





Assessing the Impact of Glycemic Index on Microbial Quality and Storage Stability of Tomato Jam

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Abstract	Article History
<p>The problem addressed is the need to assess the impact of glycemic index on microbial quality and storage stability of tomato jam, exploring alternatives to traditional sweeteners like sucrose for improved safety and quality. This study assessed the impact of glycemic index on microbial quality and storage stability of tomato jam. Tomato jam production was carried out by melding sterile dried tomato pulp, preservatives, thickeners, with varying amounts (500 g, 700 g and 900 g) of high (sucrose), medium (honey) and low (date fruit extract) glycemic index carbohydrates in stipulated proportion. The microbial qualities of the jams were determined using standard microbiological techniques. The notable microorganisms encountered in this study were characterized using morphological, biochemical and molecular methods. One way analysis of variance (ANOVA), Turkey's test and student t-test were employed at 95% confidence level to determine the significance the data obtained from this study. Microbial analysis revealed significant differences ($p < 0.05$) in microbial counts among the jams. Total bacterial, coliform, and yeast counts were detected only in sucrose-based jams (SJ), while total mold counts were detected in SJ and honey-based jams (HJ) after five months, but not in date fruit extract-based jams (DJ). Specific microorganisms, including <i>Bacillus subtilis</i>, <i>Bacillus coagulans</i>, <i>Aspergillus niger</i>, and <i>Wickerhamomyces anomalus</i>, were encountered significantly ($p < 0.05$) in SJ. However, all detected microorganisms were non-pathogenic. The variations in color, taste, texture, pH, and moisture content were statistically non-significant ($p > 0.05$). The prepared jams had stipulated microbial properties and were safe, with date fruit extract-based jams (DJ) exhibiting the best properties. The study's findings suggest that using date fruit extract as a low glycemic index carbohydrate can produce tomato jam with desirable properties, making it a potential healthier alternative to traditional jam products. The results of this study can be useful for food manufacturers and consumers seeking healthier options.</p> <p>Keywords: Coliform, Morphological, Biochemical, Molecular</p>	<p>Received: 06 Aug 2025 Accepted: 16 Sept 2025 Published: 20 Sept 2025</p>  <p>Scan QR code to view*</p> <p>License: CC BY 4.0*</p>  <p>Open Access article.</p>
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Introduction

Food storage has been described as an invaluable tool to combating food crisis, especially in developing countries such as Nigeria (Gallo *et al.*, 2016). Several edible crops are perishable such as fruits and vegetables, and preserving them after processing minimizes the level of loss (Gallo *et al.*, 2016; and Iheukwumere *et al.*, 2020).

Tomato (*Lycopersicon esculentum*) is a typically red edible fruit and belongs to the Nightshade family (Solanaceae) except for the tiny current tomato (Gallo *et al.*, 2016). This family is the most variable of all crop species in terms of agricultural utility and the third economically most important crop family, exceeded only by grasses and legumes, and the most valuable

in terms of vegetable crops (Gannje *et al.*, 2016; Iheukwumere and Iheukwumere, 2022a). This fruit contains vitamins A and C and can be eaten in a variety of ways: fresh, in salads, or processed into tomato pulp, dehydrated tomatoes, and jam. It is a fruit that grows based on climate, and its ripening process is shown by the colour change that begins around the seed and then passes to the skin, it has a high deterioration capacity and cannot be stored for a long time due (Jafari *et al.*, 2018 and Iheukwumere *et al.*, 2022b). Tomatoes are highly perishable and very susceptible to mechanical damage with poor handling and transportation system (Ganje *et al.*, 2016). In addition to mechanical damage at high temperatures, fruits and vegetables transpire and respire, which leads to spoilage (Koh *et al.*, 2012; Ganje *et al.*, 2016).

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Research has revealed that the only way to optimizing the value of tomato is to process and preserve it into jam or paste otherwise known as tomato jam (Kapira *et al.*, 2023). Jam is a product obtained by concentrating pulp or juice using enough carbohydrates, pectin, and acid to reach a concentration needed to solidify when cooled. Proper postharvest handling and storage methods are essential for maintaining acceptable quality and extending the market life (Machalela *et al.*, 2023; Kapira *et al.*, 2023; and Ilheukwumere *et al.*, 2022f).

It is worthy to note that food products are susceptible to microbial contamination, which has a great impact on the shelf life of the product (Ganje *et al.*, 2016; Anie, *et al.*, 2022; Kapira *et al.*, 2023). According to Arkoub-Djemoune *et al.* (2016), storage of tomato jam results in changes in the microbiological and physicochemical qualities. The changes that occur in these features depend on the duration of storage and the glycemic index of the carbohydrate used during the production process (Anie *et al.*, 2022). Microbiological quality of tomato jam provides information on the bacterial and fungal growth, which are mostly involved in contamination of stored food products, especially spore formers such as *Bacillus* species and strict anaerobes such as *Clostridium* species (Dim *et al.*, 2025f).

Several studies have been documented on microbial qualities and physicochemical characteristics of tomato jam such as Ganje *et al.* (2016), Anie *et al.* (2022), and Kapira *et al.* (2023) but few studies are available on microbial qualities, shelf life, and storage qualities of tomato jam prepared using high and low glycemic index carbohydrates. Hence, the aim of this study is to evaluate the microbial qualities, shelf life, and storage qualities of tomato jam prepared using high and low glycemic index carbohydrates.

Materials and Methods

Preparation of the Tomato Jams

Materials procurement: Fresh, hard, and ripe tomato fruits, date fruits, and honey were purchased from Eke-Awka market in Awka South LGA, Anambra State. The tomato fruits were carefully transported to the laboratory in polythene bags. Analytical-grade culture media, chemicals, and reagents were sourced from commercial vendors, ensuring the quality and reliability of the materials used in the study.

Preparation of tomato pulp: Five kilograms (5kg) of tomato fruits were washed with distilled water to ensure cleanliness. The fruits were then ground using a sterile electric blender (Brabantia/BBEK1051) to produce a pulp. The ground fruit was filtered through sterile muslin cloth to remove seeds and fiber, resulting in a fresh and clean pulp. The pulp was weighed into different 1000 mL conical flasks (PYREX) and sterilized by autoclaving at 121°C, 15 PSI for 15 minutes. This process ensured the pulp was free of contaminants and ready for use in the preparation of tomato jam. The sterile pulp was then used as the base ingredient for the jam production process.

Preparation of *Phoenix dactylifera* (Date) fruits juice (Zaldi type): This was carried out using the method described by Ilheukwumere *et al.* (2022c), Ilheukwumere *et al.* (2022d)

and Ilheukwumere *et al.* (2022e). Date fruits were washed with distilled water to ensure cleanliness. They were then ground using a sterile Juice extractor (Century CJE8221D) to extract the juice. The extracted juice was filtered through sterile muslin cloth to remove any solids. The juice was then measured and poured into a clean 500 mL beaker (PYREX) for use in the preparation of tomato jam. This process ensured that the date juice was clean and free of contaminants, making it suitable for use in the jam production process. The sterile equipment and clean environment helped to maintain the quality and safety of the juice.

Tomato Jam: The production of tomato jam was carried out using a modified method of Kapira *et al.* (2023), Ilheukwumere and Ilheukwumere (2022g), Ilheukwumere *et al.* (2023a) and Ilheukwumere and Ilheukwumere (2023b). The modifications made to the original method included adjusting the mixing ratio of the ingredients, varying the weights of glycemic carbohydrates, and using pectin as a thickening enhancer and citric acid instead of lemon juice. To prepare the tomato jam, 1.5 kg of prepared tomato pulp was weighed into a clean, sterile pot and boiled with varying amounts (500 g, 700 g and 900 g) of sucrose. The mixture was stirred properly, and then 4.0 g of pectin powder and citric acid were slowly added until an optimum pH of 3.0-3.3 was reached to enhance gelation. The mixture was heated until it formed a gel, and the setting point was checked using a drop test. The jam was scooped with a spoon and dropped into clear cold water, and when it did not disperse within a minute, it was considered ready. The same procedure was used to produce honey jam, where varying concentrations (500 g, 700 g and 900 g) of honey were used instead of sucrose. Similarly, date juice was used at varying weights (500 g, 700 g and 900 g) for jam production, replacing sugar in the recipe. These modifications allowed for the production of tomato jam with different sweeteners and varying concentrations, while maintaining the desired gelation and texture properties. The use of pectin and citric acid helped to achieve the optimal pH and gelation properties, resulting in a high-quality jam product.

Packaging and storage: After the jam had reached its setting point, it was filled while still hot into sterile transparent plastic containers (100 g) and labeled. The jam was then kept at room temperature (30°C) in a cool and dry place for 6 months, during which it underwent weekly analysis to monitor its quality and stability over time.

pH of the samples: Ten grams (10 g) of the sample was weighed into 250 mL test beaker (PYREX). This was followed by addition of 30 ml of distilled water, and this was thoroughly shaken and then made up to 100 ml using the distilled water. The Table top pH meter was first standard using buffers (pH = 4.0, 7.0 and 11.0), and measured the pH readings of the sample solutions (AOAC, 2019).

Moisture content: This was determined using the method of AOAC (2019). A crucible was dried and cooled, then initial weight of the crucible was taken as W_1 , 10 g of the sample was transferred into the crucible and the weight of the crucible was taken W_2 . The crucible and its content were then heated in an

oven at 105°C for 4–6 h. After drying the final weight of the crucible and its content were taken as W_3 . Then the percentage moisture content was calculated as follows:

$$\% \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Microbiological Analysis of the Tomato Jams

The microbiological analysis will be carried out at monthly interval during the storage period.

Determination of Total Bacterial Counts (TBC): One gram (1.0 g) sample was aseptically transferred into a sterile test tube (PYREX) containing 2.0 ml of the diluent (distilled water). This was shake thoroughly and made up to 10ml using the distilled water. One milliliter of the prepared sample was aseptically plated on Petri dishes (60 mm OD × 55 mm ID × 13mm high) containing Nutrient agar medium (NA/BIOTECH) using pour plate method. All the plates in triplicates were incubated inverted at 37±2°C for 24 h. The total bacterial counts were determined after incubation using an electric colony counter and colonies counted were expressed at CFU/g as described by AOAC (2019) and Obianom *et al.* (2024). The procedure was repeated for other samples.

Determination of Total Coliform Counts (TCC): One gram (1.0 g) sample was aseptically transferred into a sterile test tube (PYREX) containing 2.0 ml of the diluent (distilled water). This was shake thoroughly and made up to 10ml using the distilled water. One milliliter of the prepared sample was aseptically plated on Petri dishes (60 mm OD × 55 mm ID × 13mm high) containing MacConkey agar medium (MA/BIOTECH) using pour plate method. All the plates in triplicates were incubated inverted at 37±2°C for 24–48 h. The total coliform counts were determined after incubation using an electric colony counter and colonies counted were expressed at CFU/g as described by AOAC (2019). The procedure was repeated for other samples.

Determination of Total Mold Counts (TMC) and Yeast Counts (TYC): One gram (1.0 g) sample was aseptically transferred into a sterile test tube (PYREX) containing 2.0 ml of the diluent (distilled water). This was shake thoroughly and made up to 10ml using the distilled water. One milliliter of the prepared sample was aseptically plated on Petri dishes (60 mm OD × 55 mm ID × 13mm high) containing Sabouraud Dextrose agar (SDA/BIOTECH) supplemented with 0.05 % using spread plate method. All the plates in triplicates were incubated inverted at room temperature (30) for 5 days for mold counts, and at 37±2°C for 24 h for yeast counts. The total mold/yeast counts were determined after incubation using an electric colony counter and colonies counted were expressed at CFU/g as described by AOAC (2019). The procedure was repeated for other samples

Characterization of the Microbial Isolates Recovered from the Samples

Purification of the isolates

The plates that will show discrete colonies will be selected and aseptically streaked each colony on sterile plates (90mm×15mm) containing Sabouraud dextrose agar (BIOTECH) or Nutrient Agar (BIOTECH) prepared according to the manufacturer's description. The streaked plates will be incubated at room temperature (30 ± 2°C) for 5 days for fungi and at 35±2°C for 24 h for bacteria as described in Cheesbrough (2010), Egbe *et al.* (2025a), Ekechukwu *et al.* (2025a) and Ekechukwu *et al.* (2025b).

Identification of the isolates

The isolates will be identified to the genus/species level based on macroscopic, microscopic and molecular characteristics (for fungi) and morphological, biochemical and molecular characteristics (for bacteria) of the isolates obtained from pure cultures as described in the study published by Iheukwumere *et al.* (2020), Ekechukwu *et al.* (2025c), Egbe *et al.* (2025b), and Egbe *et al.* (2025c).

Gram staining technique

This was done using the modified method of Iheukwumere *et al.* (2025a) and Iheukwumere *et al.* (2025b). A thin smear will be made in a cleaned grease free microscopic slide (75mm×25mm), air dried heat fixed. The smear will be flooded with crystal violet solution (0.2%) for 60 seconds and rinsed with cleaned water. Gram iodine solution (0.01%) will then be applied and allowed for 60 seconds. This will be rinsed with cleaned water. This will be followed by decolourizing the slide content with 95%w/v ethyl alcohol for 10seconds and then will be rinsed with cleaned water. The smear will then be counter stained with safranin solution (0.025%) for 60 seconds, rinsed with cleaned water, blot drained and air dried. The stained smear will be covered with a drop of immersion oil and will be observed under a binocular compound light microscope using ×100 objective lens.

Motility test: A semi-solid medium prepared by mixing 5.0g of bacteriological agar (BIOTECH) with 2.0g of nutrient broth (BIOTECH) in 1 Litre of distilled water was used. The solution will be dissolved and sterilized using autoclaving technique after dispensing 10 ml portion in different test tubes. The test tubes were allowed to set in vertical positions and then inoculate the test organisms by performing a single stab down the centre of the test tube to half the depth of the medium using sterile stabbing needle. The test tubes were kept in an incubator in vertical position at 35±2°C for 24h.

Biochemical characteristics of the isolates

The capability of the isolates to produce catalase, indole, oxidase, acetoin, grow in 6.55 % NaCl and to utilize sugars, sugar alcohols and other substances (ribose, sorbitol, arabinose, sacharose, glucose trehalose, lactose, starch, inulin, salicin, hiparate) and also the haemolytic activity of the isolates were done using the methods described by Cheesbrough (2010), Iheukwumere *et al.* (2018) and Iheukwumere *et al.* (2025c).

Indole test: This was done using the modified method Iheukwumere *et al.* (2025d). Indole is a nitrogen containing compound formed when the amino acid tryptophan is hydrolyzed by bacteria that have the enzyme tryptophanase. This is detected by using KOVAC's reagent. For this test, isolates were cultured in peptone water in 500.0 ml of deionized water. Ten millilitres of peptone water was dispensed into the test tubes and sterilized. The medium was then inoculated with the isolates and kept in an incubator at 37°C for 48 hr. Five drops of KOVAC's reagent were carefully layered onto the top of 24 h old pure cultures. The presence of indole was revealed by the development of red layer colouration on the top of the broth cultures.

Sugar fermentation test: This was done using the modified method Iheukwumere *et al.* (2025e). The capability of the isolates to metabolize some sugars with the resulting formation of acid and gas or either were carried out using sugar fermentation test. One litre of 1% (w/v) peptone water was added to 3 mL of 0.2% (w/v) bromocresol purple and 9 ml was dispensed in the test tube that contained inverted Durham tubes. The medium was then sterilized by autoclaving. The sugar solution were prepared at 10% (w/v) and sterilized. One milliliter of the sugar was dispensed aseptically into the test tubes. The medium was then inoculated with the appropriate isolates and the cultures incubated at 37°C for 48 h and were examined for the formation of acid and gas. Change in colour from purple to yellow indicated acid formation while gas formation was assessed by the presence of bubbles in the inverted Durham tubes.

Hydrogen sulphide production: This was done using the modified method Iheukwumere *et al.* (2025f). This was performed using triple sugar iron (TSI) agar. The TSI agar was made in accordance to the manufacturer's instruction. This was sterilized using autoclaving technique and left to cool to 45°C. The isolate was aseptically inoculated by stabbing vertically on the medium and streaked on the top and incubated at 37°C for 24-48 h. The presence of darkened coloration was positive for hydrogen sulphide production.

Citrate utilization test: This was done using the modified method Dim *et al.* (2025a). The Simmon's Citrate Agar was prepared according to the manufacturer's direction and the isolates were inoculated by stabbing directly at the center of the medium in the test tubes and incubated at 37°C for 48 hr. Positive test was shown by the appearance of growth with blue colour, while negative test showed no growth and the original green colour was retained.

Catalase test: The test was carried out as described by Cheesbrough (2010). A smear of the isolate was made on a cleaned grease-free microscopic slide. Then, a drop of 30% hydrogen peroxide (H₂O₂) was added on the smear. Prompt effervescence indicated catalase production.

Oxidase test: The test involved two drops of freshly prepared oxidase reagent dispensed on Whatman No. 1 filter paper which was placed in Petri dish, and a smear of the test isolate

was made on the spot using a sterile stick. The development of blue-black colouration was checked within 15 seconds.

Molecular characterization of the isolates

3.3.3.1 Extraction and purification of DNA: The bacterium isolate was plated on Nutrient Agar (Biotech) and incubated at 37°C for 24 h and the *Candida albicans* was plated on SDA (Biotech) and incubated at 37°C for 24 h. By means of the procedures of Zymo Research (ZR) DNA miniprep™ kit, bacterial and fungal genomic DNA were then extracted and purified (Category No. D6005; Irvine, California, USA) as described by Iheukwumere *et al.* (2018) and Dim *et al.* (2025b).

Determination of the quality of extracted DNA: Using mass spectrophotometer (Nanodrop), One micro litre (1µL) was aseptically dropped into a fresh space in the chamber and the chamber was lightly closed which was then linked to a computer system which showed the window that discovered the value of the sample at 260/280nm as described by (Iheukwumere *et al.*, 2018 and Iheukwumere *et al.*, 2025g).

Amplification of DNA and gel electrophoresis of PCR product: This was analysed using Master cycler Nexus Gradient (Eppendorf). A mixture of primer (20 µL), template DNA (20µL), water (72 µL) and master mix (108 µL), which comprises taq polymerase, dimethylsulfoxide (DMSO), magnesium chloride (MgCl₂) and nucleotides triphosphates (NdTPs), was made in 1.5 mL tube and homogenized using vortex mixer (Eppendorf). This was then positioned in the block chamber of the master cycler and then programmed. The PCR program for conditions were as follows: initial incubation at 94°C for 5 mins, followed by 35 cycles of denaturation at 94°C for 15 secs, annealing at 55°C for 15 secs, elongation at 72°C for 21 secs and final extension period for 10 mins at 72°C. The amplified products were electrophoresed in 1.0% agarose gel and a 1kb DNA ladder was used as a size reference. After staining with 3µL of nucleic acid stain (GR green), the gel was documented with gel documentation apparatus (Iheukwumere *et al.*, 2018 and Iheukwumere *et al.*, 2025h).

DNA sequencing of the amplicons: The amplicons were used for the sequencing using ABI DNA sequencer (Applied Biosystem Inc) at International Institute of Tropical Agriculture (IITA), Ibadan using the method of Iheukwumere *et al.* (2018).

Computational analysis: This was analysed making use of the modified method of Iheukwumere *et al.* (2018) and Ike *et al.* (2025a). The chromatograms generated from the sequences were cleaned to obtain regions with normal sequences. The cleaned nucleotides were aligned using pair wise alignment tool. The consensus sequences formed by the alignment of the forward and reverse sequences were used to perform the Basic Local Alignment Search Tool (BLAST) using National Centre for Biotechnology Information BLAST over the internet. The sequences of the isolates with 95% and above similarities were accepted. Also, the maximum scores, total scores and accession numbers of the isolates were assessed. The relatedness of the isolates was determined by tracing their

phylogenetic tree using DNA distance neighbour phylogenetic tree tool.

Screening the Bacterial Isolates for Pathogenic Potentials

In vitro technique: The *in vitro* pathogenic potentials of the bacterial isolates was carried out by testing for the ability of the bacterial isolates to produce haemolysis on blood agar and took up Congo red dye as described in the study published by Zahid *et al.* (2016), Ugwu *et al.* (2020) and Ike *et al.* (2025b).

Haemolysis on blood agar: Blood agar was prepared following the manufacturer's instruction, the medium was allowed to solidified and aseptically streaked with the test isolates. This was incubated in inverted position at $35\pm 2^\circ\text{C}$ for 24 h. The presence of clear zones around the colonies was an indication of β haemolysis, partial zones of inhibition which was detected by greenish to gray zones was an indication of γ -haemolysis whereas absence of clear zones as described by Zahid *et al.* (2016)

Reaction with Congo red dye: Nutrient agar was prepared following the manufacturer's instruction, this mixed with Congo red dye, and the medium was sterilized and allowed to solidified. The medium was aseptically streaked with the test isolates. This was incubated in inverted position at $35\pm 2^\circ\text{C}$ for 24 h. The presence of colonies with tiny red with wrinkled surface was an indication of positive test whereas colonies with pink colour and smooth surface was an indication of negative colour as described by Ugwu *et al.* (2020)

Statistical Analysis

The data obtained in this study were presented in Tables and figures. Their percentages were also calculated. The sample mean and standard deviations of some of the analytical data were also calculated. One way analysis of variance (ANOVA) was employed at 95% confidence level to determine the significance the data obtained from this study. Post hoc analysis was carried out using Tukey's HSD (Honestly Significant Difference) tests. Pairwise comparison was carried out by using student "t" test in Excel package as described in study published by Ike *et al.* (2025c), Ike *et al.* (2025d), Ike *et al.* (2025e), Ugwu *et al.* (2025a) and Ugwu *et al.* (2025b).

Results

Prepared Jam and its properties

The physicochemical characteristics of the prepared tomato jams are presented in Tables 1-3. The jams exhibited distinct differences in color, taste, texture, and surface appearance, depending on the type and amount of sweetener used (Table 1). Specifically, the jams made with sucrose, honey, and dates displayed red, brown, and peach colors, respectively. The sucrose-based jam had a sweet taste and a slightly smooth texture, while the honey-based jam had a floral or fruity taste with a smooth texture. The date-based jam had a sweet or caramel-like taste, similar to the honey-based jam, with a smooth texture. These variations in characteristics are summarized in Table 1.

The pH levels of the tomato jams varied significantly depending on the type and amount of glycemic carbohydrate used, as well as the storage duration (Table 2). Notably, the

sucrose-based jams had the lowest pH values, while the date-based jams had the highest. Increasing the amount of glycemic carbohydrate resulted in a non-significant ($p>0.05$) decrease in pH. Conversely, the pH of the jams increased non-significantly ($p>0.05$) over time. Interestingly, the pH of the date-based jams remained relatively uniform across different carbohydrate concentrations and storage duration, particularly evident in jams produced with 700g of date fruit, which showed no change in pH.

The moisture content of the prepared tomato jams varied depending on the type and amount of glycemic carbohydrate used, as well as storage duration. A slight, non-significant ($p>0.05$) increase in moisture content was observed over time, while an increase in glycemic carbohydrate amount resulted in a decrease in moisture content. Notably, sucrose-based jams had the lowest moisture content, followed by date-based jams, and then honey-based jams. Interestingly, date-based jams had lower moisture content than honey-based jams, and the variations in moisture content over time were non-significant ($p>0.05$) compared to other substrates.

Microbial Qualities of the prepared Tomato Jams

The microbiological analysis of the prepared tomato jams is presented in Tables 4-7. Total aerobic bacterial counts (TBCs) were only detected in sucrose-based jams, with counts increasing non-significantly ($p>0.05$) over time and being highest at the 900g sucrose level (Table 4). Total coliform counts (TCCs) followed a similar trend, except that jams produced with 900g of sucrose had no detectable TCCs (Table 5). No TBCs or TCCs were detected in jams produced from other sweeteners.

The total yeast count (TYCs) analysis revealed yeast presence only in sucrose-based jams at 500g and 700g levels, with counts increasing over time (Table 6). The total mold count (TMCs) analysis showed mold growth patterns varying by sweetener type and amount (Table 7). Molds were detected in sucrose-based jams from the third month (500g) to the fourth month (700g and 900g). In honey-based jams, molds appeared from the fifth month (500g) to the fifth and sixth months (700g and 900g). For date-based jams, molds were only detected at the 500g level in the fifth month, while no molds were detected at 700g and 900g levels.

Characterization of the isolates encountered in the Tomato Jams

The cultural, morphological and biological characteristics of the bacterial isolates are presented in Table 8. The isolates exhibited similar characteristics but differed in their colors in nutrient Agar, position of their spores and their reaction to dulcitol. The macroscopic and microscopic characteristics of the fungal isolates (C_1 and C_2) revealed that isolate C_1 was mold whereas isolate C_2 was yeast. The ratio of absorbances of the nucleic acids extracted from the isolates at 260nm were within 1.8 – 1.9, indicating those nucleic acids were DNA (Table 10) The molecular characteristics of the isolates in table eleven revealed that isolates B, B_2 , C_1 and C_2 were *Bacillus subtilis* strain DKU-09 (BSD), *Bacillus coagulans* strain 2-6 (BC2), *Aspergillus niger* strain HG-48 (ANH) and

Wickarharmomyces anomalus strain NRRL-Y-366 (WAN) respectively, as shown in Table 11.

Pathogenic Potential of the Isolates

The microbiological analysis of the prepared tomato jams revealed two fungal isolates. Further characterization of these isolates on blood agar plates showed γ -hemolysis, indicating

no clear zones or hemolysis. Additionally, the isolates exhibited pink and smooth colonies on Congo red agar. These reactions suggest that the isolates are non-pathogenic and lack virulence factors (Table 12). The absence of hemolysis and specific colony morphology on Congo red agar supports the conclusion that the isolates are unlikely to cause disease.

Table 1: Characteristics of the prepared tomato jams

Characteristics	Sucrose	Honey	Dates
Colour	Red	Brown	Peach
Odour	Satisfactory	Satisfactory	Satisfactory
Taste	Sweet	Floral/fruity	Sweet
Texture	Slightly smooth	Smooth	Smooth
Surface	Slightly smooth	Smooth	Smooth
Consistency	Semi-solid	Semi-solid	Semi – solid

Table 2: pH of the prepared jams

Month	Sucrose			Honey			Dates		
	500g	700g	900g	500g	700g	900g	500g	700g	900g
1	2.80±0.10	2.60±0.00	2.40±0.00	3.30±0.00	3.10±0.00	3.00±0.00	3.60±0.00	3.50±0.00	3.30±0.00
2	2.90±0.00	2.60±0.00	2.40±0.00	3.40±0.00	3.20±0.00	3.10±0.00	3.60±0.00	3.50±0.00	3.40±0.00
3	2.90±0.00	2.70±0.00	2.50±0.00	3.60±0.00	3.30±0.00	3.10±0.00	3.60±0.00	3.50±0.00	3.40±0.00
4	3.00±0.00	2.90±0.00	2.60±0.00	3.60±0.00	3.40±0.00	3.20±0.00	3.60±0.00	3.50±0.00	3.40±0.00
5	3.10±0.00	2.90±0.00	2.60±0.00	3.70±0.00	3.40±0.00	3.20±0.00	3.70±0.00	3.50±0.00	3.50±0.00
6	3.20±0.00	3.00±0.00	2.80±0.00	3.90±0.00	3.60±0.00	3.30±0.00	3.70±0.00	3.50±0.00	3.50±0.00

Table 3: Moisture content of the prepared jams

Month	Sucrose			Honey			Dates		
	500g	700g	900g	500g	700g	900g	500g	700g	900g
1	20.18±0.07	18.23±0.07	14.23±0.01	22.18±0.03	20.18±0.04	19.62±0.03	21.03±0.03	20.62±0.07	20.01±0.11
2	21.43±0.03	18.76±0.11	14.58±0.12	23.62±0.07	20.92±0.02	19.93±0.07	21.63±0.03	20.73±0.11	20.22±0.07
3	21.76±0.01	19.11±0.03	15.33±0.03	23.92±0.12	21.44±0.11	20.36±0.11	22.07±0.11	20.78±0.17	20.31±0.03
4	22.66±0.04	19.67±0.33	16.47±0.07	24.52±0.11	21.87±0.12	20.78±0.07	22.61±0.07	20.82±0.03	20.46±0.07
5	23.04±0.01	19.86±0.07	16.82±0.03	24.82±0.07	22.66±0.11	21.41±0.07	22.93±0.07	20.89±0.07	20.67±0.07
6	23.48±0.03	20.07±0.07	17.02±0.04	25.96±0.11	23.42±0.07	21.94±0.11	23.56±0.13	20.96±0.11	20.72±0.03

Table 4: Total aerobic bacterial counts

Month	Sucrose (LogCFU/g)			Honey (LogCFU/g)			Dates (LogCFU/g)		
	500g	700g	900g	500g	700g	900g	500g	700g	900g
1	2.46±0.01	2.26±0.01	2.15±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2	2.56±0.01	2.46±0.01	2.28±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3	2.67±0.01	2.53±0.01	2.32±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	2.76±0.01	2.57±0.01	2.43±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5	2.79±0.01	2.62±0.01	2.49±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6	2.83±0.01	2.72±0.01	2.56±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 5: Total coliform counts

Month	Sucrose (LogCFU/g)			Honey (LogCFU/g)			Dates (LogCFU/g)		
	500g	700g	900g	500g	700g	900g	500g	700g	900g
1	1.60±0.01	1.00±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2	1.90±0.01	1.70±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3	1.95±0.01	1.78±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	2.15±0.01	1.90±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5	2.28±0.01	1.95±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6	2.45±0.01	2.40±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 6: Total yeast counts

Month	Sucrose (LogCFU/g)			Honey(LogCFU/g)			Dates (LogCFU/g)		
	500g	700g	900g	500g	700g	900g	500g	700g	900g
1	1.00±0.01	1.00±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2	1.95±0.01	1.60±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3	2.46±0.01	1.95±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	2.53±0.01	2.15±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5	2.57±0.01	2.28±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6	2.76±0.01	2.43±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 7: Total mold counts

Month	Sucrose (LogCFU/g)			Honey(LogCFU/g)			Dates (LogCFU/g)		
	500g	700g	900g	500g	700g	900g	500g	700g	900g
1	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3	2.28±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	2.43±0.01	2.15±0.01	1.90±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5	2.46±0.01	2.26±0.01	2.15±0.01	1.95±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6	2.76±0.01	2.43±0.01	2.28±0.01	2.26±0.01	2.04±0.01	1.90±0.00	1.90±0.01	0.00±0.00	0.00±0.00

Table 8: Cultural, morphological and biochemical characteristics of bacterial isolates encountered in the Jam samples

Characteristics	B ₁	B ₂
Color on nutrient Agar	whitish	Cream-white
Elevation	flat	Flat
Edge	irregular	Irregular
Surface	Rough	Rough
Gram reaction	Positive	Positive
Cell morphology	Rods	Rods
Endospore	Present	Present
Position of spore	Central	Terminal
Motility	Positive	Positive
Catalase	Positive	Positive
Citrate	Positive	Positive
Indole	Negative	Negative
Oxidase	Negative	Negative
Water production	Negative	Negative
Glucose	Positive	Positive
Maltose	Positive	Positive
Xylose	Positive	Positive
Dulcitol	Positive/negative	Positive
Sorbitol	Positive/negative	Positive/negative

Table 9: Characteristics of the fungal isolates encountered in the Jam samples

Isolate code	Macroscopic characteristics	Microscopic characteristics
C1	The initial colonies were, white, later changed to dark. It showed fast growth and pale at reverse side. The texture was wooly or cottony	The conidiophore was long and hyaline. The conidia were dark. The phialide covered the entire vesicle.
C2	The colony was butyrous and creamy in colour. Fast growth with yeast morphology. The colony was flat and smooth	The cells were spheroidal and elongated. It exhibited multilateral budding characteristics. There was presence of hat-shaped ascospores.

Table 10: Nature of nucleic acids extracted from the isolates

Isolate/Code	Conc (µg/ml)	ABS 260	ABS 280	260/280
B1	110.20	3.2540	1.7780	1.83
B2	108.40	3.2530	1.7680	1.84
C1	88.10	2.8360	1.5580	1.82
C2	86.60	2.8060	1.5170	1.85

Table 11: Molecular characteristics of the isolates

Isolate code	Max score	Total score	Query cover (%)	E-value	Percent identity (%)	Accession number	Description
B1	1164	1164	100	0.0	100	CP141283.1	<i>Bacillus subtilis</i> strain DKU_09 complete genome (BSDK)
B2	1035	1035	100	0.0	100	CP0024721	<i>Bacillus coagulans</i> strain 2-6 complete genome (BC2)
C1	1029	1029	100	0.0	100	KX099668.1	<i>Aspergillus niger</i> strain HG48 (ANH)
C2	1164	1164	100	0.0	100	NG-062034.1	<i>Wickarharmomyces anomalus</i> strain NRRL-Y-306 (WAN)

Table 12: Pathogenic potentials of the isolates

Isolates	Hemolytic activity	Reaction with Congo red
BSD	γ - Hemolysis	Pink colonies with smooth surface
BC2	γ - Hemolysis	Pink colonies with smooth surface
C1	γ - Hemolysis	Pink colonies
C2	γ - Hemolysis	Pink colonies

Discussion

he properties of tomato jams prepared with sucrose in this study align with previous research by Khashaba *et al.* (2019), Kapira *et al.* (2023), and Machalela *et al.* (2023), who also used sucrose as a glyceic carbohydrate. Our findings on color, texture, and surface appearance are consistent with their reports, but we observed a slight deviation in taste, likely due to differences in sucrose amounts used. Notably, Machalela *et al.* (2023) produced tomato jam with varying proportions of pulp and sugar, which might impact taste profiles. The use of natural honey as a sucrose substitute in our study echoes Kapira *et al.* (2023) research, which also explored honey as an alternative sweetener in tomato jam production. Our study's novel approach lies in utilizing date fruit extract, which yielded distinct properties compared to sucrose-based jams. Regarding pH and moisture content, our sucrose-based jams' results concur with those of Khashaba *et al.* (2018), Kapira *et al.* (2023), and Machalela *et al.* (2023), who reported similar ranges. However, jams prepared with date fruit extracts showed slight deviations, underscoring the unique characteristics of this sweetener. Date fruit extracts have been

explored for their potential benefits in food production, given their nutritional value and preservative properties. Our study's findings on total aerobic bacterial counts (TBCs), total coliform counts (TCCs), total yeast counts (TYCs), and total mold counts (TMCs) being within stipulated limits align with research by Olaitan *et al.* (2015) and Garcia-Ulloa *et al.* (2021). However, they contradict studies by Oviasogie *et al.* (2015), Ganje *et al.* (2016), and Andre *et al.* (2017), which reported counts exceeding limits. High microbial counts often result from poor hygiene and ingredient contamination. Notably, jams made with honey and date fruit extract showed no microbial counts, likely due to their potent inhibitory phytochemicals, particularly in date fruit extract. Aerobic bacterial counts serve as a useful measure of hygienic practices during processing, highlighting the importance of cleanliness in production lines. Microbial loads can vary significantly depending on factors like ingredients, handling, and storage conditions. Ensuring accurate microbiological testing is crucial for product safety and quality. Acceptance criteria for microbiological quality vary by product type, with specific limits for total aerobic microbial counts (TAMC) and total combined yeast and mold counts (TCYM)

Our study found that bacterial and fungal isolates in sucrose-based jams were non-pathogenic, consistent with Anie *et al.* (2022) and Kapira *et al.* (2023). However, our findings contradict those of Koh *et al.* (2012), Oviasogie *et al.* (2015), Ganje *et al.* (2016), and Khashaba *et al.* (2018), who detected spoilage and pathogenic organisms. The presence of such organisms in these studies may be attributed to ingredient sources, working environments, or poor sanitary conditions. The safety of food products depends on factors like ingredient quality, processing, and storage. Ensuring good manufacturing practices and quality control can minimize microbial contamination risks. Our study's results suggest that the jams produced were safe for consumption, with no evidence of pathogenic organisms.

Conclusion

This study has demonstrated that tomato jam produced with low glycemic index carbohydrates, such as date fruit extract, exhibits desirable microbiological and storage qualities. Date fruit extract-based jams showed no microbial growth compared to sucrose-based jams. The findings suggest that using date fruit extract can produce a safer and healthier tomato jam product. This study's results can inform food manufacturers and consumers seeking healthier alternatives to traditional jam products. Date fruit extract is a promising natural sweetener for developing low-glycemic tomato jam with desirable microbial quality.

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