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Quality of Tomatoes Produced in the Irrigated Area of Chókwè

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Abstract

The tomato plant is considered a creeping vegetable, with a flexible stem and determinate or indeterminate growth, which can be cultivated in any region and is very complex from an agronomic point of view. Its fresh fruit has a low caloric value, low dry matter content and is rich in calcium and vitamin C. It is recommended for people who need an easily digestible food or who wish to follow a hypocaloric diet. The aim of this study was to evaluate the quality of tomatoes produced in the irrigated area of Chókwè, Gaza Province. 100 samples from smallholders and 100 from the commercial sector were characterised for pH by potentiometry, soluble solids content by refractometry, fat content by Soxhlet extraction method, ash by incineration method, moisture by desiccation loss method, protein by biuret method, lycopene by spectrophotometry, total titratable acidity by titration and vitamin C by spectrophotometry. The data were analysed using R 4.1.2 statistical software. The results showed values from 1.30 to 11.15 μg/100g for lycopene, 2.6 to 8.78mg for protein, 0.23 to 1.95% for ash, 91.19 to 95.16% for moisture, 2.88 to 14.91% for total titratable acidity, 0.26 to 3.44% for fat, 3.64 to 4.65 for pH and 79.89 to 85.15mg/100g for vitamin **C.**The study showed that the tomatoes produced by the smallholders were of better quality than those produced by the commercial sector.

Keywords: Commercial and smallholder production; food quality.

1. Introduction

Tomato is considered a vegetable with a creeping development, flexible stem and determinate or indeterminate growth habit, which can be grown in any region, is highly complex from an agronomic point of view and presents growth varieties [1].

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The composition of tomato fruit varies depending on the cultivation, environmental conditions during the production period and plant nutrition. Fresh fruits are low in calories, low in dry matter and rich in calcium and vitamin C, and are therefore recommended for people who need an easily digestible food or who want to follow a hypocaloric diet [2].

In Mozambique, the practice of consuming tomatoes was introduced by the Portuguese, and it is currently verified that tomatoes are one of the most used and consumed vegetables in Mozambican cuisine [1].

The district of Chókwé is essentially agricultural and is considered the barn of Mozambique due to its high productivity of cereals and vegetables, mainly tomatoes.The smallholders occupy prominent areas along the irrigation system and their harvests are intended for self-consumption, in nature and to guarantee subsistence [3].

Covering about 30,000 ha, the Chokwe irrigation system is of socio-economic importance, contributing to food security, employing 80% of the active population in productive activities and increasing farmers' incomes. It also serves as a water reserve in times of drought for agriculture, livestock watering and other activities. In irrigated areas, different food crops are grown in different production systems, with the emphasis on cereals and vegetables (rice, maize, beans, tomatoes and cabbage) [4].

In Chokwe district, especially in the irrigated areas, tomatoes are grown both by smallholders and in the private sector, as an important source of income for farmers [5]. According to [6], in Mozambique, the best tomato yields are obtained in the cool season (May to August), when fruit formation does not coincide with high temperatures (above 28°C) and with a higher incidence of pests and diseases.

According to [6], the degradation of the soil caused by the production system used in the Chókwe region and the lack of information on the quality of the food produced are the current discussion, challenges and reflections. The main issue today is to produce food in an ecological and sustainable system, maintaining food diversification, preserving biodiversity, food security and increasing productivity and production without damaging the environment. The aim of this study was to evaluate the quality of tomatoes produced in the irrigated area of Chókwè.

2. Materials and Methods

2.1. Study area

The study was conducted in the laboratory of the Higher Polytechnic Institute of Gaza, please indicate the institute coordinates in Chókwè district (Figure 1). According to [7], this district is located in the south of Gaza Province, in the middle course of the Limpopo River, with the districts of Massingir, Mabalane and Guija as the northern limit of the Limpopo River; in the south with Bilene district and Mazimuchope River, which separates it from Magude district, in the east it borders with Bilene and Chibuto districts, and in the west with Magude and Massingir districts.

The district has, [7], an area of 2450 km², with a population of 197 thousand inhabitants, and the relief is a plain with less than 100 m of altitude and soils are alluvial along the Limpopo River, which crosses the entire district and consists of undifferentiated deposits in the rest of the district (administrative post of Macarretane and Lionde). There are also terraces in the extreme south-east of the district (Chilembene), near Bilene and Macarretane, and red clays in the Matuba area.

According to [7], agriculture is one of the most widely practised economic activities in Chókwè district and offers excellent conditions for its practice. It has an irrigated area of about 30,000 ha and employs 80% of the active population, where the intercropping system, based on local varieties and the use of animal traction and tractors, can be seen in smallholdings with a total area of 10,000 ha. The main crops are maize, rice, cowpeas, cassava, sweet potatoes, butter beans and vegetables, especially tomatoes and cabbage. Livestock is also raised. The hydrography is composed of great potential, being bathed on the right bank by the Limpopo River and the Mazimuchope River, also having the periodic streams of Ngonwane, Munhuane, Chiezi, Nhambabwe and the lakes of Chinangue,gondzo, Nha-nhai, Mbalambe and Khokhotiva.

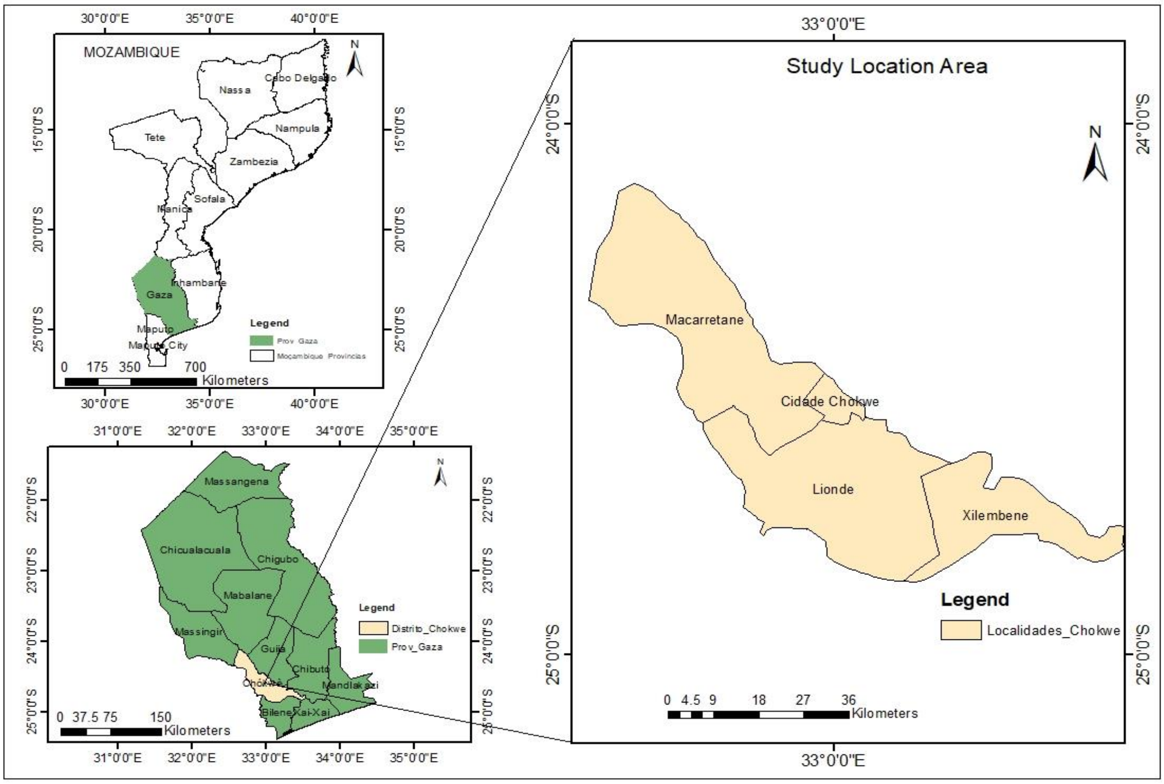

Figure 1: Location of Chókwè district and data collection points.

3.2. Sample collection

Using the stratified sampling recommended by Catanese and [8] 100 samples were collected from smallholder associations (SF) and another 100 from commercial growers (SC). Following the procedures described by [9] and in triplicate, 100 g of tomato fruit samples, free from disease and/or attack by fungi and other insects, were manually collected at 20 points in each field, placed in polyethylene plastic, labelled, placed in isothermal boxes and taken to the laboratory for physicochemical analyses. Occasionally, some samples were kept at a refrigeration temperature of 5 to 10±2°C while awaiting analysis.

3.4. Determination of the physico-chemical quality of tomatoes.

According to the procedures described by AOAC [8], moisture, ash, lipid, protein, pH, total titratable acidity, lycopene and vitamin C) were evaluated in triplicate.

3.4.1.Moisture

It was determined by the dissection method in an oven at 105°C for two hours on 5 g of sample, the content being calculated by equation 1.

$$H = \frac{n}{p}\text{x}100 \qquad (1)$$

Where:H – moisture expressed in percentage;N – number of grams of moisture (loss of mass in g);P – number of grams of the sample.

3.4.2.pH

The pH was determined by potentiometry by weighing 5 g of the crushed sample in an Erlenmeyer flask on a precision balance (brand Adam) and diluting it in 50 ml of water, stirring the contents manually until the particles were suspended. The HANNA pH meter electrode was then inserted and the value read directly on the instrument's display.

3.4.3. Titratable acidity

It was evaluated by the titration method, where 5 g of the ground sample was weighed and transferred to a 100 ml conical flask, to which 50 ml of distilled water and 2 drops of 1% phenolphthalein solution were added. Titration was carried out with 0,1 N NaOH solution to the equivalence point and the volumes consumed were recorded for the calculation of acidity according to equation 2.Titratable acidity $= \frac{v * f * 100}{p}$ (2)

Where:V – number of mL of 0.1N sodium hydroxide solution used in the titration;f – 0.1N sodium hydroxide solution factor;P – number of g of the sample used in the titration.

3.4.4. Protein

Protein was determined by the Biuret method, in which 10 g of sample was weighed into Erlenmeyer flasks, 100 ml of distilled water was added and the samples were kept under constant stirring for 3 hours to prepare the aqueous extract, which was then filtered. 300 µl of sample and 2000 µl of biuret reagent were added to previously tared test tubes and the tubes were kept in the dark for 30 minutes, after which the absorbances were read in triplicate in a UV-Vis spectrophotometer at a wavelength of 540 nm. The protein content was then calculated by extrapolation using a calibration curve constructed with casein and represented by Y=Ax+B.

3.4.5.Lipids

Lipids were determined using the light extraction method with light petroleum. 5 g of the sample on filter paper was weighed and transferred to the dry matter lipid extractor attached to a previously tared capsule at 105 °C. 50 ml of extractor solvent was added and the sample was held under continuous extraction for 5 hours at a temperature of ±70°C, after which the capsules were removed and transferred to an oven at 105°C where they were held for 1 hour to evaporate the remaining ether and then cooled to room temperature. The lipid content was determined using equation 3.

$$\text{Ethereal Extract}== \frac{n}{p}x100 \qquad (3)$$

Where: N – number of grams of lipids (calculated by the difference between the final and initial weight of the capsule);P – number of grams of the sample.

3.4.6.Lycopene

The concentration of lycopene was determined by spectrophotometry. 20 ml of acetone was added to 5 g of sample in a volumetric flask and the mixture was stirred with a mechanical stirrer for 30 minutes, after which the contents were filtered with laboratory filter paper. The sample was washed 3 times with acetone to completely extract the pigments. 10 ml of light petroleum was added and the sample was washed 4 times to completely remove the acetone, then the solution of pigments in light petroleum was transferred to a volumetric flask and the volume was made up to 50 ml with light petroleum. The absorbance was read at a wavelength of 470 nm and the lycopene concentration was estimated from equation 4.

$$\text{Lycopene } (\mu g/g)=\frac{A*V*1000000}{CE*M*100} \qquad (4)$$

Where: A - absorbance of the solution at a wavelength of 470 nm; V - final volume of the solution; CE - is the extinction coefficient or molar absorption coefficient of a pigment in a given specific solvent; M - mass of the sample taken for analysis.

3.4.7. Vitamin C

20 ml of the liquid extract of the sample was prepared and transferred to a 200 ml volumetric flask, the volume was made up with 4/1000 oxalic acid and 10 ml was pipetted into a beaker containing 3 ml of sodium citrate buffer pH 4,5. After homogenisation, 5 ml was pipetted into another beaker containing 5 ml of 2,6-dichlorophenol-indophenol and the absorbances were read in a spectrophotometer at 530 nm, zeroed with oxalic acid. The ascorbic acid content was determined by the difference of the two readings against a standard curve constructed with a 2,6-dichlorophenol-indophenol solution, represented by

y = 0,0039x + 0,1771.

3.4.8. Ashes

The ash was determined by the muffle combustion method at 550 °C, in which 3 g of the sample were weighed into tared crucibles, then the material was carbonised on an electric plate and burnt in the muffle for six hours until the ash turned white. The ash content was calculated using equation 5.

$$C=\frac{N}{P} * 100 \quad (5)$$

Where:C – ash expressed in percentage;N – no of g of ashes;P – number of grams of the sample.

3.5. Data analysis

The analysis of variance (ANOVA) of the data was carried out using the statistical software R version 4.1.2 and the difference between the means was determined using the Tukey test at 5% significance level. The effect of the smallholder and/or commercial sectors was examined using a two independent samples t-test, with a probability of 0.05.

4. Results and discussion

4.1. Physico-chemical analyses of tomato

4.1.1. Family sector (SF)

Table 1 shows the physico-chemical characteristics of the tomatoes produced by the family sector of the Chókwè irrigated area.

Table1: Variation of physicochemical parameters of tomato in small-scale farmer.

AP	Lycopene (μg/100g)	Protein (mg)	Ashes (%)	Moisture (%)	ATT (%)	Fat (%)	pH	Vitamin C (mg/100g)
A	11±0.07^{a}	5.±0.57^{ab}	1.0.±1.59^{a}	95±0.11^{a}	14±0.25^{a}	0.4±0.52^{b}	4±0.01^{d}	81±2.82^{b}
B	11±0.07^{a}	6.±0.39^{ab}	1.0±0.50^{a}	94±0.95^{ab}	13±0.32^{a}	3.0±2.91^{a}	4±0.02^{cd}	83±0.52^{ab}
W	9.0±4.45^{ab}	8.±1.21^{a}	1.0±0.85^{a}	95±0.04^{a}	8.0±0.83^{b}	0.5±0.41^{b}	4±0.13^{ab}	83±0.90^{ab}
D	6.0±0.34^{bc}	8.±0.83^{a}	0.4±0.52^{b}	91±3.33^{b}	14±0.83^{a}	0.6±0.60^{b}	4.±0.02^{ab}	84±0.13^{ab}
E	3.0±0.11^{c}	7.±1.98^{ab}	0.1±0.56^{a}	95±0.06^{a}	3.0±0.32^{c}	0.6±0.44^{b}	4±0.01^{ab}	83±0.0^{ab}
F	11.±1.75^{a}	6.±1.00^{ab}	0.4±0.66^{a}	94±0.08^{ab}	6.0±0.12^{bc}	1.3±1.75^{ab}	4±0.02^{ab}	85±1.66^{a}
G	3.0±0.17^{c}	6.±1.27^{ab}	0.3±0.26^{a}	97±1.54^{a}	15±0.83^{a}	3.0±3.03^{a}	3±0.01^{cd}	81±0.36^{ab}
H	11±2.47^{a}	5.±4.20^{ab}	0.1±0.10^{a}	95±0.16^{a}	5.0±0.64^{bc}	0.6±0.08^{c}	4±0.33^{a}	83±0.0^{ab}
I	11±0.04^{a}	3.±0.34^{b}	0.3±0.07^{a}	91±0.15^{b}	13±0.38^{a}	0.7±0.34^{c}	3±0.03^{cd}	84±0.38^{ab}
J	4±0.13^{c}	6.±1.63^{ab}	0.3±0.01^{a}	95±0.03^{a}	8.0±0.08^{a}	0.3±0.00^{c}	3±0.04^{bc}	84±0.64^{ab}

Legend: AP, association of small farmers. Different letters in the same column indicate significant differences at the 5% level of significance by Tukey's test.

4.1.1.1. Lycopene

The tomatoes produced by the different smallholder associations showed lycopene values ranging from 2.70 to 11.15 μg/100g, with associations D, E, G and J. being significantly different from the others ($p \leq 0.05$). This may be related to soil fertility.

According to [10], lycopene contents ranging from 2.967 to 6.029μg/100g of tomato pulp are considered high and show an important nutritional aspect, since it is a functional component, as it is strongly related to the reduction of free radical production, thus acting in the prevention of various diseases such as cancer and cardiovascular diseases. In comparison with[10] .

[11], in his work on the physico-chemical quality of tomatoes, estimated the lycopene content in organic and conventional ketchup samples at 3.1 and 13.89 μg/100 g respectively, results similar to those obtained in this study.

4.1.1.2. Protein content

Associations of producers in small-scale C and D differed significantly from Association I in terms of protein content, which ranged from 3.06 to 8.77 mg/100 g, and the other associations did not show statistical differences between them. [12], in their analysis of the quality of different tomato varieties produced in organic systems, reported protein values below 1 mg/100 g, confirming the results presented in this study. However, [13], in his analysis of tomato production systems, reported an average protein value of more than 1g/100g, which is higher than that found in this study. [15], in their study evaluating the chemical and energetic composition of tomatoes in nature, obtained protein levels around 1.1 mg/100g, which were lower than the results found in this study, and the analysis of tomatoes containing seeds, climate and genotype may have influenced these results.

4.1.1.3. Ashes

Statistical differences ($p \geq 0.05$) were observed between the plots, with mineral contents ranging from 0.16 to 1.95%, the best values being observed in plots A, B and C in relation to the others. This finding is probably related to the way the tomatoes are produced, since the family sector associations opt for the use of organic fertilisers, which may have generated mineral residues that are compatible with the tomato.

[14], investigating the ash content of cherry tomatoes produced in an organic system, reported a general average ash content of around 0.5g/100g. According to [16], soil, fertilisation, cultural practices, climate and region are likely factors that can influence the levels of nutrients in food.

The averages of the samples grown in the family sector showed a tendency towards a higher amount of ash, which was also confirmed by [17], who found a mineral content of 9.5g/100g in samples of organic tomatoes. However, the results reported by [18] show that there was no difference in the mineral content of tomatoes grown in commercial and organic systems, which were found to be 0.81 and 0.87g/100g, in the same order. On the other hand, [19].

4.1.1.4. Moisture

As can be seen in Table 1, the moisture levels of the associations in the family sector tend not to show statistical differences among themselves ($p \geq 0.05$), with the exception of associations D and I. The observed averages are between 91, 19 and 96.92%. The moisture values found in this research are in line with those of [20] who, when studying the influence of production systems on the physico-chemical and sanitary quality of cherry tomatoes, reported an average moisture concentration of around 93g/100g. They are also in line with the results obtained by [21, 22] in their study evaluating the nutritional quality of tomatoes in nature, who obtained a moisture content of 93.76%. [17], in his study on tomato quality and consumer opinion, found values of 93%.

4.1.1.5. Total titratable acidity

The tomato acidity values ranged from 2.88 to 14.91%, with statistical differences ($p \leq 0.05$) observed between the associations in the family sector, with emphasis on associations C, E, F and H, which presented values of lower acidity. This difference may be related to the concentration of acidic compounds and/or the ripeness index of the tomato[23], in their study on the quality of organic table tomatoes, obtained different results, with values ranging from 0.21 to 0.49% for organic tomatoes. [24], in his study evaluating the physico-chemical and sensory quality of commercial and organic tomatoes sold in the city of São Paulo, obtained acidity values between 32.59 and 37.25%, which are much higher than those found in this study. . This scenario could be related to the tomato genotype, the climatic conditions and the soil. According to [25], the total acidity of tomatoes indicates the amount of organic acids present and the astringency of the product, and is the main attribute that influences the flavour of the fruit.

4.1.1.6. Fat content

The fat content ranged from 0.33 to 3.44% and significant differences ($p \leq 0.05$) were found between the productions of different associations of family sector producers. This difference may be related to the use of chemical agents in production, which may contain a certain amount of lipid substances. [17], in their study evaluating the chemical and energetic composition of tomatoes in nature, obtained values of 0.2%, which are within the values found in this study. [26], in his study dedicated to the analysis of tomatoes from the fields of associations in the family sector, presented acceptable levels, since their levels varied between 0.26 and 3.44%, which are above the minimum acceptable levels and which are in line with those found in this study. The same author, evaluating the lipid content of tomatoes from different production systems, found that the conventional system had a low fat content, with 0.2% being the minimum acceptable average value, a result that differs from that found in this study.

4.1.1.7. pH

The average pH values ranged from 3.62 to 4.26, with better significant results ($p \leq 0.05$) in the plots of Associations A, B, G and I. This difference in pH values within the sector may be related to the chemical composition of the soil used by the Associations, as well as to the type of production in these same Associations. The average pH values are in line with those considered ideal for quality tomatoes, which, according to[27], are

3.7 and 4.9, confirming the values found by [27], who measured pH values lower than 4.5 in several cherry tomato genotypes. According to [16],, lower pH values impart a more acidic flavour to the fruit, a characteristic that favours the preservation of the fruit after harvest. [24],in their study evaluating the quality of organic tomatoes, found values close to these, at 4.47. [24], in his study evaluating the physical, chemical and sensory quality of organic tomatoes, found pH values ranging from 4.38 to 4.47, which is within the range found in the present study.

4.1.1.8. Vitamin C

Associations in the family sector showed differentiated production among themselves ($p \leq 0.05$), with averages between 81.68 and 85.15mg/100g. [28]), in their study on the quality of tomatoes produced in different systems, observed levels between 0.52 and 0.46mg/100g in organic tomato crops, and these levels are extremely lower than those found in this study, possibly due to the location, climate and soil type. [29] state that tomatoes produced in the organic sector or in family farms have a higher vitamin C content due to the high soluble solids content, between 5.0 and 7.0 mg/100g, and in agreement with this author, it can be seen that the tomatoes from associations in this sector had a higher vitamin C content 6. 0 to 7.5 mg/100g [30], in their study on the evaluation of tomato quality, found high levels of 0.6 to 3.0 mg/100g of vitamin C in tomato from the family sector and/or organic being, in agreement with the results found in this study.

4.1.2. Commercial sector (SC)

The physico-chemical parameters of tomatoes produced in the commercial sector are shown in Table 2.

Table 2: Variation of physicochemical parameters of tomato in the commercial sector.

PC	**lycopene (μg/100g)**	**Protein (mg)**	**ashes (%)**	**Moisture (%)**	**ATT (%)**	**Fat (%)**	**pH**	**Vitamin C (mg/100g)**
A	4±1.48de	9±0.14a	0.3±0.01a	94±0.10bc	5±0.12a	0.4±0.00b	4±0.00bcd	84±0.18a
B	4±1.48de	5±0.17bc	0.7±0.66a	93±0.15cd	6±0.12a	1±1.46a	4±0.03d	84±0.9ab
W	4±0.29de	3±1.56c	1±0.56a	96±0.04a	5±0.01a	0.4±0.26b	3±0.005bcd	81±0.36cd
D	6±0.40bc	5±1.97bc	0.1±0.09a	92±0.04e	3±0.06b	0.6±0.43b	3±0.17cd	84±1.26ab
E	3±1.75de	3±0.14bc	0.1±0.56a	93±0.56d	4±0.06a	1±1.23a	4±0.35b	82±0.72ab
F	1.±0.0e	2±0.53c	0.3±0.20a	94±0.01cd	6±0.11a	0.7±0.78b	3±0.01d	82±0.54ab
G	11±0.09a	3±0.98c	0.3±0.25a	94±0.07cd	6±0.32a	0.6±0.32b	4±0.05y	81±2.53cd
H	5±0.76cd	4±0.39bc	0.2±0.11a	94±0.19b	5±1.04a	0.8±0.24b	4±0.05y	81±2.53cd
I	8±0.13ab	5±1.06bc	0.2±0.06a	93±0.30d	6±0.12a	0.8±0.50b	4±0.01b	80±1.45d
J	10±2.85a	6±1.78ab	0.3±0.19a	94±0.20cd	6±0.12a	0±0.00b	4±0.005b	81±2.35^{cd}

Legend: PC, commercial producers. Different letters in the same column indicate significant differences at the 5% level of significance by Tukey's test.

4.1.2.1. Lycopene

There was a significant difference between producers in the commercial sector, with values ranging from 1.30 to 10.68μg/100g, with commercial producers G, I and J presenting the best values of this substance. According to [30], raw tomatoes have an average of 30 mg lycopene/kg, and these levels are within the average limits of 1 to

11 µg/100g recommended by [31]. [32] found lycopene levels ranging from 2.967 to 6.029µg/100g of tomato pulp, characterising this range as an aspect of great nutritional importance, since it is a functional component strongly related to the reduction of free radical production, thus acting in the prevention of various diseases such as cancer and cardiovascular diseases. [5], in his study analysing the lycopene content of vegetables, found values of 8.8µg/g, which are close to the values found in this study. [33], in his study evaluating the chemical composition of tomatoes, obtained protein levels around 2.05 µg/100g, which were lower than the results found in this study.

[33], in their study evaluating tomato paste as a possible functional ingredient, obtained protein levels of 24.67%, which is much higher than the results found in this study.

4.1.2.2. Protein

There was a statistically significant difference between the producers, with values ranging from 2.06 to 8.78%, with the best results observed in producers A and J. A similar situation was observed by [34], who, in a study on the composition of tomatoes grown conventionally, obtained values of 19.27% of protein content, much higher than those found in this study. [35], in his study evaluating the chemical composition of tomatoes, obtained protein levels of around 1.5g/100g, which were lower than the results found in this study. [33], in their study evaluating tomato paste as a possible functional ingredient, obtained a protein level of 24.67%, which is much higher than the results found in this study.

4.1.2.3. Ash

There was no significant difference between commercial producers, with mean values ranging from 0.15 to 1.32%. [36] in their study evaluating the quality of tomatoes in the commercial sector, found ashes ranging from 0.46 to 0.59%, which is within the range found in this study. [37] in their study on the impact of international voluntary standards on smallholder market participation in developing countries, presented an average value of ash content around 2.5%, which is different from the value found in this work for tomatoes grown in a commercial system. [19], in their study comparing the quality of tomatoes from the family and commercial sectors, found lower ash levels (1.3%) in tomatoes from the commercial sector, which is similar to the results of this research.

4.1.2.4. Moisture

The significant difference found between producers can be explained by the fact that each producer in the commercial sector uses a different technique than the other, which is in line with the finding of [38], in their comparative physico-chemical analysis study. of organic and commercial tomatoes from open markets in the city of Cuité - PB, which presented averages between 94.72 and 95.19%, with the highest percentage evidenced by commercial tomatoes, slightly above the results of the present study.

[39], obtained a moisture level of 94.5% in tomatoes in nature, which is within the values found in this study, and [40], in their study evaluating the nutritional quality of tomatoes in nature, found a moisture level of 93.76%

in tomatoes grown in conventional fields.

4.1.2.5. Total titratable acidity

There were no significant differences between commercial producers, except that D. [41], evaluating the quality of tomatoes in commercial cultivation, obtained values that varied from 6.75 to 6.71% of acidity content, and these values are within the values found in the present study. [43], analysing processed tomatoes from conventional cultivation, obtained values of 2.63%, which is lower than the results found in this study and the processing factor may have influenced the differentiation. [44], in their work on the quality of tomatoes produced in different cultivation systems, had values ranging from 3 to 6% of acidity, justifying that this could be related to factors such as genotype and temperature, which could have influenced the acidity content. In line with the present study, [42], in their work on the composition of tomatoes, had acidity values ranging from 7.96 to 6.34%, similar to those of this study.

4.1.2.6. Lipids

The lipid content of the tomato samples differed significantly ($p \leq 0.05$) from that of the commercial producers, where averages between 0.40 and 1.61% were observed. [45], in his study on tomato quality, found a low content (0.56%) of lipids, which is within the range of values of this study.

[46] in his work aimed at analysing the quality of tomatoes, had a fat content ranging from 0.26 to 3.44%, which is higher than that found in this study. [48] in his study evaluating the chemical composition of tomatoes from different farms and produced in different systems in the natural state, obtained values of 0.6, 0.7 and 1% in the fat content, which are within the limits of the values found in this study.

4.1.2.7. pH

Hydrogen potential values ranged from 3.64 to 4.65%, with significant differences between producers. [49], in his study of compliance with physico-chemical parameters, obtained pH values between 3.6 and 4.2% for the commercial sector, which are within the limits found in this study.

In the study carried out by [49], the pH ranged from 4.6 to 4.96, with the lowest value being for the tomato from the commercial sector, different results from those of the present study, where the tomato from the commercial sector had a lower pH (5.1 to 4.6). [50], in their study on the physicochemical characterisation of Italian tomatoes, found higher values than in this study, registering pH values of 4.35 and 4.60% for tomatoes without and with seeds, and also for tomatoes without and with skin, respectively.

The study carried out by [47], which aimed to evaluate the variation in the physicochemical characteristics of tomatoes under different traditional forms of preservation, found pH values ranging from 3.17 to 4.02, close to those found in the present study. [51] in their work on tomato extract, observed pH values ranging from 4.02 to 4.31 in different brands of tomato extract, which is higher than the value found in the present study.

4.1.2.7. Vitamin C

With regard to the vitamin C content in the study of commercial growers, average vitamin C concentrations ranging from 79.89 to 84.12 mg/100 g were observed, with significant differences between growers. This difference may be related to the genotypic and phenotypic characteristics of the tomatoes. [36] in their study on the comparative physico-chemical analysis of organically and conventionally grown tomatoes, found values of ascorbic acid ranging from 65.05 to 82.91 mg/100g, with lower values found in tomatoes grown in a commercial system, therefore similar to those of the present study. [39] in their study evaluating the levels of ascorbic acid in whole tomatoes, skinless and seedless, found average values ranging from 19.57 to 26.23mg/100g for commercial producers, which are much lower than those found in this study, and the variety factor, soil type and state of ripening may have influenced this difference.

4.1.3. Comparative evaluation of tomatoes from the family and commercial sectors

The results of the comparative test between the physico-chemical parameters of tomatoes produced in the family sector and the commercial sector are shown in Table 3.

Table 3: Means and standard deviations of the physico-chemical characteristics of tomatoes from the family sector (SF) and the commercial sector (SC).

parameters	**tomato sample**		***T test***	
	SF	**SC**	*T-Value*	*P-Value*
Lycopene (µg/g)	7.94±3.76	5.46±3.0	1.63	0.12 ns
Protein %	6.40±1.64	4.39±1.96	2.47	0.024 ns
Ash %	0.62±0.56	0.42±0.35	0.95	0.35 ns
Moisture %	94.31±1.8	94.12±0.86	0.28	0.78 ns
ATT %	9.89±4.36	5.44±1.07	3.13	0.01 ns
Fat %	1.15±1.10	0.78±0.42	1	0.339 ns
pH	3.91±0.27	4.0±0.36	-1.04	0.314 ns
Vit. C (mg/100g)	83.93±1.0	82.28±2.07	-2.27	0.041 ns

For each row, means and standard deviations followed by (ns) not significant and (**) significant by the student t test (P>0.05).

4.1.3.1. Lycopene

No significant difference was found (p>0.05), although the average concentration of lycopene in the commercial sector was 7.94µg/100g compared to 5.46µg/100g in the family sector.

This observation may be related to the variety and ripening stage of the tomato and to the management of the system. According to [31] in their study on the quality of tomatoes, 30 mg of lycopene/kg were produced in both the conventional and organic systems. These results are similar to those found in this study. [32] in his study analysing the lycopene content of vegetables produced in different production systems, found values of 8.8µg/g, which are close to the values found in this study.

4.1.3.2. Total titratable acidity

There was no significant difference between the two sectors, probably because the ripeness of the tomatoes was uniform and there was no difference in the size of the crops or in the degree of ripeness of the tomatoes. [52] in their study of table tomatoes grown in conventional and organic systems, found no significant differences between tomatoes from the two systems, with acidity values ranging from 0.29% to 0.33%, similar to those of this work. [53], in his work on conventional and organic tomato production systems, showed a significant difference and was close to 33.07 and 37.76% of the titratable acidity verified for conventional and organic fruit, respectively, which differs from the results obtained in this article. [54], in their study on the quality of tomatoes from different production systems, found 0.35% of titratable acidity in different tomato production systems. [56], in their work on ripening and comparative quality of different tomato production systems, found 0.45% to 0.46% acidity, which is consistent with the results of this paper.

4.1.3.3. Protein

No significant difference was found between the two sectors, since, according to [55], the protein content is not affected by the production systems. [57], in their study on the nutritional composition of tomatoes in organic and conventional systems, obtained protein values ranging from 16.18 to 23.25%, levels much higher than those found in this study. In this state is also the protein content (19.27%) found by [34], in their study on the quality of tomatoes in different production systems, and by [68] (24.67%), in their study on the evaluation of tomato paste produced in different systems.

4.1.3.4. Fat content

Regarding the fat content presented in the study, it was found that there was no statistical difference between the family and commercial sectors, with values ranging from 1.15% to 0.78%. [55], in his work on organic and conventional tomato production, showed fat contents ranging from 65.2 to 72.7%, with organic tomatoes obtaining significantly higher values, a different result from this study. [57], in their work evaluating the quality of tomato fruit, did not find significant differences between the conventional and organic systems, with values ranging from 11.4 to 16.09%, which is higher than the results obtained in this study. [34] , in their study on the comparative evaluation of tomatoes from different systems, found mean values between 10.6 and 12.6%, which are much higher than those obtained in this study.

4.1.3.5. Ash content

With ash contents ranging from 0.62% to 0.42%, the results show that there is no statistical difference between the two production sources. This can be explained by the fact that the mineral composition of the soils in the production systems is at the same level. Hernández-[58] in their study on food quality, found values ranging from 0.57 to 0.68%, with no significant differences between tomatoes grown in organic and conventional systems. [59] , in their work on the composition of tomatoes in different production systems, found no difference in ash content (1.89%) for both production systems.

[60], in their study on the quality of organic and conventional tomatoes, had a value of 0.78% to 1.2%, with no difference between organic and commercial tomatoes, which is in line with the present study.

4.1.3.6. Vitamin C

The vitamin C content ranged from 83.93 to 82.28 mg/100g, with no significant differences between the two sectors. [55], in his work evaluating the effects of production systems on vitamin C composition, presented mean variations from 15.69 to 22.61 mg/100g between the systems, with no significant difference between them, which is in line with the present research. [36], who studied the quality of tomatoes from different production systems, had results from 13.43 to 15.38 mg/100g of vitamin C with no significant difference and higher than those of the present study. [49], working with conventional and organic cultivation of tomato hybrids, found values of 12.32 and 15.71 mg/100g, respectively, without significant difference between them, in line with the present study. [62], studying variants of tomato quality determinants from different cropping systems, found values of 14.77 and 18.16 mg/100g, with significant differences between them.These findings were lower than those of the present study.

4.1.3.7. Moisture

For the moisture parameter, no significant differences were observed between the samples, probably due to the similarity of the production methods and the irrigation systems used. [65], in their work on the physicochemical evaluation of mini tomatoes in conventional and organic systems, found that the moisture content of tomatoes produced in both systems ranged from 91.47 to 92.94% and 93.68%, respectively, which is different from that found in this article. Also different from this study, were the values reported by [63], in their study on the physicochemical quality of tomatoes produced in organic and conventional systems, 93.3 to 94.5%; by [64], with the work on the physicochemical quality of tomatoes, 90.17%; and by [65], on the comparative physicochemical analysis of tomatoes from organic and commercial cultivation, 94.72 and 95.19%, without significant differences.

4.1.3.8. pH

No statistical difference was found between the production systems, which can be explained by the fact that the ripening stage of the tomatoes from the different production systems is the same. The pH was 3.91 in the family sector and 4.0 in the commercial sector, with no significant difference. [70], who measured pH values in different systems, found higher values, from 4.09 to 4.38, but when compared between them, they do not differ significantly. [29], accessing the quality of tomatoes from different production systems, did not find significant differences between the systems and presented pH values from 4.16 to 4.20, results similar to those of the present study. [25], evaluating the degree of ripeness and quality of tomatoes produced in different systems, organic and conventional, had a pH of 3.87 for both systems.

[72], comparing tomato quality, found pH values significantly higher in the organic system, which was not observed in this study.

5. Conclusion

No significant differences were found between the quality of tomatoes produced by the family and commercial sectors of the Chókwè irrigated area.

Family tomato cultivation is part of a technological pattern of production that preserves the economic and cultural aspects that allow the production of quality food and is in constant interaction with the technical-scientific knowledge present in the commercial model of production.

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