23±0.31^{ab}
BR3T2	6.96±0.77^{bcd}	7.42±0.50^{a}	6.73±0.78^{b}	7.02±0.72^{b}	7.04±0.77^{abc}	6.78±0.74^{cd}	7.01±0.30^{c}
BR4T1	6.89±0.68^{cd}	7.44±0.50^{a}	7.58±0.69^{a}	7.58±0.75^{a}	7.40±0.72^{ab}	7.64±0.68^{a}	7.29±0.26^{a}
BR4T2	6.49±0.51^{d}	7.49±0.59^{a}	6.87±0.73^{ab}	6.96±0.74^{bc}	7.49±0.76^{a}	7.02±0.78^{bc}	7.09±0.30^{bc}
CV (%)	**10.21**	**9.57**	**10.46**	**9.21**	**11.87**	**11.27**	**4.61**
p-Value	**0.026**	**0.024**	**0.000**	**0.010**	**0.015**	**0.013**	**0.002**

***Notes**: Values are expressed as mean ± standard deviation of triplicate determinations. Means within the same column followed by different superscript letters are significantly different at* $P \leq 0.05$ *according to Tukey's HSD test. C0=100% carrot pulp(control), BR1= 90% carrot pulp +10% orange pulp, BR2=80% carrot pulp +20% orange pulp, BR3= 75% carrot pulp+25% orange pulp, BR4=25% carrot pulp+ 75% orange pulp whereas T1= 90 ^{o}C and T2= 105 ^{o}C are cooking temperature.*

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The present study demonstrated that both blending ratio and cooking temperature significantly ($p < 0.05$) influenced the physicochemical properties, phytochemical constituents, minerals composition and sensory properties of carrot-orange composite jam. The quality parameters including physicochemical properties, phytochemical constituents, minerals composition and sensory properties showed statistically significant differences among treatments ($p \leq 0.05$) indicating that blending ratios and cooking temperature strongly influenced final product quality. Increasing orange pulp enhances vitamin C content, phenolics content, calcium content, flavonoids content, acidity, aroma, flavor, spreadability and overall acceptability of composite jam due to its rich organic acids and antioxidants. However, increasing orange pulp decreased the protein content, fat content, fiber content, ash content, tannins content, potassium content, sodium content, pH value and color of composite jam. At a higher temperature of 105°C, there was an increase in total soluble solids, ash and viscosity of composite jam due to moisture evaporation. However, this elevated temperature adversely affected heat-sensitive nutrients and sensory qualities, leading to reductions in vitamin C content, phenolic compounds, flavonoids content, tannins content, moisture content, protein content, color, taste, texture and spreadability of composite jam. In contrast, a lower cooking temperature of 90°C better preserved the nutritional components and sensory characteristics of the composite jam samples. Among all treatments, BR4T1 which contained high proportion of orange cooked at 90 °C pulp produced the with better nutritional quality and sensory acceptability.

5.2 Recommendation

The study recommends BR4T1, containing 25% carrot pulp and 75% orange pulp cooked at 90°C resulted in high quality composite jam. Food processors engaged in jam production in Ethiopia can use this technology to process carrot and orange production which enables them to decrease post-harvest losses, while generating extra income for both farmers and food processors. The development of such nutritional products will reduce the postharvest losses and impart value to high appreciated fruits and vegetables, but it needs further study for the following recommendations:

- Further research work should be carried out on the microbial quality of composite jam during storage to determine its microbiological safety, identify potential spoilage microorganisms and ensure that the product remains safe for consumption throughout its intended storage period
- Research should be carried out on shelf-life stability of the composite jam to evaluate changes in physicochemical, nutritional, phytochemical and sensory properties under different storage conditions. Such information is essential for establishing an appropriate shelf life, selecting suitable packaging materials and determining optimal storage conditions for commercialization
- Further work is needed to determine beta-carotene value of composite jam because carrot is a rich source of pro-vitamin Carotenoids. Quantifying beta-carotene would provide a more comprehensive assessment of the nutritional quality of the product and support future health and nutrition claims

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7. APPENDIX

7.1 Analysis of Variance Table for Physicochemical Properties, phytochemical constituents, minerals composition and Sensory Properties of composite jam

Appendix Table 1: Summary ANOVA of Physicochemical Properties of Composite Jam

1. Moisture Content

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	40.5209	10.1302	1617.21	0.000
Cooking Temperature	1	1.3997	1.3997	223.45	0.000
Blending Ratio*Cooking Temperature	4	2.2474	0.5619	89.70	0.000
Error	20	0.1253	0.0063		
Total	29	44.2932			

2. Crude Protein

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	0.805576	0.201394	466.41	0.000
Cooking Temperature	1	0.007906	0.007906	18.31	0.000
Blending Ratio*Cooking Temperature	4	0.005954	0.001489	3.45	0.027
Error	20	0.008636	0.000432		
Total	29	0.828071			

3. Crude Fat

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	1.22918	0.307294	9011.56	0.000
Cooking Temperature	1	0.00114	0.001141	33.46	0.000
Blending Ratio*Cooking Temperature	4	0.00053	0.000132	3.87	0.017
Error	20	0.00068	0.000034		
Total	29	1.23153			

4. Crude Fiber

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	2.81575	0.703937	25848.37	0.000
Cooking Temperature	1	0.00189	0.001888	69.33	0.000
Blending Ratio*Cooking Temperature	4	0.00038	0.000096	3.53	0.025
Error	20	0.00054	0.000027		
Total	29	2.81857			

5. **Ash Content**

Source	**DF**	**SS**	**MS**	**F-Value**	**P-Value**
Blending Ratio	4	0.018580	0.004645	392.53	0.000
Cooking Temperature	1	0.001968	0.001968	166.34	0.000
Blending Ratio*Cooking Temperature	4	0.000232	0.000058	4.89	0.006
Error	20	0.000237	0.000012		
Total	29	0.021016			

6. **Carbohydrate**

Source	**DF**	**SS**	**MS**	**F-Value**	**P-Value**
Blending Ratio	4	51.6133	12.9033	2209.11	0.000
Cooking Temperature	1	2.0316	2.0316	347.83	0.000
Blending Ratio*Cooking Temperature	4	2.0003	0.5001	85.61	0.000
Error	20	0.1168	0.0058		
Total	29	55.7620			

7. Vitamin C Content

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	332.234	83.0584	82401.97	0.000
Cooking Temperature	1	0.189	0.1887	187.16	0.000
Blending Ratio*Cooking Temperature	4	0.045	0.0112	11.08	0.000
Error	20	0.020	0.0010		
Total	29	332.487			

8. Titrable Acidity

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	1.20016	0.300040	9241.47	0.000
Cooking Temperature	1	0.00087	0.000875	26.94	0.000
Blending Ratio*Cooking Temperature	4	0.00044	0.000111	3.42	0.028
Error	20	0.00065	0.000032		
Total	29	1.20213			

9. pH

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	1.77485	0.443712	435.01	0.000
Cooking Temperature	1	0.01121	0.011213	10.99	0.003
Blending Ratio*Cooking Temperature	4	0.01249	0.003122	3.06	0.040
Error	20	0.02040	0.001020		
Total	29	1.81895			

10. Total Soluble Solid

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	40.5209	10.1302	1617.21	0.000
Cooking Temperature	1	1.3997	1.3997	223.45	0.000
Blending Ratio*Cooking Temperature	4	2.2474	0.5619	89.70	0.000
Error	20	0.1253	0.0063		
Total	29	44.2932			

11. Viscosity

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	96.132	24.0330	617.66	0.000
Cooking Temperature	1	4.324	4.3244	111.14	0.000
Blending Ratio*Cooking Temperature	4	8.134	2.0335	52.26	0.000
Error	20	0.778	0.0389		
Total	29	109.369			

Appendix Table 2: Summary ANOVA of Phytochemical Constituents of Composite Jam

1. Phenolics Content

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	5975.90	1493.98	28424.13	0.000
Cooking Temperature	1	1.85	1.85	35.20	0.000
Blending Ratio*Cooking Temperature	4	0.72	0.18	3.43	0.027
Error	20	1.05	0.05		
Total	29	5979.52			

2. Flavonoids Content

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	3074.04	768.509	37047.83	0.000
Cooking Temperature	1	0.47	0.467	22.50	0.000
Blending Ratio*Cooking Temperature	4	0.30	0.076	3.64	0.022
Error	20	0.41	0.021		
Total	29	3075.22			

3. Tannins Content

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	2.12896	0.532240	3127.76	0.000
Cooking Temperature	1	0.02821	0.028213	165.80	0.000
Blending Ratio*Cooking Temperature	4	0.00270	0.000676	3.97	0.016
Error	20	0.00340	0.000170		
Total	29	2.16328			

Appendix Table 3: Summary ANOVA of Minerals Composition in Composite Jam

1. **Sodium Content**

Source	**DF**	**SS**	**MS**	**F-Value**	**P-Value**
Blending Ratio	4	325.420	81.3550	176054.87	0.000
Cooking Temperature	1	0.016	0.0162	35.04	0.000
Blending Ratio*Cooking Temperature	4	0.015	0.0036	7.85	0.001
Error	20	0.009	0.0005		
Total	29	325.460			

2. **Potassium Content**

Source	**DF**	**SS**	**MS**	**F-Value**	**P-Value**
Blending Ratio	4	881.708	220.427	28171.51	0.000
Cooking Temperature	1	0.016	0.016	2.01	0.172
Blending Ratio*Cooking Temperature	4	0.193	0.048	6.18	0.002
Error	20	0.156	0.008		
Total	29	882.074			

3. Calcium Content

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	202.422	50.6056	19347.83	0.000
Cooking Temperature	1	0.192	0.1923	73.53	0.000
Blending Ratio*Cooking Temperature	4	0.163	0.0408	15.60	0.000
Error	20	0.052	0.0026		
Total	29	202.830			

Appendix Table 4: Summary ANOVA of Sensory Properties of Composite Jam

1. Color

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	33.720	8.4300	16.77	0.000
Cooking Temperature	1	12.836	12.8356	25.53	0.000
Blending Ratio*Cooking Temperature	4	5.631	1.4078	2.80	0.026
Error	440	221.244	0.5028		
Total	449	273.431			

2. Aroma

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	316.080	79.0200	203.14	0.000
Cooking Temperature	1	4.109	4.1089	10.56	0.001
Blending Ratio*Cooking Temperature	4	4.436	1.1089	2.85	0.024
Error	440	171.156	0.3890		
Total	449	495.780			

3. Taste

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	8.156	2.0389	3.92	0.004
Cooking Temperature	1	2.722	2.7222	5.24	0.023
Blending Ratio*Cooking Temperature	4	13.489	3.3722	6.49	0.000
Error	440	228.578	0.5195		
Total	449	252.944			

4. Texture

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	30.822	7.7056	18.86	0.000
Cooking Temperature	1	4.302	4.3022	10.53	0.001
Blending Ratio*Cooking Temperature	4	5.542	1.3856	3.39	0.010
Error	440	179.778	0.4086		
Total	449	220.444			

5. Flavor

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	120.422	30.1056	46.81	0.000
Cooking Temperature	1	16.820	16.8200	26.15	0.000
Blending Ratio*Cooking Temperature	4	8.058	2.0144	3.13	0.015
Error	440	282.978	0.6431		
Total	449	428.278			

6. Spreadability

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	278.036	69.5089	131.98	0.000
Cooking Temperature	1	12.500	12.5000	23.73	0.000
Blending Ratio*Cooking Temperature	4	6.711	1.6778	3.19	0.013
Error	440	231.733	0.5267		
Total	449	528.980			

7. Overall acceptability

Source	DF	SS	MS	F-Value	P-Value
Blending Ratio	4	62.303	15.5758	167.86	0.000
Cooking Temperature	1	0.457	0.4565	4.92	0.027
Blending Ratio*Cooking Temperature	4	1.592	0.3981	4.29	0.002
Error	440	40.828	0.0928		
Total	449	105.180			

Appendix Table 5: Sensory Evaluation Format Sheet

Instruction: Dear panelist, please evaluate the given sample (s) honestly based on your personal preference and rate each of sensory attribute using the 9-hedonic scale where 1 = dislike extremely,2=dislike very much 3 = dislike moderately, 4 = Dislike slightly, 5=neither like nor dislike, 6= like slightly, 7 = like moderately,8=like very much and 9 = like extremely

Samples code	Sensory attributes						
	Color	Aroma	Taste	Texture	Flavor	Spreadability	Overall acceptability

Comment/ suggestion_____

Panelist signature_____



Appendix Figure 1: Raw material for composite jam preparation



Appendix Figure 2: Carrot pulp preparation



Appendix Figure 3: Orange pulp preparation



Appendix figure 4: Lemon juice (citric acid) preparation



Appendix Figure 5: Weight pulp for composite jam formulation



Appendix Figure 6: Cooking of composite jam



Appendix Figure 7: Sterilization of glass bottles and composite jam



Appendix Figure 8: composite jam products and stored in refrigerator



Appendix figure 9: pH and TSS determination of composite jam





Appendix Figure 10: TA determination of composite jam





Appendix Figure 11: vitamin C analysis of composite jam



Appendix Figure 12: fiber analysis of composite jam



Appendix Figure 13: Moisture and Ash analysis of composite jam



Appendix Figure 14: sensory evaluation of composite jam