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## Research Article

### Ripe and unripe tomato jams: formulation, acceptability tests, physicochemical and microbiological characteristics

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#### Abstract

Tomato cultivation has been growing rapidly in Burkina Faso in recent years. But its preservation remains a problem. This study was initiated with a view to contributing to tomato preservation and the diversification of tomato products. Four formulas of ripe tomato jam and four green tomato jams were developed after numerous trials. The sensory quality of these jams was determined. The results of the various sensory tests carried out led to the selection of two jams, CTM 2 and CTV 4, with acceptability levels of 46% and 33% respectively; these jams were used as samples for physico-chemical and microbiological analyses. For ripe tomato jam, physicochemical characteristics were as follows: moisture  $34.95 \pm 0.02\%$ , pH  $3.43 \pm 0.01$ , acidity  $1.10 \pm 0.03\%$ , SST  $65.33 \pm 0.38^\circ\text{Brix}$ , total ash  $0.89 \pm 0.11\%$ . The results for green tomato jam were as follows: moisture content  $28.85 \pm 0.05\%$ , pH  $2.88 \pm 0.01$ , acidity  $2.31 \pm 0.01\%$ , Brix  $68.40 \pm 0.10\%$ , total ash  $0.91 \pm 0.02\%$ . Microbiological analyses showed results in line with recommended criteria for fungal flora, total flora, total coliforms and *Staphylococcus aureus*, so the tomato jams produced could be consumed without fear of food poisoning for the germs investigated in this study.

#### Keywords

Tomato, jam, formulation, sensory quality, physicochemical quality, microbiological quality

#### Abbreviations

ANOVA – analyses of variance; CTM – ripe tomato jam; CTV – green tomato jam; DTA – Food Technology Department; INERA – Institute of Environment and Agricultural Research; IRSAT – Research Institute of Applied Sciences and Technologies; PCA – plate count agar; TM – ripe tomato; TV – green tomato; VRBL – neutral red crystal violet bile; UFC – colony-forming unit

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## Introduction

The tomato (*Solanum lycopersicum* L.) is one of the most widely grown and consumed fruit vegetables in the world (Naika et al. 2005). It has many nutritional virtues and is used in the preparation of many dishes, both fresh and processed. Tomatoes are also a main raw material for many agri-food processing industries, which supply consumers with a varied range of processed products, making tomatoes the leading vegetable in terms of production volume, ahead of watermelon and cabbage (FAOSTAT 2017). Global tomato production in 2018 was estimated at around 182 million tonnes, with around 5 million tonnes in West Africa (FAOSTAT 2020).

In Burkina Faso, tomato (*Lycopersicum esculentum* Mill.), is the country's second most important vegetable crop after onion (MAAH 2020). It is produced in many parts of the country and over large areas. Production has been rising steadily since 2004. It was estimated at 10,000 tonnes in 2014 (FAOSTAT 2016) and over 167,400 tonnes in 2018 (MAAH 2020). And it has risen to 300,000 tonnes in 2020 (CILSS 2022). Indeed, the Boucle du Mouhoun region was the largest tomato production area with 36,824 tonnes, or 22% of total production, followed by the Centre-Nord, Haut Bassins, Nord, Centre-Sud and Centre-Ouest regions with varying production (DGESS/MAAH 2020).

However, the perishable nature of vegetables and fruit, particularly tomatoes, means that the availability of this vegetable fruit throughout the year is an equation that producers and consumers are still unable to resolve. In Burkina Faso, during periods of tomato overproduction, significant post-harvest losses are recorded due to its perishability (Parkouda et al. 2017). Productions of tomato by-products have remained intact for many years, consumed in the form of: tomato concentrates, peeled tomatoes, dried tomatoes, tomato pulp. Post-harvest losses could be reduced by introducing and promoting new tomato-based products such as jams, marmalades and jellies, as tomatoes are rarely used as fruit. According to the Codex Alimentarius, jam is a product prepared from whole fruit(s) or pieces, concentrated or unconcentrated pulp and/or purée, of one or more kinds of fruit, mixed with foodstuffs imparting a sweet flavour, with or without the

addition of water, until a suitable consistency is obtained (CXS 296 2009).

Tomato jam is rich in various nutrients, and its energy value can exceed 200 Kcal.100 g<sup>-1</sup> of product, making it a food that can be eaten as a snack, with breakfast and other snacks.

The aim of this study is to add value to the tomato as a fruit, namely tomato jam of the COBRA F1 variety, produced from ripe and unripe tomatoes, in order to help reduce post-harvest losses and introduce Burkinabe consumers to another way of consuming tomatoes.

## Materials and Methods

### Plant material, ingredients and collection site.

Tomatoes of the variety COBRA F1 were produced at the Institute of Environment and Agricultural Research (INERA) Farakoba station, harvested at physiological maturity and transported to the Food Technology Department (DTA) of the Research Institute of Applied Sciences and Technologies (IRSAT) in Ouagadougou. These tomatoes were used as raw materials for jam formulation in the DTA pilot workshop.

### Ingredients.

- powdered sugar
- lemon (juice and zest)
- agar-agar powder
- ginger
- cloves

**Making jams from ripe and green tomatoes.** The jams were formulated in several trials, varying the different ingredients to obtain different tastes and textures. The resulting formulas were subjected to physico-chemical, microbiological and sensory analyses, evaluated by a tasting panel with the aim of collecting criticisms and suggestions for improving the formulations (Table 1 and Table 2).

**Production of tomato jams.** The tomatoes are then carefully washed and blanched by immersing them in hot water. The tomatoes are then carefully washed and blanched by immersing them in a hot water bath (100°C) for 5 min for ripe tomatoes and 10 min for green tomatoes. Next came peeling and seed removal, which consisted in removing the skin and seeds from the blanched tomatoes. The cut pieces were then macerated with sugar for 3 to 4 h

at room temperature before cooking. Cooking was carried out over low heat for 30 min for the ripe tomato jams and 45 min for the green tomato jams, stirring constantly to prevent the jam from sticking to the bottom of the pan. When the Brix degree reaches 63°, the end of cooking is near. Fresh lemon juice is added at the end of cooking to acidify the jam. When the sugar content of the mixture measured on the refractometer reaches 65°Brix, cooking is complete (105°C) for ripe tomato jam. For green tomato jam, cooking ends (107°C) at 68°Brix, due to the slow gelation of the green tomatoes. The jam, still hot, is packaged in sterile glass jars, then labelled and stored at room temperature (Fig.1).

**Sensory analysis.** Sensory analysis is the examination of a product's organoleptic properties using the sense organs. It enables us to study the sensory characteristics of products by using man as a "measuring instrument", using his five senses: smell, taste, sight, hearing and touch. Twenty-four tasters were selected for this sensory evaluation, where the analysis was carried out following the procedure described by [Meilgaard et al. \(2006\)](#). The four samples were coded using a combination of four (04) digits. These codes were chosen using the [ISO 8587 \(2006\)](#) random allocation table. This study was authorized by the health research ethics committee (CERS) under deliberation no. 2024-11-346.

To carry out this analysis of the various recipes prepared, three types of method were used: Sensory profile, hedonic test, ranking test. The three tasting tests were carried out on the same day for the red tomato jam and on another day for the green tomato jam.

**Sensory profile.** For this test, the following attributes are asked of the taster: appearance, color, taste, texture, aroma, sugar, acidity, texture, tomato taste perception, jam taste. The test describes the product according to these attributes. The panel for the sensory profile test is made up of a total of 26 tasters for ripe tomato jams and 24 tasters for unripe tomato jams, trained and authorized to do so. Eight jams, four red tomato-based and four green tomato-based, were presented to the taster in this test.

**Hedonic test.** During the hedonic evaluation process, all panellists used a questionnaire to measure degrees of how much they liked. Tasters

tasted each sample of tomato jam and gave a number between 1 and 5: each attribute is measured on a point acceptability scale, 1: I don't like at all and 5: I like a lot. Panellists were given water between each sample. During the evaluation process, volunteers were free to comment on each tomato jam sample, and comments were recorded at the bottom of the questionnaire.

**Ranking test.** As its name suggests, the aim of the ranking test is to determine a preference ranking between the products tasted. In the ranking test, the subject is presented with a set of products and asked to rank them according to his or her assessment.

**Physicochemical analysis.** Determination of water content: The water content of the samples was determined by weighing, before and after oven drying at a temperature of  $105 \pm 2^\circ\text{C}$  for 12 h in accordance with the Standard [ISO 712 \(2024\)](#).

**Determination of pH and titratable acidity.** For pH determination, 5 g of the sample was taken and added to 30 mL of distilled water. After homogenization, the pH of the suspension was measured using a pH meter ([AOAC 2005](#)). Titratable acidity was determined by titration with phenolphthalein, in accordance with norm [ISO 750 \(1998\)](#). The suspension used for pH measurement was then centrifuged at 5000g for 5 min. 20 mL of the supernatant was collected and titrated with 0.1N NaOH in the presence of phenolphthalein as a color indicator. Titratable acidity was expressed as a percentage of citric acid.

**Determination of soluble dry matter or Brix degree.** The Brix level of samples is determined in accordance using an ATAGO refractometer. The reading is taken by placing a drop of jam on the instrument's hinge plate, facing the light. The Brix value is read through the instrument's eye.

**Determination of ash content.** Ash is the incombustible residue obtained after incineration in accordance with international standard [ISO 2171 \(2023\)](#). To determine ash content, 5 g of the sample was taken from a porcelain crucible and placed in an oven at 550°C for 5 h.

**Microbiological analysis.** The preparation of the samples, the mother suspension and the decimal dilutions was carried out in accordance with the international standard [ISO 6887-1 \(2017\)](#).

**Total aerobic mesophilic flora count.** Mesophilic aerobic flora was counted according to the international standard [ISO 4833-2 \(2013\)](#). Plates were inoculated onto Plate Count Agar (PCA) and incubated in an oven at 30°C for 72 h ± 3 h.

**Total coliform count.** Coliforms were enumerated according to the international standard [ISO 4832 \(2006\)](#). Inoculation was carried out in neutral red crystal violet bile agar (VRBL agar) and plates were incubated at 37°C in an oven for 24 h ± 2 h. Characteristic colonies were counted after the incubation period.

**Yeast and mold counts** [ISO 21527 \(2008\)](#) was used for yeast and mold enumeration. Inoculation was carried out on SABOURAUD chloramphenicol agar. Plates were incubated at 25°C in an oven for 5 to 7 days, and colonies were counted.

**Staphylococcus aureus count.** International standard [ISO 6888-1 \(2021\)](#) was used for *Staphylococcus aureus* enumeration. Inoculation was carried out on mannitol agar. Plates were incubated at 37°C for 24 to 48 h and colonies were counted.

**Statistical analysis.** The results of the analyses were entered into Excel 2016 for description. One-way analyses of variance (ANOVA) were performed using XLSTAT (2016). The various analyses carried out during the course of the work are performed in a minimum of two trials to obtain a standard deviation between the results. For the sensory profile, the hedonic test and the ranking test, data processing was carried out using SPSS version 20 software.

## Results and Discussion

**Sensory profile of ripe and green tomato jams.** The sensory profile (Fig. 2) included descriptions of appearance, color, aroma, acidity, sugar, texture, tomato taste perception and taste of jam.

The four formulations had different appearances. The CTM 2 jam was judged very beautiful, while the CTM 1, CTM 3 and CTM 4 jams were characterized as beautiful by the tasters.

As for color, most tasters found the four formulations to be of different hues. The CTM 2 formulation was judged very light red, CTM 3 was characterized light red, while CTM 1 and CTM 4 were judged dark red. As for aroma, the tasters

found the scents to be good in all the ripe tomato jam formulations.

The acidic taste was perceived differently by the tasters: while some found the CTM 2, CTM 3 and CTM 4 formulations quite acidic, others judged the CTM 1 formulation to be acidic.

As for sugar, tasters judged the CTM 1 and CTM 2 jam formulations to be very sweet. Formulations CTM 3 and CTM 4 were judged to be sweet jams.

The texture of CTM 3 and CTM 4 was described as very thick. However, CTM 1 and CTM 2 were judged to be fairly thick by tasters.

In terms of tomato taste perception, tasters found the tomato taste to be fairly pronounced in the CTM 2, CTM 3 and CTM 4 formulations, and very pronounced in the CTM 1 formulation of ripe tomato jams.

As for the taste of the jam, the tasters found all the ripe tomato jam formulations pleasant.

Following sensory analysis, the CTM 2 jam was selected for physicochemical and microbiological analysis.

**Hedonic test of ripe tomato jam.** The results (Fig. 3) of the hedonic test show that all the formulations presented were liked by the tasters. Of the four formulations presented, CTM 2 was the most popular, followed by CTM 1 and CTM 4.

**Grading test for ripe tomato jam.** CTM 2 came out on top in the ranking test, followed by CTM 4. CTM 3 and CTM 1 came third and fourth respectively (Fig. 4).

**Sensory tests of unripe tomato jams.** The sensory profile (Fig. 5) included descriptions of appearance, color, aroma, acidity, sugar, texture, tomato taste perception and jam taste.

For appearance, all four formulations of green tomato-based jams were characterized as beautiful by the tasters.

As for color, most tasters found the four formulations to be of different hues. Formulations CTV 1 and CTV 3 were judged to be dark green, CTV 2 was characterized as very light green, while formulation CTV 4 was judged to be light green.

In terms of aroma, tasters found that scents were good in all green tomato jam formulations. Some tasters rated the CTV 1, CTV 2 and CTV 4 formulations as fairly acidic, while others rated the CTV 3 formulation as fairly acidic.

As for sugar, tasters judged CTV 1 and CTV 3 jams to be sweet, and CTV 2 fairly sweet. CTV 4 was judged to be very sweet.

In terms of texture, CTV 2 and CTV 4 were rated as fairly thick jams. However, formulation CTV 1 was judged not thick and CTV 3 thick by the tasters.

In terms of tomato taste perception, tasters found the tomato taste to be fairly pronounced in CTV 1, CTV 2 and very pronounced in CTV 4 green tomato jams. However, CTV 3 was selected as a jam with a fairly pronounced tomato taste.

As for the taste of the jam, the tasters found all the green tomato jam formulations pleasant.

Following sensory analysis, CTV 4 was selected for physicochemical and microbiological analysis of green tomato jam.

**Hedonic test for unripe tomato jams.** The results (Fig. 6) of the hedonic test show that all the formulations presented were liked by the tasters. Of the four formulations presented, CTV 4 was the most popular, followed by CTV 2 and CTV 3/1.

**Grading test of unripe tomato jams.** CTV 4 came out on top in the ranking test, followed by CTV 2, while CTV 3 and CTV 1 ranked third and fourth respectively (Fig. 7).

**Physicochemical characteristics of tomatoes and tomato-based jams.**

Physicochemical parameters were significantly different (Table 3). Ripe tomatoes had the highest moisture content  $96.14 \pm 0.05$  followed by green tomato  $95.21 \pm 0.12$ , ripe tomato jam  $34.95 \pm 0.02$  and green tomato jam  $28.85 \pm 0.05$ .

The pH of tomatoes and jams was  $4.05 \pm 0.01$ ;  $4.02 \pm 0.01$ ;  $3.43 \pm 0.01$  and  $2.88 \pm 0.01$  for ripe tomatoes, green tomatoes, ripe tomato jam and green tomato jam respectively. Titratable acidity levels were  $0.42 \pm 0.01$  and  $0.45 \pm 0.01$  respectively for ripe and green tomatoes, and  $1.10 \pm 0.03$  and  $2.31 \pm 0.01$  respectively for ripe and green tomato jams. In terms of Brix in descending order, green tomato jam was  $68.40$  °B; ripe tomato jam was  $65.33$  °B. As for ash, the results showed no significant difference between the samples analyzed.

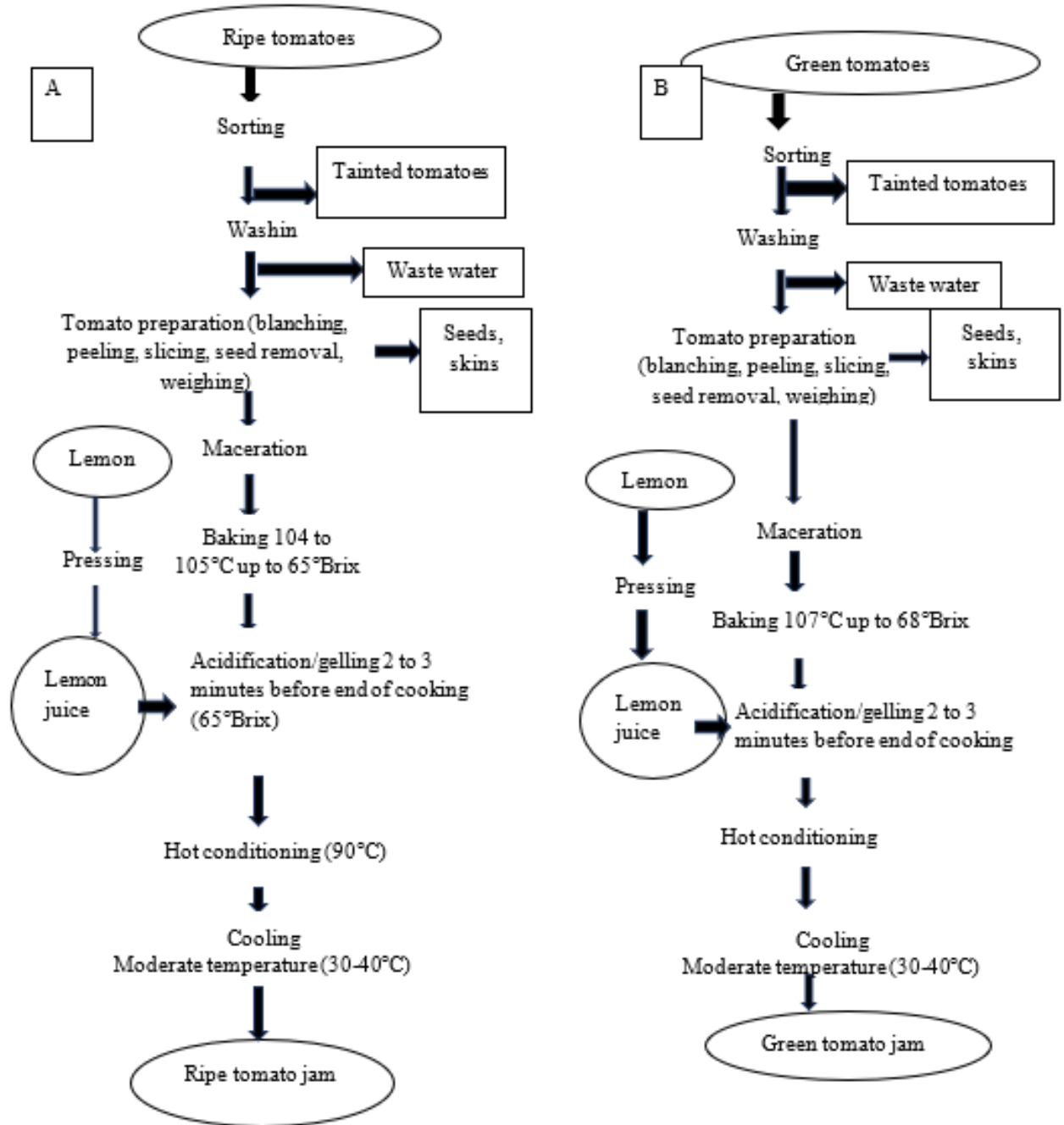
**Microbiological quality of tomato jams.** The results of the tomato jam microorganism enumeration concerned total flora, yeasts and molds, total coliforms and Staphylococcus aureus. The germs tested were all below those set by the Official Journal of the Algerian Republic (JORA 2017) (Table 4).

**Table 1.** Formulations of ripe tomato jam

Formulations Ingredients	Jam 1 (CTM 1)	Jam 2 (CTM 2)	Jam 3 (CTM 3)	Jam 4 (CTM 4)
Ripe tomato pulp (red)	850 g	850 g	850 g	850 g
White sugar	425 g		425 g	425 g
Brown sugar		425 g		
Lemon juice	90 mL	90 mL	90 mL	90 mL
Lemon zest	4 g	4 g		
Agar-agar powder			3.4 g	

**Table 2.** Formulations of green tomato jam

Jam recipes Ingredients	Jam 1 (CTV 1)	Jam 2 (CTV 2)	Jam 3 (CTV 3)	Jam 4 (CTV 4)
Unripe tomato pulp (green)	850 g	850 g	850 g	850 g
White sugar	425 g	425 g	425 g	425g
Lemon juice	105 mL	105 mL	105 mL	105 mL
Lemon zest	5 g	4 g		
Agar-agar powder		3.4 g	3.4 g	
Ginger juice			120 mL	
Clove powder			0.2 g	



**Figure 1.** Diagram of jam production from ripe tomatoes A and green tomatoes

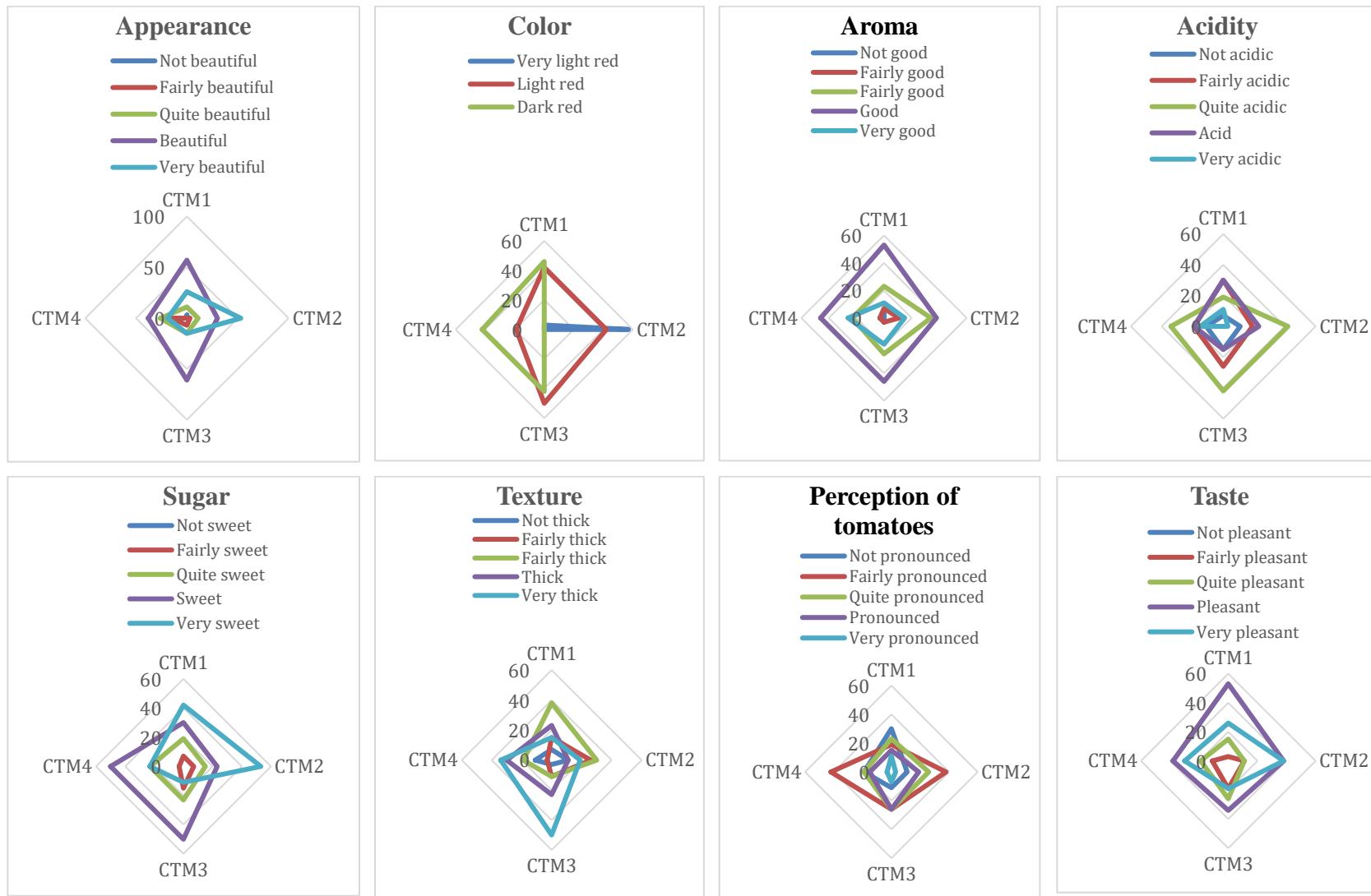
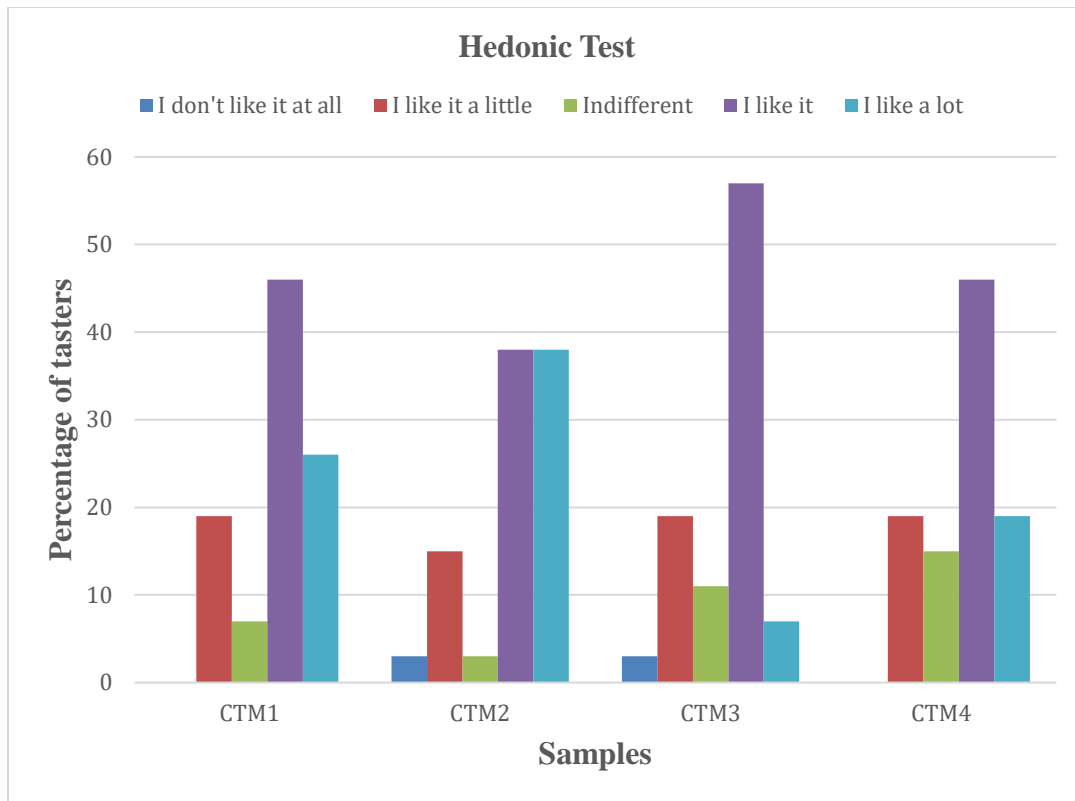
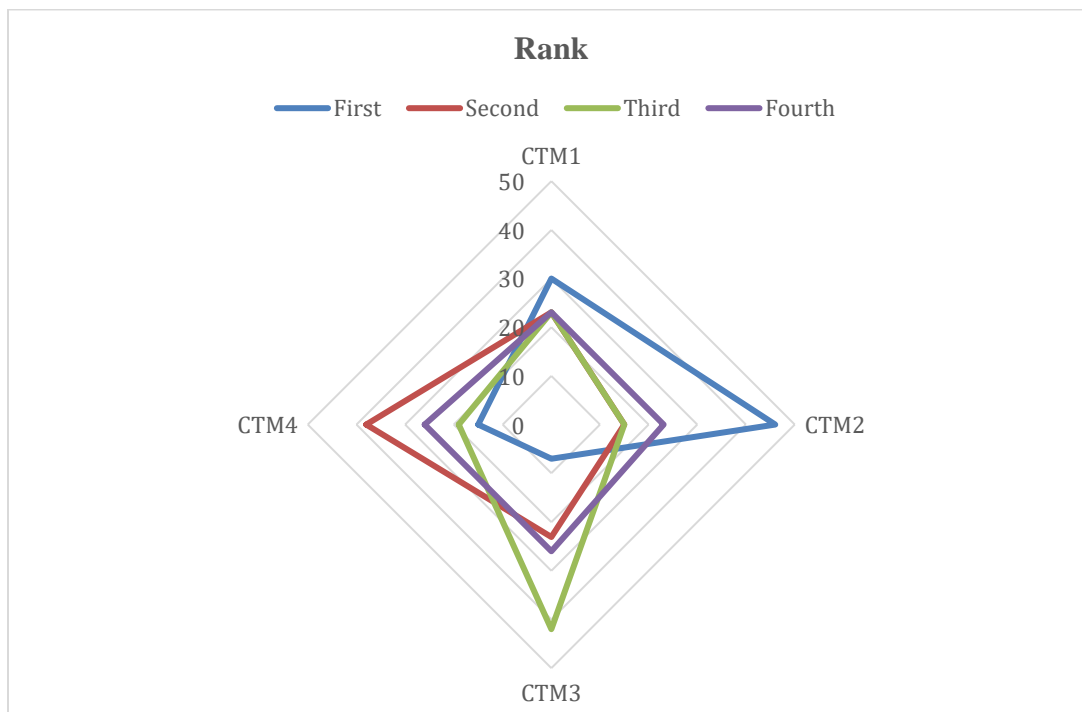


Figure 2. Sensory profile of ripe tomato jams



**Figure 3.** Hedonic test for ripe tomato jam



**Figure 4.** Grading test for ripe tomato jam

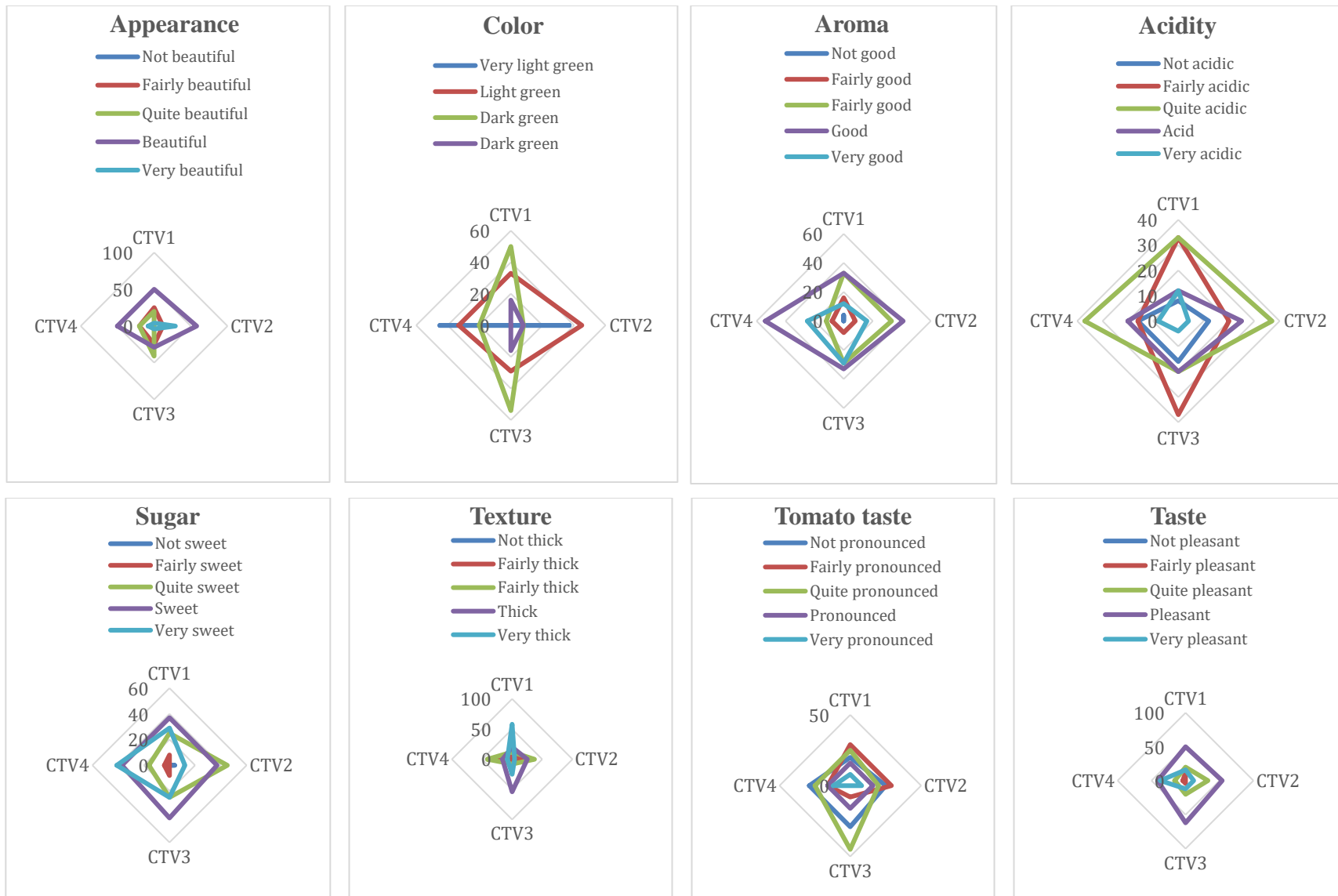
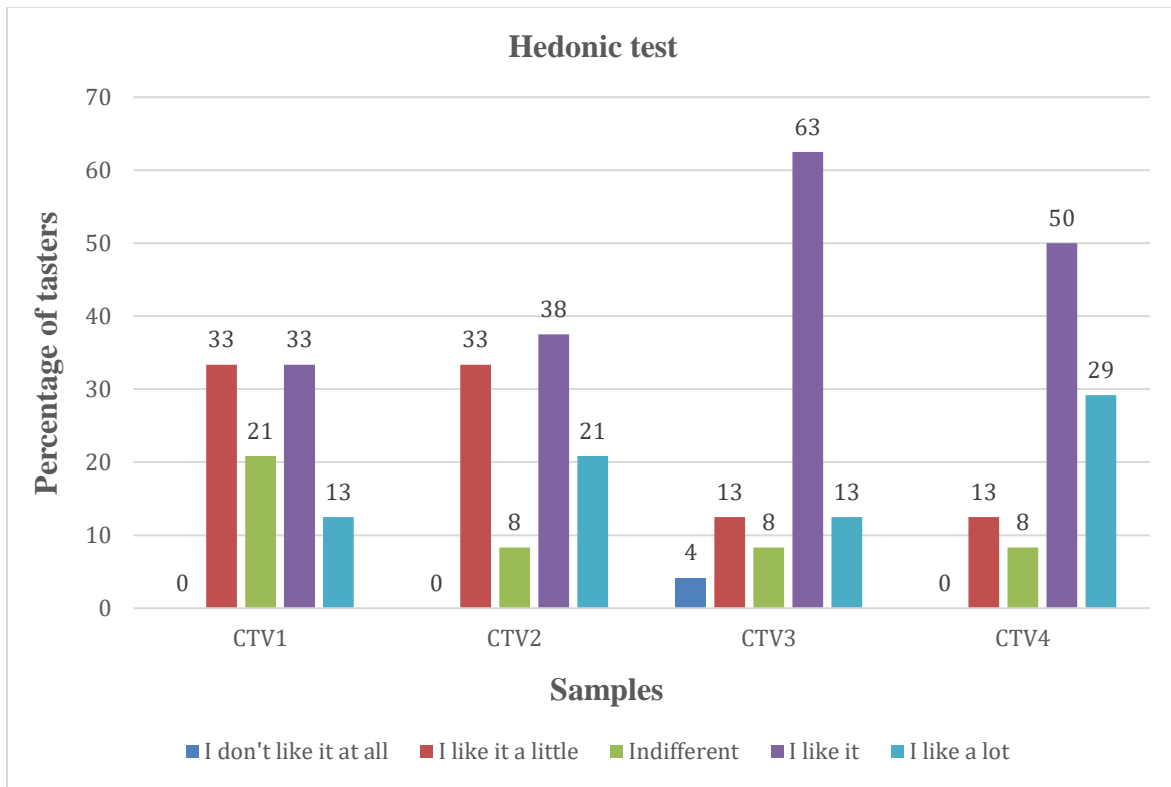
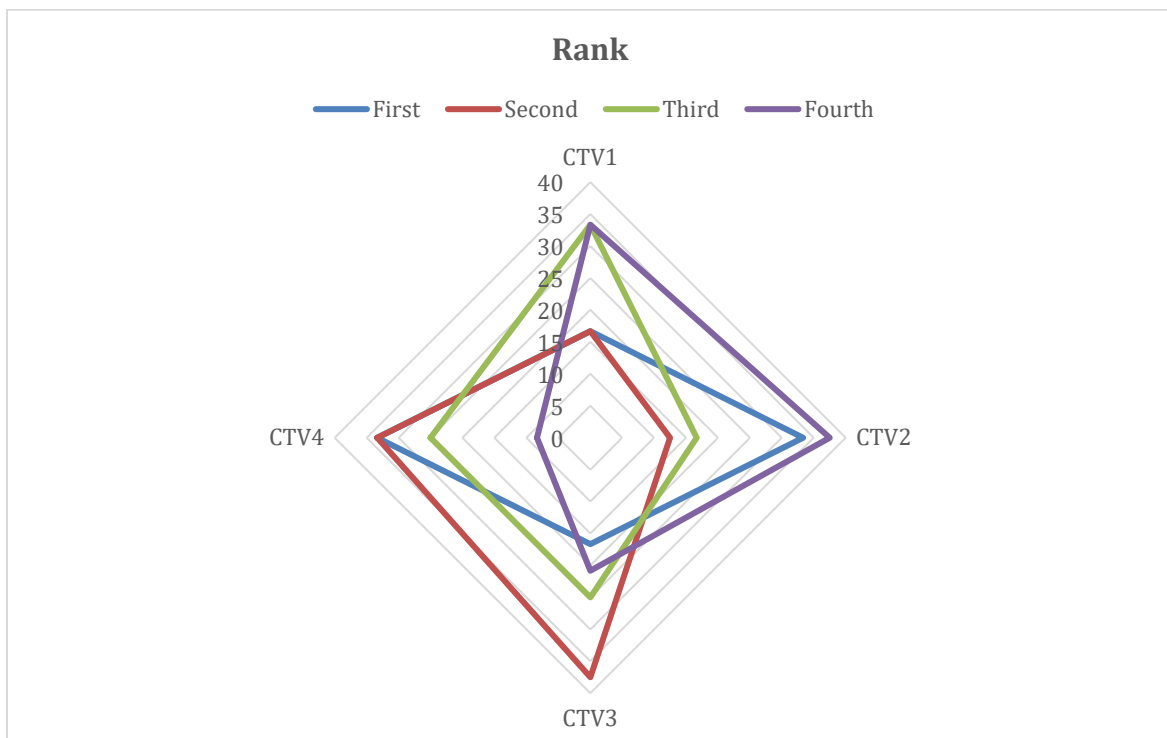


Figure 5. Sensory profile of unripe tomato jams



**Figure 6.** Hedonic test of unripe tomato jams



**Figure 7.** Grading test of green tomato jams

**Table 3.** Results for physicochemical parameters

Parameters Codes Samples	Moisture, %	pH	Titratable acidity, %	Brix, Bx	Ash, %
TM	96.14±0.05 <sup>d</sup>	4.05±0.01 <sup>d</sup>	0.42±0.01 <sup>a</sup>	5.60±0.1 <sup>b</sup>	0.69±0.22 <sup>a</sup>
CTM 2	34.95±0.02 <sup>b</sup>	3.43±0.01 <sup>b</sup>	1.10±0.03 <sup>c</sup>	65.33±0.38 <sup>c</sup>	0.89±0.11 <sup>a</sup>
TV	95.21±0.12 <sup>c</sup>	4.02±0.01 <sup>c</sup>	0.45±0.01 <sup>a</sup>	4.63±0.15 <sup>a</sup>	0.75±0.24 <sup>a</sup>
CTV4	28.85±0.05 <sup>a</sup>	2.88±0.01 <sup>a</sup>	2.31±0.01 <sup>b</sup>	68.40±0.1 <sup>d</sup>	0.91±0.02 <sup>a</sup>
p-value	< 0,0001	< 0,0001	< 0,0001	< 0,0001	0,3719
Significativity	***	***	***	***	

Abbreviations: TM – ripe tomato; CTM 2 – ripe tomato jam; TV – green tomato; CTV 4 – green tomato jam, : no difference, \*: significant, \*\*: very significant, \*\*\*: highly significant, Values are presented as mean ± standard deviation. Values with different superscript letters are significantly different (p < 0.05).

**Table 4.** Microbiological quality results

Codes of samples	Total flora, UFC.g <sup>-1</sup>	Yeasts and molds, UFC.g <sup>-1</sup>	Total coliforms, UFC.g <sup>-1</sup>	<i>Staphylococcus aureus</i> , UFC.g <sup>-1</sup>
	1.2.10 <sup>2</sup>	NE = less than 10	NE = less than 10	NE = less than 10
CTV 4	3.6.10 <sup>3</sup>	7.3.10 <sup>1</sup>	NE = less than 10	NE = less than 10
STANDARD	10 <sup>5</sup> (JORA, 2017)	10 <sup>2</sup> (JORA, 2017)	10 <sup>2</sup> (JORA, 2017)	

### Discussion

The relationship between water content and equilibrium relative humidity is an essential factor in transformation processes. Water can be a useful element in the formulation of products such as jam. The results (Table 3) show that the average water content of the various samples analyzed ranged from 96.14 ± 0.05% to 95.21 ± 0.12% for ripe (red) and unripe (green) tomato raw materials, and from 34.95 ± 0.02% to 28.85 ± 0.05% for ripe (CTM 2) and green (CTV 4) tomato jams respectively. The results for the raw material samples are very similar to those found by Oboulbiga et al. (2020), with an average moisture content of 95.09 to 96.17%. It can be seen that the moisture contents of both types of

jam comply with the standards (CXS 296 2009; NBF 2009), which require a moisture content of less than 40% (Brat and Cub 2007; Degmara et al. 2019). Similarly, jam moisture is reported to vary between 30% and 40% (Fredot 2005); the results for green tomato-based jam also concur with the value quoted by Parkouda et al. (2015), which is 28.92% for goïne liana jam.

pH is a parameter that determines the shelf life of foods. The pH of raw material samples ranged from 4.05 ± 0.01 to 4.02 ± 0.01 for red and green tomatoes respectively. Studies have shown that a pH of between 3 and 6 is highly favourable to the development of yeasts and molds. In addition, it constitutes one of the main obstacles that microbial flora must overcome to ensure their proliferation

(Kamal et al. 2015). The addition of lemon juice during jam preparation was a necessity and resulted in average pH values of jam samples ranging between  $3.43 \pm 0.01$  and  $2.88 \pm 0.01$  for ripe (CTM 2) and green (CTV 4) tomato jam, respectively. This acidity guarantees protection against pathogenic bacteria and most microorganisms. The results obtained are in line with standards, which require pH values of between 2.8 and 3.5 or more for jams (CXS 296 2009). The results are close to values of 3.69 for apricot and orange jam and 3.29 for strawberry jam (Degmara et al. 2019; Grigelmo-Miguel and Martin-Belloso 1999).

The acidity value of jams (CTM 2 and CTV 4) found in this study is  $1.10 \pm 0.03\%$  and  $2.31 \pm 0.01\%$  respectively. These values are higher than those found by Sindumathi and Amutha (2014) with an acidity value of 0.53% for coconut jam, and by Aslanova et al. (2010) with a value of 0.44% for apricot jam. These high values could be explained by the low pectin content of the raw material (tomatoes), which means that lemon juice was added in sufficient quantities to enable the jams to gel properly.

Brix level measures the weight in grams of soluble dry matter (the sugar content of fruit) contained in 100 g of product. In jam making, it is important to know the Brix level during the process (Dongare et al. 2014). For all the jams studied, soluble dry matter contents ranged from 65 to 68 °Brix. The values recorded for CTM 2 and CTV 4 jams are  $65.33 \pm 0.38$  °Brix and  $68.40 \pm 0.10$ °Brix, respectively. These results are lower than those obtained by (Aslanova et al. 2010), who recorded values of 72.7° Brix for strawberry jam and 75.1° Brix for quince jam. However, the results are very close to those reported by Touati et al. (2014) who found a value of 64.42 °Brix for apricot jam and those given by Chauhan et al. (2013) for coconut jam with a value of 68.6 ° Brix and by Inam et al. (2012) with a value of 67.12 ° Brix for a jam based on mango, pineapple and orange. Goyary et al. (2024) found in a journal article a TSS of  $19.52 \pm 0.17$  in wood apple jam. The results obtained for ripe tomato jam (CTM 2) are similar to those obtained by Chauhan et al. (2013) on coconut jam which is 68.6 °Brix and to those found by Vidhya and Narain (2011) which is 68.5 °Brix for apple jam. The results (CTM 2 and CTV 4 jams) obtained are in line with CXS 296 (2009) standards, which

require Brix values of between 60 and 65 °Brix and above for jams.

The ash content represents the total quantity of mineral salts present in the sample. The ash content is around  $0.89 \pm 0.11\%$  for ripe tomato jam (CTM 2) and  $0.91 \pm 0.02\%$  for green tomato jam (CTV 4). These high ash values can be explained by the high ash values of  $0.69 \pm 0.22\%$  and  $0.75 \pm 0.2\%$  of the red and green tomato raw materials, respectively. The average amount of ash noted in CTM 2 and CTV 4 jams is higher than the values reported by Degmara et al. (2019) who found values of 0, 2 and 0.4% for strawberry jams. This could be explained by the high mineral content of the jams. The ash content of the jams agrees with those reported by Parkouda et al. (2015) who found values of 0.32% and 1.93% for goine liana jams.

The enumeration results showed the presence of total aerobic mesophilic flora (FAMT) particularly in the CTM 2 and CTV 4 jam samples with a colony-forming unit (UFC) count of  $1.2.102 \text{ UFC.g}^{-1}$  and  $3.6.103 \text{ UFC.g}^{-1}$ , respectively. The results of these samples are below the limit set by the standard JORA (2017), which requires a maximum limit of 105 UFC per gram for FAMT. The results of the microbiological analyses of the CTM 2 jam samples are lower than the value found by Tapsoba (2011), which observed a presence of  $6.5.102 \text{ UFC.g}^{-1}$  for baobab jams.

However, the enumeration result for the CTV 4 jam samples is higher than the value found by the same author Tapsoba (2011) who observed a presence of  $2.0.103 \text{ UFC.g}^{-1}$  for baobab jams. Nevertheless, yeasts and molds were present in CTV 4 jam, at  $7.3.101 \text{ UFC.g}^{-1}$ , and absent in CTM 2 jam, indicating the latter's good hygienic quality. The contamination of CTV 4 jam by fungal flora is due to the fact that mold spores can be transported by the environment and thus end up in the atmosphere and then in the jam during packaging.

In addition, there was a total absence of total coliforms in both jam samples, indicating good microbiological jam quality. These values are expressed as less than  $10 \text{ UFC.g}^{-1}$  of sample and are lower than that set by standards JORA (2017), which are limited to  $102 \text{ UFC.g}^{-1}$ . The same applies to *Staphylococcus aureus*. Results were expressed at less than  $10 \text{ UFC.g}^{-1}$ . The results obtained by Amiar and Lechani (2018), also indicated that total *Staphylococcus* and coliform germs were totally

absent in the samples analyzed. These results can be explained by the use of quality raw materials, the heat treatment carried out and compliance with good production practices. In addition, the low levels of microorganisms found for AFMT and total coliforms could be eliminated by pasteurization of the jams, giving them good sanitary quality and long-term shelf-life.

Determining the total aerobic mesophilic flora, which is a hygiene indicator, gives an idea of the hygienic conditions during manufacture, as well as the wholesomeness of jams. Yeasts and molds are the most frequent cause of spoilage of fruit, vegetables and jams, and their determination in jams gives an idea of the quality of the raw material used, as well as the preservation of the product. Total coliforms and *Staphylococcus aureus* are pathogenic bacteria. They are used as an indicator of the microbiological quality of foodstuffs. Their determination therefore gives an idea of the sanitary quality of tomato jams.

## Conclusions

This study enabled us to set up the manufacturing process for tomato jams using the COBRA F1 variety, and to obtain general formulas based on nutritional characteristics and acceptability. Analyses revealed that tomato-based jams have a fairly interesting nutritional composition. From a sensory point of view, all the tasters liked all the jam formulations. However, some texture problems were noted. Microbiological analyses showed satisfactory results, in line with recommended criteria.

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## Author Contributions

Conceptualization, C.P. and T.M.A.E.; methodology, M.A.E.T., P.M.J.S.K., K.T. and

E.B.O.; formal analysis A.L., P.R.B. and M.S.; investigation, C.P. and C.O.T.; resources, C.P. and A.T.; data curation, A.L., M.A.E.T. and E.K.; writing - original draft preparation, P.M.J.S.K., E.B.O., K.T. and M.A.E.T.; writing – E.K., M.A.E.T., A.L. and M.S., review and editing, P.R.B., and C.P., visualization, CP. and M.S.; supervision, C.O.T. and A.T.; project administration, C.P. and M.A.E.T.; funding acquisition, C.P. All authors have read and agreed to the published version of the manuscript.

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## Institutional Review Board Statement

This study was authorized by the health research ethics committee (CERS) under deliberation no. 2024-11-346.

## Informed Consent Statement

Not applicable.

## Data Availability Statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

## Conflicts of Interest

The authors declare no conflicts of interest.

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