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Carrot Pomace Jam: A Sustainable Approach to Waste Utilization and Sensory Preferences

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Abstract

The development of carrot pomace jam utilizes carrot pomace, a nutrient-rich byproduct often discarded as the hero ingredient, promoting sustainability and reducing post-harvest losses. This supports sustainable food processing and waste reduction through innovative product development. This innovative product transforms food waste into a value-added functional jam made from carrot pomace, carrot juice, grated carrots, sugar, and water. The production process involves washing and peeling carrots, blanching the pomace, then cooking all ingredients with continuous stirring. Moreover, heating continues until required brix attained for jam. The research aimed to evaluate both physicochemical and sensory attributes of the developed jam. The proximate analysis showed fat content at 20±0.07%, moisture content at 8±0.02% (with a decreasing trend), and ash content at 91.6±1.22%. Physicochemical analysis revealed total soluble solids (TSS) at 69.4±0.98 °Brix and weight loss of 10±0.02%. Antioxidant activity was significant, with total phenolic contents (TPC) at 40.876±0.13 mg GAE/100g and DPPH at 29.429±0.19%. Among the treatments, T2 was the most acceptable in terms of quality and sensory evaluation, while T4 showed the least preference.

Key Words: Carrot pomace, sustainability, value added product, functional food, post-harvest losses, food waste reduction

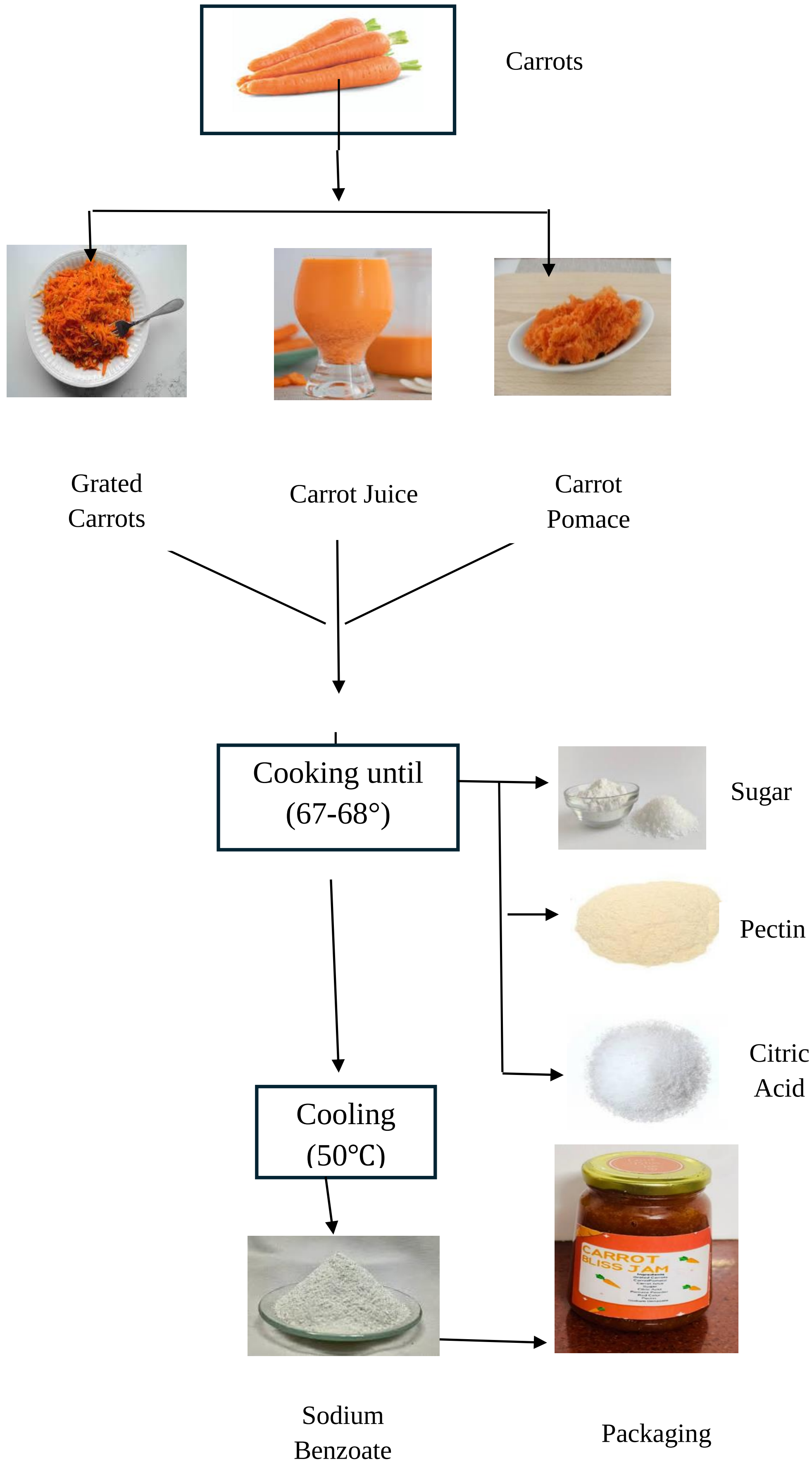


Figure 1. Graphical abstract of carrot pomace jam

1. Introduction

Carrot which is scientifically named as Daucus carota subsp. sativus, is part of the Apiaceae family. Carrots are liked just not because of their health benefits but also because one can eat them either raw or cook, making them common in many dishes, which is why they are popular (Lee et al., 2018). The value-added products made by carrots helps to reduce waste and make money. Carrot juice is commonly used in drinks, and puree is used in soups or baby food. The leftover after juicing is known as pomace and is being used for animal feed or even packaging, which is good for environment (Martinez et al., 2019).

The carrot jam gives representation of a food item that links carrot elements into production of jam so that distinct color, flavor and wellness can be provided. Carrots provide with heir sweet taste, their attractive orange color as well as their health properties. Once the carrots are processed, they become a base ingredient for various products likes purees, juices and jams (Park, 2024).

Pectin present in carrot help gelling properties which is suitable for making jams. As carrot jam production assists in waste material reservation so it does not go to waste. The essential components for preparing carrot jam are carrots with sugar together with pectin and both lemon juice and citric acid. A combination of ingredients in the mixture enables the substance to form a gel which extends its storage life. The overall quality of the jam's production alongside customer satisfaction is coherent and directly depending on each ingredient's measurement. The desirable taste quality and increased shelf life is achieved by the combination of sweeteners and preservatives in the carrot jam. Apart from that, both lemon juice and citric acid function best as organic food preservatives but sodium benzoate acts as an industrial food preservative (Heasman, 2010).

Carrot fiber acts as a crucial component in digestive health and regulates blood sugar levels. Because of their low carbohydrate amount, carrots offer suitable options to control blood sugar levels. Carrots demonstrate excellent benefits for diabetes patients and blood sugar control seekers because they present minimal glycemic index values (Muniasamy et al., 2025). Vitamin A production from beta-carotene in carrot jam helps protect eye and vision health while supporting the immune system and skin health. Dietary fibers from carrots assist with the proper functioning of the digestive system. In addition to potassium, calcium and vitamin K and C the carrot jam contains protective agents against oxygen damage. The digestive process and flavor of carrot jam improve through the addition of citric acid because this compound acts as an antioxidant (Roy et al., 2018). Apart from the carrot's benefits another main ingredient used in jam is carrot pomace which comprises of important amounts of bioactive and nutritional components. It consists of noticeable amounts of tocopherols, vitamin A, ascorbic acid and vitamin B-complex (Cozma et al., 2024).

Organoleptic properties describe the features of a product which the human senses can detect. These include appearance, texture and taste. Carrot jam products need to present a deep orange color that frequently includes beta-carotene additions. (Kamiloglu et al., 2015). The mouthfeel together with consistency help define the overall texture in carrot-based foods especially jams. The jam should maintain a firm texture that allows easy spreading by the customer. Among the physicochemical properties of the carrot pomace jam, carrot pomace jam usually has a pH level between 4.8 and 5.2. Unfortunately, this high pH can increase the risk and chances of spoilage since molds and yeasts tend to flourish in low-acid conditions (Abdel et al., 2014).

Post-harvest losses for carrots are about 20-30% worldwide, mostly because they get bruised during harvest or stored wrong, leading to rot. Pomace, the leftover from juicing, is a big waste even though it still has nutrients. Making use of pomace can target the problem of waste generation and sustainability. Food safety is highly compromised in the world right now. By making and distributing food items made with waste products can help in decreasing the problem of food security (Okafor, 2021).

2. Methodology

2.1. Procurement of raw material

The ingredients used for the development of carrot pomace jam such as grated carrots, carrot juice, carrot pomace and sugar were obtained from the local vendors in Johar Town, Lahore. Moreovre, chemicals used like pectin, citric acid and sodium benzoate were purchased from Sigma Aldrich (St. Louis, Missouri, USA).

2.2 Product development

The carrots were first washed to remove dirt and dust or other foreign particles. Then grated carrots and pomace were blanched for 5 min. After blanching, add pomace in sauce pan with 100 g grated carrots. Add 750 mL water and 150 mL carrot juice in it. Likewise, 750 g sugar was added with continuous stirring to avoid any lumps of sugar. Moreover, 7.5 g pectin was dissolved in water to prevent clumping and added gradually. Before adding citric acid, brix was checked which was 56 °Brix. About, 5 g citric acid was added and then solid content was again checked which exceeds to 61 °Brix. When required solid contents attained, turn off the stove and cool the jam to 50°C. Later on, 1 g sodium benzoate as a preservative was added to prolong the shelf life of jam. In the end, pour the jam into airtight glass jars and store in refrigerator (Ullah et al., 2018).

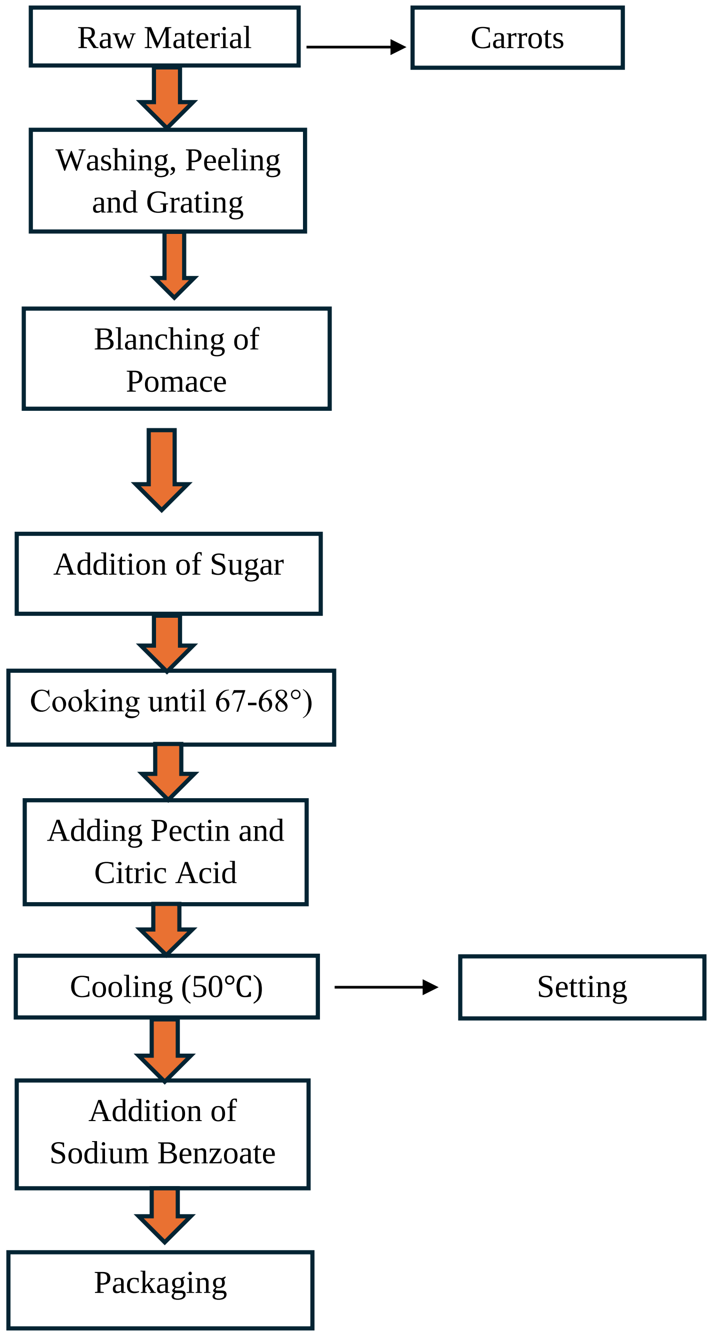


Figure 2.1. Flowchart for carrot pomace jam

2.4. Treatment Plan

Table 2.1. Treatment plan for carrot jam

Treatments	Pomace Concentration (%)
T_0	0
T_1	5
T_2	10
T_3	15
T_4	20

2.5. Proximate Analysis

2.5.1. Fat Content

A standard Soxhlet extraction method was used to determine crude fat in carrot pomace jam. A dried sample was placed in a cotton-lined thimble and inserted into the Soxhlet apparatus. A pre-weighed 500 mL round-bottom flask containing 300 mL of petroleum ether was used as the solvent and heated on an electric mantle for 6 hrs to extract fat. After extraction, the solvent was recovered by distillation. The flask was then dried at 102°C for 1–2 hr until a constant weight was achieved, cooled in a desiccator, and reweighed to determine fat content (AOAC, 2016).

Fat (%) = Weight of sample before fat extraction- Weight of sample after fat extraction / Weight of sample × 100

2.5.2. Moisture Content

For the quantitative estimation of the composition, the procedure for measurement of moisture content of carrot pomace jam was carried out according to the set standard. Accurately weigh 18g of carrot pomace jam by the help of weighing balance and record this as weight of sample before drying. Further, the sample was dried by using specific drying equipment to a uniform weight and at temperature not more than 105°C. Afterwards, the sample was allowed to cool and then weighed again (AOAC, 2016).

Moisture (%) = Weight of sample before drying – Weight of sample after drying / Weight of sample × 100

2.5.3. Ash Content

Ash content of carrot pomace jam was determined using the standard AOAC (2016) method. About 5 g of sample was weighed into a pre-weighed crucible. If excessively moist, the sample was pre-dried. The crucible was placed in a cool muffle furnace and heated at 550 °C for 5-6 hr. After cooling the furnace to around 25°C, the crucibles were carefully removed using tongs and placed in a desiccator. Once cooled, the final weight was recorded to calculate ash content (AOAC, 2016).

Ash (%) = Weight of ash/ Weight of sample × 100

2.5.4. Crude Fiber

Crude fiber content in the jam sample was determined. Two grams of sample were boiled under reflux for 30 min with 200 mL of 15% H_2SO_4 in a fume hood. The mixture was filtered using a Buchner funnel and washed with distilled water to neutrality. The residue was then boiled for another 30 min with 100 mL of 5% NaOH, filtered, and washed with distilled water and ethanol until neutral. The final residue was dried, weighed, incinerated in a muffle furnace, cooled, and reweighed to determine crude fiber content (AOAC and Imoisi et al., 2020).

$$\text{Crude Fiber (\%)} = W_2\text{-}W_3 / W_1 \times 100$$

Where;
W1 = weight of sample used
W2 = weight of crucible + oven dried sample
W3 = weight of crucible + ash

2.5.5. Crude Protein

Crude protein content in the jam sample was determined using the Kjeldahl method. One gram of sample was digested with 10 mL of nitric acid (HNO_3), heated, filtered, and diluted to 100 mL. A 10 mL aliquot of the digest was mixed with 40 mL of distilled water in a 500 mL flask, followed by the addition of 40% NaOH. The flask was connected to a distillation unit with 50 mL of 4% boric acid in a receiving conical flask. The distillate was collected and titrated with 0.1 N HCl until a faint pink endpoint appeared. The protein percentage was then calculated from the average titer value (Imoisi et al., 2020).

Wet Nitrogen (%) = (A-B) × 1.4007/ Weight of sample × 100

Where;

A= Vol (mL) Std HCl × Normality of Std HCl

B= Vol (mL) Std NaOH × Normality of Std NaOH

Dry Nitrogen (%) = Wet moisture % / 100- moisture %

2.5.6. Nitrogen Free Extract

The carbohydrate content of the sample was determined by estimation using the arithmetic difference method (De Conto et al., 2011; James, 1995) as defined by equation:

Nitrogen free extract (NFE) = 100 – (% Moisture + % Fat + % Ash+ % Fiber + % Protein)

2.6. Physicochemical Analysis

2.6.1. pH

pH of samples of carrot jam is determined by using digital pH meter. pH, determined using a Hanna HI2211 meter after homogenizing 5g of jam with 10mL distilled water, sufficient to inhibit Clostridium botulinum spores, though the meter's calibration drift in high-sugar matrices occasionally skewed readings (Sadler and Murphy, 2010).

2.6.2. Acidity

Acidity, measured potentiometrically, confirmed a pH drop from 5.2 (raw carrots) to 3.8 (final am), aligning with FDA benchmarks for high-acid foods, though the abrupt pH shifts occasionally destabilized pectin networks in poorly mixed batches (Montgomery et al., 2017).

2.6.3 TSS

Total soluble solids (TSS), quantified as °Brix, exhibited a progressive elevation from 56 (pre-citric acid) to 64 (post-sodium benzoate), a trajectory ascribed to cumulative solute concentration and water evaporation, though inconsistencies in evaporative rates between batches introduced minor deviations (Rozan, 2017).

2.6.4. Weight Loss

Weight loss across the production line approximated 20%, with contributions from peeling (5%), grating (3%), and thermal evaporation (12%), though the latter varied with atmospheric pressure during boiling (Kizi, 2025).

2.6.5. Color

Color analysis, conducted via a Hunter Lab Colo Flex EZ calibrated to the CIE LAB system, yielded L (lightness), a* (red-green), and b* (yellow-blue) by using digital colorimeter. These metrics denoted a vibrant orange hue, sensorially described as "visually appealing" by 82% of panellists, though a minority criticized it as "artificially bright" (Rozan, 2017).

2.6.6. TPC

Total phenolic content of the carrot pomace jam was determined using the method. In a 5 mL tube, 20 µL of a 2 mg/mL extract was mixed with 2 mL of distilled water and 0.2 mL of Folin-Ciocalteu reagent. After 3 min, 1 mL of 20% sodium carbonate solution was added. The mixture was incubated for 20 min, and absorbance was measured at 765 nm using a spectrophotometer. Total phenolic content was calculated using a gallic acid standard curve and expressed in mg. (Gao et al., 2000).

2.6.7. DPPH radical scavenging activity

DPPH radical scavenging activity, assessed spectrophotometrically at 517 nm, revealed 68% ± 2.1% antioxidant retention, a figure bolstered by carrot pomace's phenolic constituents, though thermal degradation during boiling reduced initial antioxidant potential by approximately 22%. Ginger-enriched variants exhibited enhanced activity (74%), likely due to synergistic interactions between carrot polyphenols and gingerol, though the mechanism remained partially elucidated due to time constraints (Samakradhamrongthai et al., 2021).

The antioxidant size percentage was found by using following formula:

Antioxidant activity (%) [(Ac-As) Ac] 100

Where:

Ac control reaction absorbance

As testing specimen absorbance

2.7. Sensory Evaluation

The sensory evaluation was prepared according to the consumer acceptance as well as consumer preferences. It was carried out by experienced and trained panellists. It was made by using a 9 points hedonic scale on color, flavor, texture and overall acceptability. The samples were served and provided to each panellist and in between questions were asked about carrot pomace jam's color, flavor, texture and overall acceptability and then our product was rated (Norouzian et al., 2023).

2.8. Statistical Analysis

All the data was obtained in triplicate presenting mean and standard deviation value was applied to check the level of descriptive analysis (Montgomery, 2017).

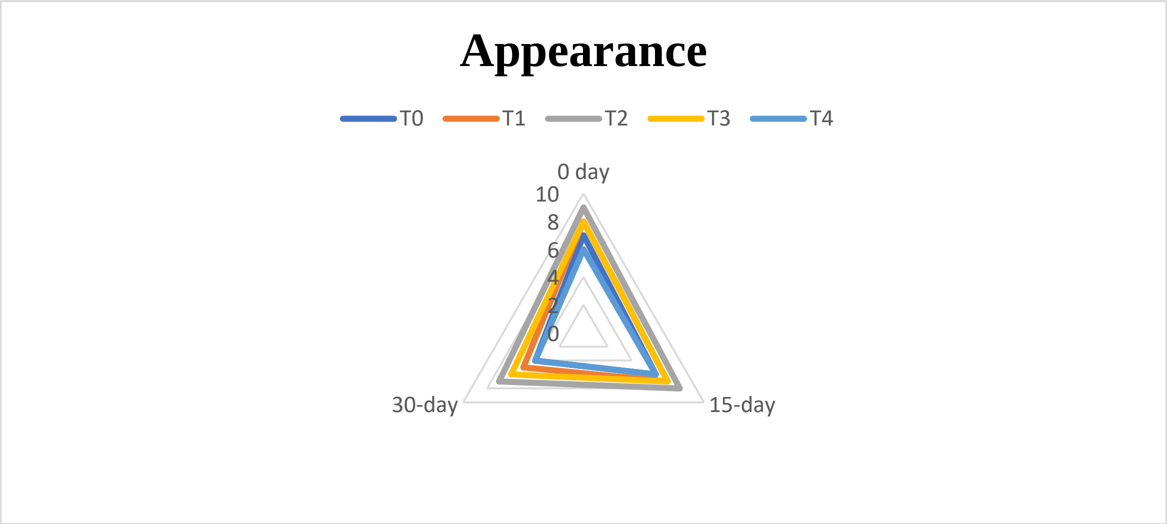
3. Results and Discussion

3.1 Sensory Evaluation

3.1.1. Appearance

The appearance of carrot pomace jam is smooth and glossy with rich orange color that reflects the natural color of pigments. The T2 sample has more superior pigment retention, as seen by its brighter and more vivid orange color compared to the other samples.

Figure 3.1. Graph of sensory evaluation of appearance of carrot pomace jam



3.1.2. Flavor

The flavor of carrot pomace jam is sweet and sour; the sour flavor is because of citric acid and sweet flavor is because of sugar. The T2 sample has more sweetish flavor compared to others.

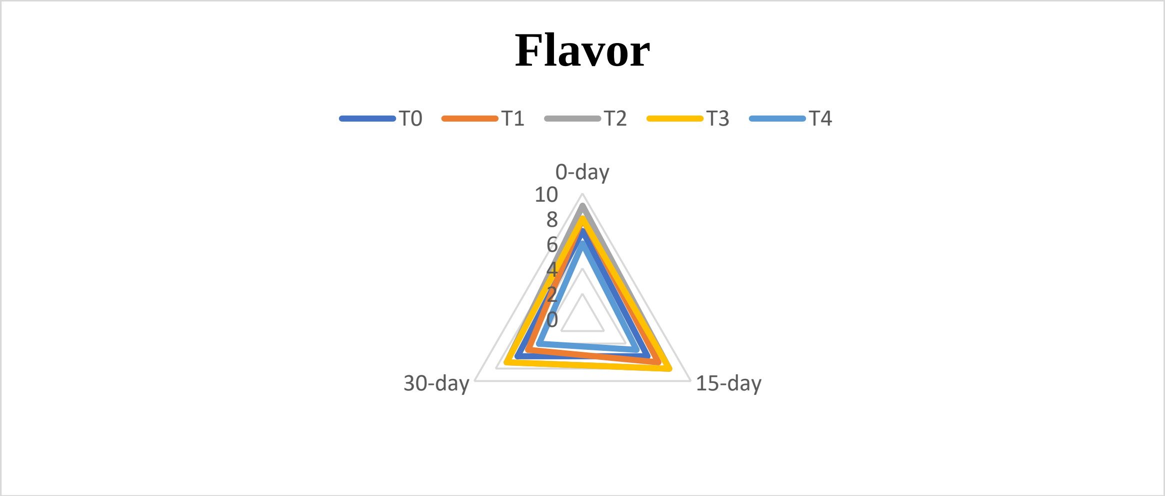


Figure 3.2. Graph of sensory evaluation of flavor of carrot pomace jam

3.1.3. Taste

The taste of the carrot pomace jam was obtained from the five treatments in which there was slight change in the ingredient's list. The best taste was showcased by T2 sample.

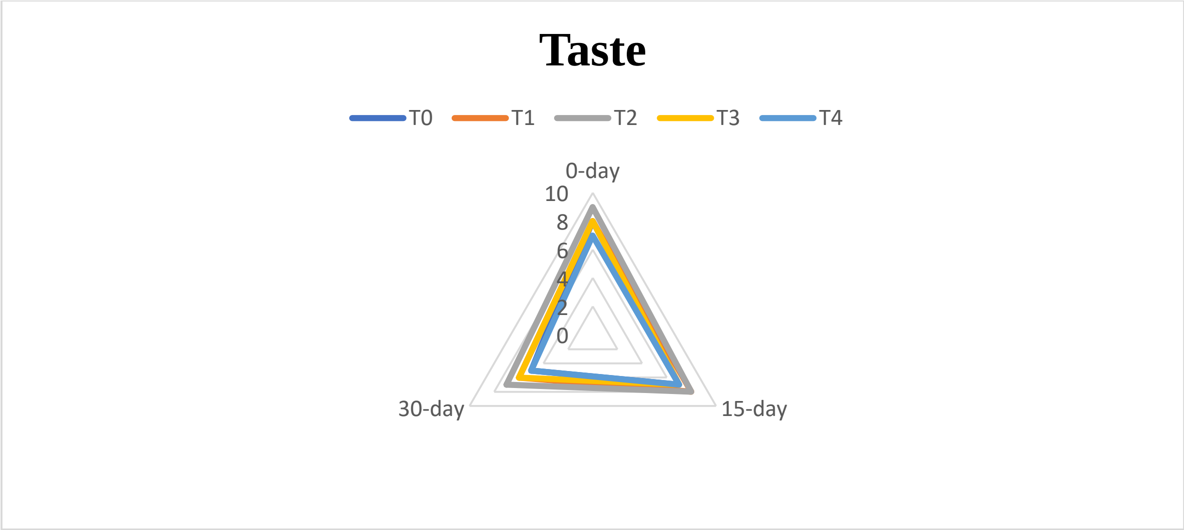


Figure 4.3. Graph of sensory evaluation of taste of carrot pomace jam

3.1.4. Texture

The texture of the carrot pomace jam was different in the five treatments depending on the ingredient's concentration. T2 processing was the most superior to others in terms of texture because of the concentration of ingredients in it. The results are described below.

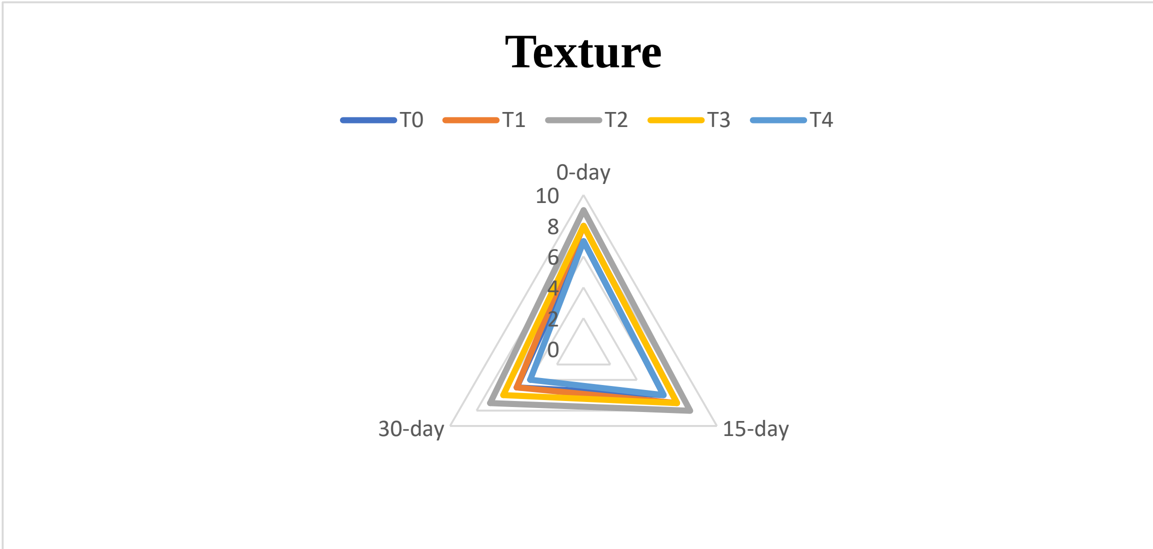
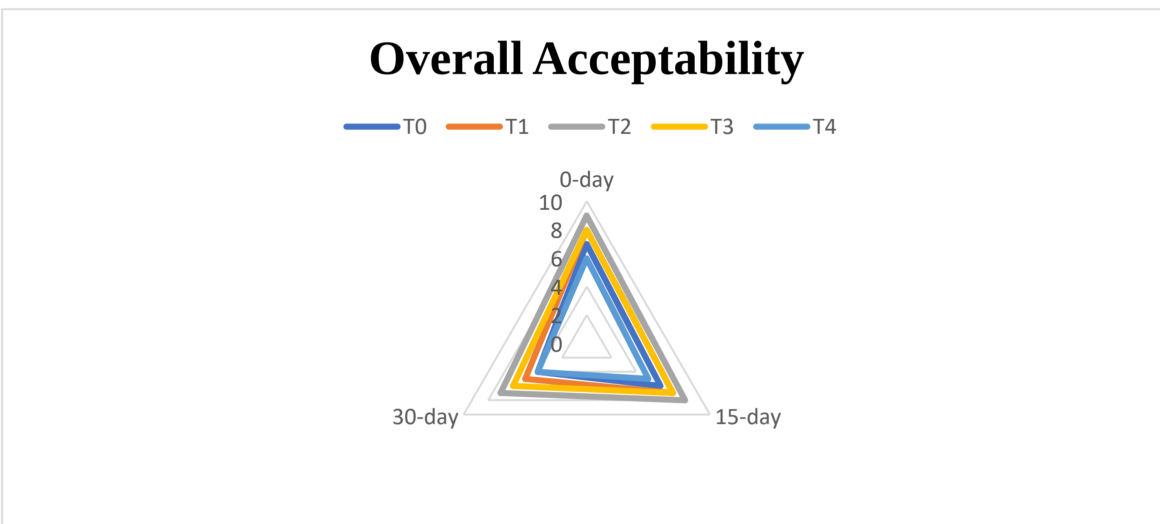


Figure 3.5. Graph of sensory evaluation of texture of carrot pomace jam

3.1.5. Overall Acceptability

The overall acceptability of the carrot pomace jam is good due to the health benefits it gives as well as the good blend and ratio of flavour, taste and colour properties in terms of sensory evaluation.

Figure 3.6. Graph of sensory evaluation of overall acceptability of carrot pomace jam



3.2. Proximate Analysis

3.2.1. Fat Content

According to the results, this type of jam has a remarkably high fat content of about 20.00 ± 0.07%, mostly from the fat-soluble carotenoids (β-carotene, lutein) and vitamins (A, E and K) found in the carrot pomace used for making the jam. The lipid in this matrix increases how well the body can absorb phytonutrients which is important for good vision, preventing oxidative damage and managing inflammation. Since the standard deviation is so low, it highlights very controlled steps, like controlling the lipid release, maintain a constant temperature during dehydration and using natural pectin's from pomace to stabilize the emulsion. Unlike ordinary fruit jams (<0.5% fat) or typical carrot powder (1-10% fat), the fat content in this product is much higher, suggesting special processing was used to keep the lipids and improve its nutraceutical benefits. Because the product is always the same, you know you are getting the essential health benefits, even if it feels different from standard jam. Since the fat content of the carrot jam is much higher than both ordinary fruit jams and carrot powder, the comparison has showed that carrot jam has a significantly increased fat content due to special processing and ingredients (like carotenoids and fat-soluble vitamins) (Ikram et al., 2024).

3.2.2. Moisture Content

The presence of very low moisture content (8.00 ± 0.02%) shows that the matrix is powerfully dehydrated and thus limits water activity ($A_w \approx 0.35$) to an extent that stops microbes and enzymes from multiplying. Cornell dried fruit and vegetables with a drying cycle, keeping them fresh for longer and concentrating ash, minerals and other beneficial compounds. Low moisture is reached by applying spray-drying or microwave dehydration which ensure heat transfer and moisture are completely controlled. Such a tiny deviation means the drying process is well controlled through proper airflow, exact temperature settings (within 1 °C) and frequent monitoring of humidity levels. Traditional jams are made to keep 25-35% moisture so they are easy to spread, but this jam gives up on texture for reliability, requiring rehydration before enjoying. Because of the low moisture, the fat does not easily react to become rancid and antioxidants are not broken down by heat, but the ash in meat may give the taste a stronger mineral flavor. A decreasing trend in moisture content was seen when comparing traditional jams to carrot pomace jam (Rana et al., 2021).

3.2.3. Ash Content

Carrot pulp has a mineral concentration of 91.60% on a dry basis or 84.27% on a wet basis which is much higher than the usual range found in carrot pomace (3-7% on a wet basis). It might mean the soil did not wash away properly, was recognized to have calcium or magnesium added or might have contained non-combustible additives that affected the results. You might notice that the primary minerals are those containing potassium (balancing fluids in the body), calcium (building bones) and magnesium (being a cofactor for enzymes), but at these levels, they make up much of the nutritional content of the powder. The bigger deviation shows that carrots and ashing methods differ which can lead to differences in mineral values. That means you need to include a lot of these minerals in your diet which may help with electrolytes and enzymes, yet can attract metallic tastes and change the food's taste. Since the ash is full of alkaline minerals, these could change the solubility and absorption of both the minerals and antioxidants contained in the jam. As a result, there is a significant increase in the ash content of the carrot pomace jam as compared to the ordinary jams (Adetoro et al., 2022).

3.2.4. Crude Fiber

It was reported that fiber content of jam processed from mixture of pineapple, banana and watermelon in the range 1.25- 3.03% (Olugbenga et al., 2018). On the other hand, it was reported that crude fiber content of different fruit jams was in the range 0.09–0.54% (Naeem et al., 2017). There was seen range of 25.61-31.88% fiber content in carrot pomace powder/jam. Hence, by comparing we can come to the conclusion that there is an increasing trend in fiber content related to carrot pomace powder/ jam (Rana et al., 2021).

3.2.5. Crude Protein

Protein is the major source of amino acids and nitrogen and is irreplaceable nutrient for human food because it is involved in all physiological functions (Ivanović et al., 2023). Although most plant proteins provide the necessary amounts of essential amino acids for human needs, plant proteins are often recognized as incomplete or nutritionally inferior to animal proteins (Sá et al., 2020). The analyzed carrot pomace jam show values between 6.32% - 7.34%. As compared to other traditional jams like coconut and pineapple with protein content 0.27 – 0.41%, there is increasing trend of protein content observed (Rana et al., 2021).

3.2.6. Nitrogen Free Extract

The total carbohydrate content of different fruit jams was observed to be in the range 65.99–67.65% as reported by (Naeem et al., 2017). Further, carrot pomace powder/jam's different samples consist of fiber content's significant amount ranging between 25.61-53.16%. As a result, a decreasing trend in the concentration of carbohydrate content was observed (Rana et al., 2021).

Treatment	Fat (%)	Moisture (%)	Ash (%)	Fibre (%)	Protein (%)	NFE (%)
Mean	20±0.07	8±0.02	91.6±1.22	27.8±0.07	6.51±0.03	35.5±0.08

Table 3.1. Mean for proximate analysis of carrot pomace jam

3.3. Physicochemical Analysis

3.3.1. pH

Since the pH is 3.91, indicating a stable trend within the microbiologically safe acidic range (<4.5), thereby affirming carrot pomace as a suitable acidifying agent in functional food formulationsA pH less than 4.5 is regarded as safe microbiologically since it suppresses the growth of harmful bacteria such as Clostridium botulinum (Rao, 2021). Organic acids such as citric, malic and fumaric acid which are present in carrot pomace, help give the concentrate its acidity. Being acidic helps preserve the jam and prevent it from turning bad, as well as ensure its flavor and color remain stable as time goes on (Ogwu and Ogunsola, 2024). Literature on fruit pomace-based jams has found comparable pH results, so carrot pomace shows the capability of being included in foods with low pH. Also, acids in the digestive process can make some micronutrients, especially iron and zinc, become easier for the body to absorb (Viegas et al., 2024).

3.3.2. Titratable Acidity (TA)

The TA level at 2.5% (with a margin of error of 0.02%) indicates an increasing trend, contributing to enhanced microbial safety, balanced flavor, and potential digestive health benefits. To ensure good consumer taste, maintaining a proper sugar-acid balance is important which TA can measure more accurately than pH. The high acidity here adds a tangy note to the jam which balances out the sweetness caused by the high TSS. Nutritionally, organic acids have been associated with benefits like acting as antioxidants and strengthening digestion (Du et al., 2024). Since acids in carrot pomace may slow down how quickly the stomach empties food, it may be a suitable option for diabetic or cautious people. Unlike guava or mango pomace jams which usually have TA values between 1.2 and 2.0%, carrot pomace jam shows stronger acids that could help with microbial safety and taste (Mall and Patel, 2024).

3.3.3. Total Soluble Solids (TSS)

According to the analysis, the Total Soluble Solids (TSS) of the carrot pomace jam made in this research was 69.4 °Brix, shows an increasing trend representing a considerable concentration of sugars, organic acids, minerals and soluble fibers in the product. Jams and preserves will be sweeter, gel more effectively and stay stable on shelves if they have a high TSS level. It helps to keep the jam less diluted, so it is more nutritious. TSS can be raised in your drink using carrot pomace which is high in dietary fiber, natural sugars and carotenoids and does not require a lot of added sugar. Unlike usual commercial fruit jams which have a maximum level of around 65 °Brix, this carrot pomace jam contains more which may offer a greater source of energy and a better mouthfeel (Rezvani and Goli, 2024). Also, high sugar content helps lower the amount of water the product absorbs which limits the chances of spoilage or microbial growth, so little or no added chemicals are necessary (Ahmad and Zia-ud-din, 2022) .

3.3.4. Weight Loss

There is only a small 10.0% percent weight loss reflects a decreasing trend, indicating improved moisture retention, gel stability, and better preservation of heat-sensitive nutrients like β-carotene and vitamin C. When jam is produced with too much moisture loss, it may shrink, crystallize and degrade important nutrients. Since there was little reduction in weight, it appears that the product preserved moisture and had a good gel texture which is very important for consumers. Accordingly, stir-frying adds less stress to compounds sensitive to heat, especially β-carotene and vitamin C present in carrots which play a role in antioxidant activity (Narwojsz et al., 2024). It was previously found that foods made from pomace often had more nutrient leaching and textural issues because of higher moisture loss. Since there is only small weight loss, it demonstrates that the formulation has achieved its main goal and guarantees the carrot pomace components, helpful compounds, are still present as well as extended shelf life. Because of its steady moisture, it releases nutrients slowly which may help the digestive and metabolic system when you eat it regularly (Ikram et al., 2024).

Table 3.2. Mean for physicochemical analysis of carrot pomace jam

Treatment	pH	Acidity (%)	TSS (°)	Weight Loss (%)
Mean	3.91±0.02	2.5±0.02	69.4±0.98	10±0.02

3.3.5. Color

The mean value for color L value attained 51.6, this shows the product is moderately dark and that its L value is far below traditional fruit jams (L > 70) due to its high amounts of carrot pomace and pigments. Several reasons contribute to this lightness such as evaporation causing high solids content (TSS 69.4°Brix) and low moisture (8%) in the food; the Maillard reactions and caramelization that happen during thermal cooking; and collected native pigments like anthocyanins (in purple carrots) or oxidized carotenoids. (Hao and Qi, 2022).

Intense green colouring in carrots is revealed by the exceptionally low a* value -44.5, as most carrot products commonly show high values for redness. Therefore, your pomace shades green because it holds on to chlorophyll very well, due to not applying heat or reducing during blanching; reduces oxidation of its highly susceptible carotenoids (avoiding them mixing with the green component) or its pH of 3.91 helps to stabilize the chlorophyllides. (Luo, 2023).

There is a slight difference between the b* value -2.4 and the bright yellow color seen in many carrots (b* well over 20). The odd shade may be caused by strong green pigments hiding other colors, having anthocyanin paired with a purple pigment or degraded carotenoids that absorb in blue light. Such a low standard deviation (±0.02) shows that the factors affecting yellow-blue balance do not vary much, probably because carotenoids are well-preserved or degrade similarly in all samples. (Choi et al., 2023).

-44.1 Chroma reveals that the color is rich, mainly because of the high greenness (a dominance). At this level, there is almost no greyness which shows there is little moisture and a lot of solids in the jam. Because the hue angle for avocado is -6.9°, it is found in the green-yellow area of color space and is quite different from the usual orange hue of carrot about 85° (Durand et al., 2021).

The hue angle that is recorded as -6.9° is also used to show the strong green profile of this carrot pomace jam, making it occupy the green-yellow quadrant of the color spectrum. The conventional carrot-based products show a hue angle of approximately 85° since they are characterized by bright orange color, which is owing to the content of carotenoids. It might be due to some significant processes namely: the acidic surroundings (pH 3.91) might have fixed chlorophyll, thermal processing and loss of carotenoid integrity might have taken place, or the addition of more carotenoid to carrots may be due (Rozan, 2017).

Table 3.3. Mean for physiochemical analysis of carrot pomace jam

Treatment	L	a*	b*	C*	h*
Mean	51.6±1.06	-44.5±0.98	-2.4±0.02	-44.1±1.22	-6.9±0.02

3.4. Total Phenolic Contents (TPC)

A moderate level of beneficial polyphenols is found in the carrot pomace, according to its Total Phenolic Content (TPC) of 40.876 mg GAE/100 g shows a decreasing trend compared to freeze-dried carrot pomace powders which range from 60–120 mg GAE/100 g, likely due to the thermal sensitivity of phenolic compounds during heat-based dehydration. By presenting chlorogenic acid, caffeic acid derivatives and coumarins, carrot pomace supports antioxidants which reduce the free radicals that cause many chronic diseases (Ikram et al., 2024). This TPC level protects against inflammation by preventing pro-inflammatory cytokines like TNF-α and IL-6 and it could protect cardiovascular health by relaxing blood vessels and lowering LDL oxidation (Mall and Patel, 2024). Nevertheless, this value is less than those found in freeze-dried carrot pomace powder (60–120 mg GAE/100 g), so it is likely that some heat-sensitive phenolics have been lost to heat during dehydration (Ziobro et al., 2022). The fact that the standard deviation is only ±0.13 mg GAE/100 g indicates that different batches are almost identical, due to strict control over both extraction and spectrophotometric processes (Babbar et al., 2011). The exact control in processing means steady health advantages from the phenolics, though it appears that some alternatives (freeze-drying) have stronger antioxidant potential (Asami et al., 2003).

3.5. DPPH Radical Scavenging Activity

The mean scavenging activity on DPPH of 29.429% shows a decreasing trend compared to raw or freeze-dried carrot pomace, indicates that the carrot pomace can somewhat neutralize free radicals, achieved mainly by phenolic antioxidants. This figure shows how much hydrogen a compound can donate to the DPPH radical which indicates how much it can protect DNA from oxidation and aging. Though correlated with TPC, the small activity compared to what is found in carrot pomace suggests certain antioxidants (specifically, chlorogenic acid) are transformed to less powerful versions or are trapped in the pomace fibers, during processing (Mall and Patel, 2024). Because standard deviation is so small at ±0.19, the DPPH assay can detect almost any tiny change among batch preparations. Since duplexes copy well, this helps in validation, yet their limited interaction with targets does not fully address sensitive diseases resulting from severe oxidative stress (Foti, 2015) .

Treatment	TPC (mg GAE/100g)	DPPH (%)
Mean	40.87±0.13	29.43±0.19

Table 3.4. Mean for Polyphenolic profile and antioxidant activity of carrot pomace jam

4. CONCLUSION

The innovation in carrot pomace jam is of carrot pomace which is loaded with bioactive and nutritional constituents. The study of development, evaluation and sensory accessibility of carrot pomace jam was carried out with the main aim of incorporating carrot pomace in carrot jam. Carrot pomace addition is done for the purpose of promoting sustainability and waste reduction. Various tests were carried out on the developed jam like proximate analysis, physicochemical analysis, antioxidant activity and total phenolic content test (TPC & DPPH) and lastly, sensory evaluation. Sensory evaluation of carrot pomace jam was carried out that included parameters like appearance, flavor, taste, texture and overall acceptability. All the results of the sensory evaluation have proved to be significant. The T_2 sample with 10% carrot pomace depicted great results for all of these parameters as it had appealed orange color, pleasant mouthfeel and no grainy texture, balanced fruity flavor due to carrot and earthy flavor due to pomace and lastly good blend of taste, flavor and texture contributed to appreciable overall acceptability. While T_4 sample containing 20% carrot pomace was below satisfactory due to unacceptable flavor, taste and texture.

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