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Lactic preservation of cherry tomato cultivated under irrigation with saline waters[1]

Conservação láctica de tomate tipo cereja cultivado sob irrigação com águas salinas

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HIGHLIGHTS:
Lactic fermentation promotes higher titratable acidity and soluble solids of cherry tomato fruits under salt stress.
Vitamin C from tomato fruits was better preserved under brine of 100 g L^{-1} of NaCl and 100 g L^{-1} of $CaCl_2$.
The moisture content of cherry tomato fruits is below the standard in all lactic conservation formulations.

ABSTRACT: The objective of this study was to evaluate the chemical composition of cherry tomato fruits produced under irrigation with saline water and subjected to lactic preservation. The design used was completely randomized, in a 6 × 5 factorial scheme, referring to the preservation by lactic fermentation with six mixtures of salts (100 g L^{-1} NaCl, 100 g L^{-1} $CaCl_2$, 100 g L^{-1} KCl, 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl, and 50 g L^{-1} NaCl + 50 g L^{-1} KCl) and five levels of electrical conductivity of water (0.3, 1.3, 2.3, 3.3, and 4.3 dS m^{-1}), with three replicates. Lactic fermentation brines promoted higher titratable acidity and soluble solids of cherry tomato fruits under saline water irrigation. Irrigation using water with electrical conductivity of 2.3 dS m^{-1} promoted higher soluble solids/titratable acidity ratio in cherry tomato fruits preserved in the formulations with 50 g L^{-1} NaCl + 50 g L^{-1} KCl and 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl. The highest moisture contents were found in fruits preserved with 100 g L^{-1} $CaCl_2$ and 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$. Brine formulations for lactic preservation containing 100 g L^{-1} NaCl and 100 g L^{-1} $CaCl_2$ promoted higher contents of vitamin C and flavonoids in cherry tomato fruits, regardless of the salinity of irrigation water.

Key words: *Solanum lycopersicum* var. *cerasiforme*, salt stress, post-harvest

RESUMO: Objetivou-se com este trabalho, avaliar a composição química dos frutos de tomate cereja produzidos sob irrigação com águas salinas e submetidos à conservação láctica. O delineamento utilizado foi inteiramente casualizado, em esquema fatorial 6 × 5, referente à conservação por fermentação láctica com seis misturas de sais para conserva (100 g L^{-1} NaCl, 100 g L^{-1} $CaCl_2$, 100 g L^{-1} KCl, 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl e 50 g L^{-1} NaCl + 50 g L^{-1} KCl) e cinco níveis de condutividades elétricas da água (0,3; 1,3; 2,3; 3,3 e 4,3 dS m^{-1}) e três repetições. As salmouras de fermentação lática proporcionaram maior acidez titulável e sólidos solúveis nos frutos de tomate cereja sob salinidade da água de irrigação. A irrigação com água de condutividade elétrica de 2,3 dS m^{-1} promoveu maiores teores de sólidos solúveis/acidez titulável em frutos de tomate cereja preservados nas formulações com 50 g L^{-1} NaCl + 50 g L^{-1} KCl e 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl. Os maiores teores de umidade foram encontrados nos frutos preservados com 100 g L^{-1} $CaCl_2$ e 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$. As formulações de salmoura para conservação láctica contendo 100 g L^{-1} de NaCl e 100 g L^{-1} de $CaCl_2$ promoveram maiores teores de vitamina C e flavonóides em frutos de tomate cereja, independentemente da salinidade da água de irrigação.

Palavras-chave: *Solanum lycopersicum* var. cerasiforme, estresse salino, pós-colheita

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Introduction

Cherry tomato (*Lycopersicon pimpinellifolium*) is an annual vegetable of the Solanaceae family and has shown significant expansion, mainly due to its organoleptic properties and the great acceptance by the population (Araújo et al., 2017). However, its production is limited in the semi-arid region due to the scarcity of water resources, besides the occurrence of water sources with high concentration of salts, mainly sodium, limiting the use in agriculture (Dias et al., 2019; Lima et al., 2020a; Pinheiro et al., 2022). Tomato is considered highly sensitive to salinity, with reductions in production in terms of weight and number of fruits (Diouf et al., 2018; Silva et al., 2022).

Another aspect to be emphasized is the post-harvest quality, because the cherry tomato fruit has high perishability, caused by the increase in respiratory metabolism, due to the high moisture content of this vegetable, depreciating the commercial value of fruits for fresh consumption (Takahashi et al., 2018). In this context, one of the techniques that can be used for post-harvest preservation in vegetables is lactic fermentation, in which bacteria, fungi, and yeasts alter the structure of foods or provide them with better taste characteristics, even extending their preservation time (Soares et al., 2020). Improvements in the antioxidant activity of tomato fruits subjected to lactic fermentation have been reported by Moayedi et al. (2016).

Despite the beneficial effects of lactic fermentation found in cherry tomatoes, there are no reports in the scientific literature about the interactive effects of salinity and lactic conservation on the post-harvest quality of cherry tomato fruits. In view of the above, the objective of this study was to evaluate the chemical composition of cherry tomato fruits produced under irrigation with saline water and subjected to lactic preservation, in the semi-arid region of Paraíba, Brazil.

Material and Methods

The study was carried out in two stages. The first one consisted in the production of cherry tomato fruits under irrigation with different levels of saline water from September 2020 to February 2021 at the Center of Sciences and Agri-Food Technology - CCTA of the Federal University of Campina Grande - UFCG, located in the municipality of Pombal, Paraíba, Brazil (6° 46' 13" S, 37° 48' 06" W, 193 m altitude). The second stage was carried out in the laboratory at the Technological Vocational Center (CVT) - UFCG, Pombal-PB, with the chemical analysis of cherry tomato fruits under lactic preservation with different formulations.

The experimental design used was completely randomized, in a 5 × 6 factorial arrangement, referring to the five electrical conductivities of irrigation water - ECw (0.3, 1.3, 2.3, 3.3, and 4.3 dS m^{-1}) and six mixtures of salts for preservation by lactic fermentation (F1 -100 g L^{-1} NaCl, F2 -100 g L^{-1} $CaCl_2$, F3 - 100 g L^{-1} KCl, F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, F5 - 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl and F6 - 50 g L^{-1} NaCl + 50 g L^{-1} KCl), with three replicates, and the readings were performed in triplicate. The electrical conductivity levels of the water were defined based on the work conducted by Vieira et al. (2016). The lactic conservation formulations were established based on the study carried out by Soares et al. (2020).

The cultivar 'Tomate Cereja Vermelho' was sown in a polyethylene tray filled with substrate obtained from the mixture of sand, soil and manure, with 162 cells, each with 50 mL capacity, where the plants were irrigated with low-salinity water (ECw = 0.3 dS m^{-1}) until 17 days after sowing (DAS), and one plant was allowed to grow in each cell. The cultivar has an indeterminate growth habit, globular fruits, and better adaptation to temperatures between 21 and 28 °C.

At 18 DAS, the plants were transplanted into plastic pots adapted as drainage lysimeters with 20 L capacity, which received a 3 cm layer of crushed stone and a geotextile covering their bottom, to avoid clogging by soil material, and then 22 kg of a sandy loam Entisol from the rural area of Pombal-PB, previously pounded to break up clods and sieved (10 mm). Each pot had a transparent tube, connected to its base coupled to collectors of drainage with volumetric capacity of 2 L to determine the water consumed by the crop. The physicochemical attributes (Table 1) were determined according to the methodology of Teixeira et al. (2017).

At transplanting, irrigation was performed manually and the soil moisture content was increased to the level corresponding to field capacity using low-salinity water (ECw - 0.3 dS m^{-1}) until 17 days after transplanting (DAT). The waters of different electrical conductivity were prepared by dissolving sodium chloride (NaCl) in public-supply water of Pombal-PB, considering the relationship between ECw and salt concentration: Q (mg L^{-1}) = 640 × ECw. From 18 DAT, irrigation began to be performed with water of different salinity levels, and the volume of water for irrigation was determined considering the water requirement of the plants, determined by the water balance, obtained by Eq. 1:

$$VC = \frac{VA - VD}{1 - LF} \quad (1)$$

Table 1. Chemical and physical characteristics of the soil used in the experiment

Chemical characteristics								
pH H_2O) (1:2.5)	OM (g kg^{-1})	P (mg kg^{-1})	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+
			($cmol_c$ kg^{-1})					
5.58	2.93	39.2	0.23	1.64	9.07	2.78	0.0	8.61

Chemical characteristics			Physical characteristics				
ECse (dS m^{-1})	CEC ($cmol_c$ kg^{-1})	ESP (%)	Particle-size fraction (g kg^{-1})			Moisture (dag kg^{-1})	
			Sand	Silt	Clay	33.42 kPa[1]	1519.5 kPa[2]
2.15	22.33	7.34	572.7	100.7	326.6	25.91	12.96

pH - Hydrogen Potential; OM - Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} - Extracted with 1 M KCl at pH 7.0; Na^+ and K^+ - Extracted with 1 M NH_4OAc at pH 7.0; Al^{3+} + H^+ - Extracted with 0.5 M CaOAc at pH 7.0; ECse - Electrical conductivity of saturation extract; CEC - Cation exchange capacity; ESP - Exchangeable sodium percentage; [1, 2] referring to the limits of field capacity and permanent wilting point where:

VC - volume of water consumed (L);

VA - volume of water applied to plants in last irrigation;

VD - volume drained, quantified after last irrigation; and,

LF - leaching fraction estimated at 15%, applied every 15 days to minimize the accumulation of salts in the root zone.

Fertilization started 10 days after transplanting and followed the recommendation for the crop (Trani et al., 2015), using urea (45% N) as nitrogen source, applying 38.9 g per plant, monoammonium phosphate (50% P_2O_5) as phosphorus source, applying 20.35 g per plant and potassium chloride (60% K_2O) as potassium source, applying 65.94 g per plant, starting 10 DAT and split into 20 applications performed weekly via irrigation water.

Throughout the experiment, the following operations were carried out: pruning of shoots growing from the axils of the leaves (unwanted branches) until 45 DAT, pruning of the apical bud at 67 DAT, and the control of pests and diseases by chemical intervention, with insecticide and fungicide recommended for the crop.

Fruit harvest started at 126 DAT when the fruits reached the red ripe maturity stage and, after harvest, they were taken to the Laboratory of Hydraulics and Irrigation - CCTA - UFCG. At harvest, cherry tomato fruits that showed no injury due to physical damage, insect attack or visual presence of microorganisms were selected and subjected to washing and sanitization by 100 mg L^{-1} of sodium hypochlorite (NaClO). Then, 197 g of fruits and 197 mL of solution of the formulation were weighed and stored in a glass container with lid, where they remained at a temperature of 25 °C, on a benchtop until pH stabilization (Goldoni et al., 1981).

The formulations were defined by the mixture of salts, as shown in Table 2. The total sum of the components of the mixtures (100%) of salts was equivalent to the proportion of NaCl (10%) in the fermentation brine normally used in the industrial production of fermented green olives.

The initial values of the electrical conductivity of the brines observed were: F1 -94.13; F2 - 79.09; F3 - 103.1; F4 - 90.99; F5 - 95 and F6 - 166.2 dS m^{-1}. The initial pH values measured in the different brines were: F1 - 5.55; F2 - 5.93; F3 - 5.83; F4 - 5.99; F5 - 6.03 and F6 - 6.19. The pH values of the brines were monitored daily, for three days, in order to provide the ideal lactic fermentation time for the product, and at the end of the process the brines showed the following mean pH values: F1 - 3.71; F2 - 3.72; F3 - 4.00; F4 - 3.44; F5 - 3.56 and F6 - 3.86.

After verifying stability in the pH of the cherry tomato brines, the samples were taken to the Technological Vocational

Table 2. Mixtures of salts present in the fermentation brine of cherry tomato fruits

Formulation	Brine concentration g L^{-1}		
	NaCl	$CaCl_2$	KCl
F1	100	0	0
F2	0	100	0
F3	0	0	100
F4	50	50	0
F5	0	50	50
F6	50	0	50

Center - CVT of the Federal University of Campina Grande - UFCG, Campus of Pombal - PB, where they were kept under refrigeration (temperature of 10 °C ± 5 and relative air humidity of 60% ± 5) to perform the physicochemical analyses of the fermented fruits, determining the following variables in triplicate: soluble solids content (SS) (°Brix), by refractometry in crushed samples using a manual refractometer; titratable acidity - TA (%), by the volumetry method with indicator, using a 5-g aliquot of the sample, which was mixed with 50 mL of distilled water and two drops of alcoholic phenolphthalein at 1.0%, with titration performed up to the turning point with a previously standardized NaOH solution (0.1 N); soluble solids/titratable acidity ratio (SS/TA), obtained by dividing the values of soluble solids by the values of titratable acidity; and moisture (%), determined by direct drying of 10 g of sample in an oven at 105 °C (IAL, 2008).

Flavonoid and anthocyanin contents (mg $100g^{-1}$ of pulp) were measured from the reading in spectrophotometer of a solution containing 10 mL of 95% ethanol and HCl (85:15). The levels of vitamin C (mg $100g^{-1}$ of pulp) were determined by the Tillman method, based on the reduction of the 2,6-dichlorophenol indophenol sodium salt dye by an acidic solution of vitamin C. Total sugar contents (mg of glucose g^{-1}) were determined by the Anthrone method (Hodge & Hodfreiter, 1962).

The obtained data were subjected to analysis of variance (F test) at 0.05 and 0.01 probability levels and, in cases of significance, linear and quadratic polynomial regression analysis was performed for the irrigation water salinity factor and Scott-Knott test was applied for the brine formulations, using SISVAR statistical software.

Results and Discussion

There were significant effects of water salinity levels on titratable acidity (TA), soluble solids (SS), and soluble solids/titratable acidity ratio (SS/TA) of cherry tomato fruits (Table 3). Lactic fermentation brines significantly affected all variables measured. The interaction between factors (SL × F) significantly influenced soluble solids, titratable, and soluble solids/titratable acidity ratio.

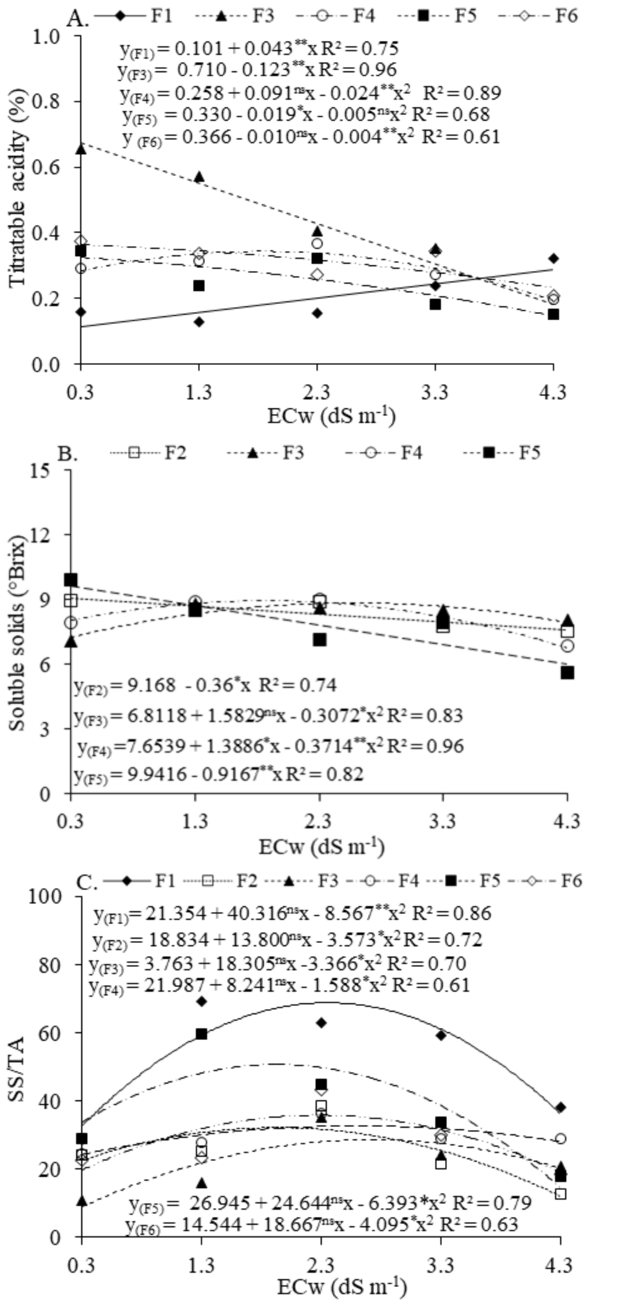
The data of titratable acidity of tomato fruits preserved in F2 did not adjust satisfactorily to tested model ($y = 0.2723 + 0.0477^{ns}x$ $R^2 = 0.35$) and for this reason this formulation is

Table 3. Summary of the analysis of variance for titratable acidity (TA, %), soluble solids (SS, °Brix), soluble solids/titratable acidity ratio (SS/TA), and moisture (MOIST, %) of fresh cherry tomato fruits subjected to different salinity levels of irrigation water and lactic fermentation brines

Sources of variation	DF	Mean squares			
		TA	SS	SS/TA	MOIST
Salinity levels (SL)	4	0.053^{**}	3.341^{**}	811.23^{**}	1.900^{ns}
Linear regression	1	0.038^{**}	11.001^{**}	1.685^{ns}	4.217^{ns}
Quadratic regression	1	0.161^{**}	1.508^{ns}	2520.67^{**}	0.225^{ns}
Fermentation brines (F)	5	0.012^{**}	4.331^{**}	2065.59^{**}	2.879^{*}
SL × F	20	5.938^{**}	2.416^{**}	1.778^{**}	0.773^{ns}
CV (%)		16.99	10.87	25.72	1.05
Mean		0.31	8.28	32.24	89.72

ns, *, **, - Respectively not significant and significant at p ≤ 0.05 and p ≤ 0.01; CV - Coefficient of variation not included in Figure 1A. For the titratable acidity of fresh cherry tomato fruits, there were increments of 151.94% in fruits preserved in the formulations 100 g L^{-1} NaCl (F1) and under water salinity of 4.3 dS m^{-1} (Figure 1A). The higher value obtained in formulation 1 indicates a dependence of the titratable acidity present in cherry tomato fruits on the presence of NaCl in the brine formulation, accentuating the oxidation of organic acids in the cycle of tricarboxylic acids due to fruit respiration (Zachow et al., 2014).

However, there were decreases in the TA of the fruits, in formulations 100 g L^{-1} KCl (F3), 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$ (F4), 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl (F5), and 50 g L^{-1} NaCl + 50 g L^{-1} KCl (F6), which led to decreases of 73.18, 32.24, 7.26, and 12.25% in plants irrigated with ECw of 4.3 dS m^{-1}, respectively, when compared to the control treatment (0.3 dS m^{-1}). The marked reduction of titratable acidity observed in the formulation 100 g L^{-1} KCl (F3) is probably caused by the neutralization of organic acids due to high levels of K^+ in tissues, resulting in reduced acidity in the fruits (Silva et al., 2013).



ns, *, **, - Respectively not significant and significant at $p \leq 0.05$ and ≤ 0.01 by F test
Brine formulations: F1 - 100 g L^{-1} NaCl, F2 -100 g L^{-1} $CaCl_2$, F3 - 100 g L^{-1} KCl, F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, F5 - 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl, and F6 - 50 g L^{-1} NaCl + 50 g L^{-1} KCl

Figure 1. Titratable acidity - TA (A), soluble solids - SS (B), and soluble solids /titratable acidity ratio - SS/TA (C) of fresh cherry tomato fruits as a function of the interaction between the salinity levels of irrigation water - ECw and lactic fermentation brines

Values higher than the standard (0.4%) were found in fruits preserved with 100 g L^{-1} KCl when irrigated with water salinity of 0.3, 1.3, and 2.3 dS m^{-1} with values of 0.65, 0.57, and 0.40%, respectively, and when conserved with 100 g L^{-1} $CaCl_2$ associated with irrigation with water of electrical conductivity of 4.3 dS m^{-1} (0.58%). The other treatments were below the recommended quality standard (Brasil, 2018).

The soluble solids contents of tomato fruits preserved in F1 ($y = 9.44 - 0.1514^{ns}x + 0.0286^{ns}x^2$ $R^2 = 0.03$) and F6 ($y = 7.6113 + 0.9606^{ns}x - 0.269^{ns}x^2$ $R^2 = 0.55$) were not described satisfactorily by the tested regression models and, because of the relatively low values of coefficient of determination, are not included in Figure 1B. Regarding the soluble solids content of fresh cherry tomato fruits (Figure 1B), there were significant differences between the salinity levels in the brine formulations F3 - 100 g L^{-1} KCl and F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, with quadratic fit to the data, and the highest values (8.85 and 8.46 °Brix) were obtained when plants were subjected to irrigation with ECw levels of 2.6 and 1.8 dS m^{-1}, respectively. On the other hand, for fruits subjected to the formulations F2 -100 g L^{-1} $CaCl_2$ and F5 - 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl, there was a linear and negative effect on SS of the order of 3.92 and 9.22% per unit increase in ECw, respectively, that is, reductions of 1.44 and 3.66 °Brix, respectively, when plants were cultivated under ECw of 4.3 dS m^{-1} compared to those under lowest salinity level (0.3 dS m^{-1}).

The SS values obtained in fruits produced under different salinity levels and fermentation brines in the present study are above the standard in all treatments (5 °Brix) (Brasil, 2018) and were also higher than those reported by Paiva et al. (2018), who evaluated the quality of tomato fruits grown under different ECw levels (0.5, 2.0, 3.5, and 5.0 dS m^{-1}) and found values ranging from 3.12 to 6.32 °Brix. It is likely that this reduction in the SS values of cherry tomato fruits due to the increase in salinity occurred due to the nutritional imbalance in the soil resulting from the ionic effect, thus leading to the competition of Na^+ with NH_4^+ and K^+, which are constituents of amino acids and proteins important in the formation of carbohydrates, organic acids, proteins, fats, and minerals of the fruit (Lacerda et al., 2021).

Tomato flavor is related to the presence of several chemical constituents, especially sugars and acids, in addition to their interactions (Torres, 2012). Once the soluble solids and titratable acidity contents of the fruits are known, it is possible to establish the SS/TA ratio. Thus, the regression equations (Figure 1C) showed that the SS/TA ratio was influenced by the salinity of irrigation water and fruit preservation formulations, increasing in the formulations F1, F2, F3, F4, F5, and F6 up to salinity levels of 2.4, 1.9, 2.7, 2.6, 1.9, and 2.3 dS m^{-1} with SS/TA values of 68.76, 32.15, 28.64, 32.67, 50.68, and 35.81, and from these levels the effects of salinity intensified, with reductions in SS/TA of 47.20, 62.37, 29.40, 14.15, 70.99, and 46.70% at water salinity of 4.3 dS m^{-1}, respectively.

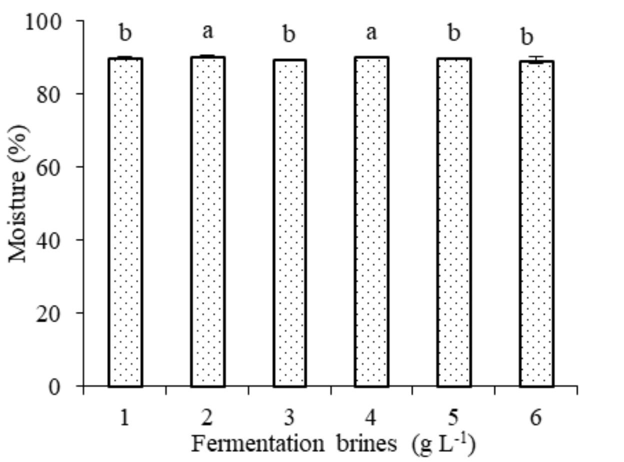
High values of SS/TA ratio determine mild flavor due to the excellent combination of sugar and acid, pointing to a great product for processing as well as fresh consumption, while low values are correlated with acidic and unpleasant taste, so the recommendation is an SS/TA ratio greater than 10, which is lower than those found in the fruits of this study subjected to lactic fermentation brines, regardless of the salinity of irrigation water (Ferreira et al., 2004).

The highest moisture contents of cherry tomato fruits were obtained in the formulations containing Ca in their composition (F2 - 100 g L^{-1} of $CaCl_2$ and F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$), being equal to 90.33 and 90.07%, respectively (Figure 2). The benefits caused by the various forms of calcium chloride application in the post-harvest are associated with decreased ethylene production, ripening delay, reduction of respiratory rate and maintenance of firmness (Sanches et al., 2017).

The beneficial effects of Ca^{+2} on fruit conservation may be related to the formation of bonds between residues of galacturonic acid in the middle lamella, responsible for the union of adjacent pectic chains, and the calcium-pectin complex acts as a cement, giving firmness to the tissue and preventing water loss (Yamamoto et al., 2011).

There was a significant effect of the salinity levels of irrigation water on the contents of soluble sugars (SS), vitamin C (Vit C), flavonoids (FLA) and anthocyanins (ANT) of fresh cherry tomato fruits (Table 4). Lactic fermentation brines significantly affected all variables measured. The interaction between the factors (SL × F) also significantly affected all the variables evaluated in fresh cherry tomato fruits.

For the soluble sugar contents of tomato fruits (Figure 3A), the data were described by a quadratic model for the formulations F1, F2, F3 and F5, and the highest values of SS



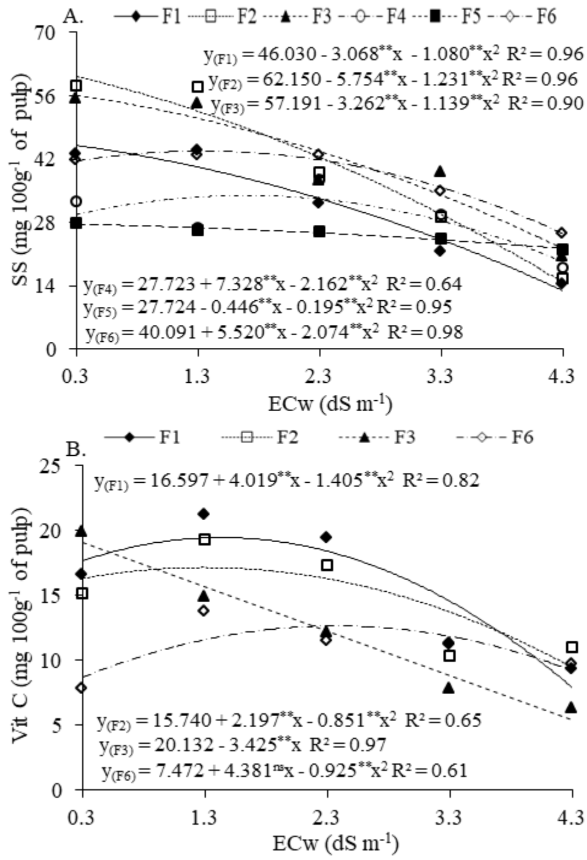
Brine formulations: F1 - 100 g L^{-1} NaCl, F2 -100 g L^{-1} $CaCl_2$, F3 - 100 g L^{-1} KCl, F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, F5 - 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl and F6 - 50 g L^{-1} NaCl + 50 g L^{-1} KCl. Means with different letters indicate that the treatments differ from each other by the Scott-Knott test ($p \le 0.05$). Vertical bars indicate mean ± standard error (n=3)

Figure 2. Moisture content of cherry tomato fruits as a function of lactic fermentation brines

Table 4. Summary of the analysis of variance for soluble sugars (SS, 100g^{-1} of pulp), vitamin C (Vit C, mg 100g^{-1} of pulp), flavonoids (FLA, 100g^{-1} of pulp) and anthocyanins (ANT, 100g^{-1} of pulp) of fresh cherry tomato fruits subjected to different salinity levels of irrigation water and lactic fermentation brines

Sources of variation	DF	Mean squares			
		SS	Vit C	FLA	ANT
Salinity levels (SL)	4	677.7344**	88.6357**	12.7922**	0.0859**
Fermentation brines (F)	5	494.0275**	145.2299**	14.9117**	0.3157**
SL × F	20	514.0832**	28.3119**	7.3825**	0.1468**
CV (%)		0.08	11.51	1.05	3.53
Mean		34.56	11.68	6.09	0.650

ns, *, **, - Respectively not significant and significant at $p \le 0.05$ and ≤ 0.01; CV - Coefficient of variation



ns, **, - Respectively not significant and significant at $p \le 0.01$ by F test
Brine formulations: F1 - 100 g L^{-1} NaCl, F2 - 100 g L^{-1} $CaCl_2$, F3 - 100 g L^{-1} KCl, F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, F5 - 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl and F6 - 50 g L^{-1} NaCl + 50 g L^{-1} KCl

Figure 3. Soluble sugars - SS (A) and vitamin C - Vit C (B) of fresh cherry tomato fruits as a function of the interaction between the different salinity levels of irrigation water - ECw and lactic fermentation brines

(45.01; 60.31; 56.10 and 41.50 mg 100g^{-1} of pulp) were obtained in plants subjected to ECw of 0.3 dS m^{-1}. The fruits preserved in F4 and F6 formulations had the highest levels of soluble solids achieved under ECw of 1.7 and 1.3 dS m^{-1}, respectively.

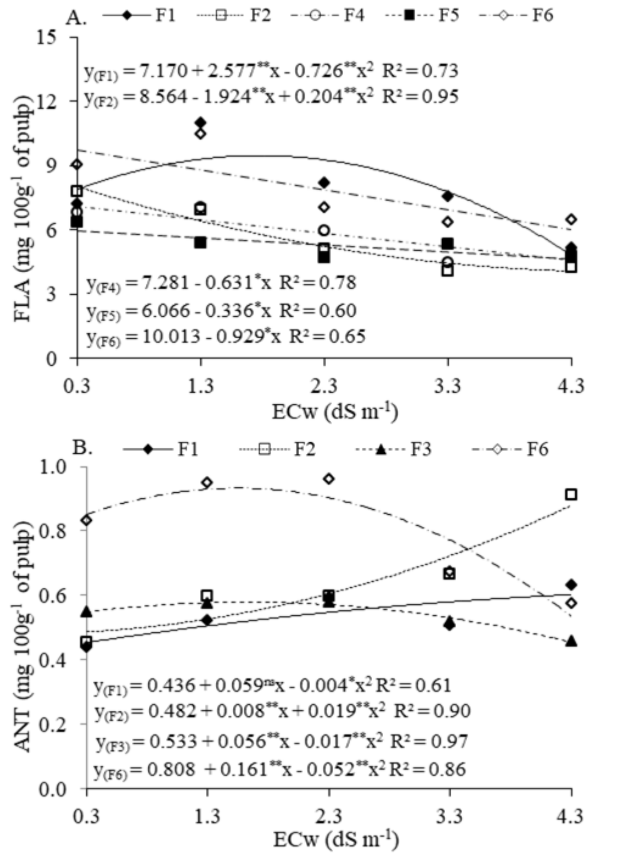
Despite showing the same trend, the reduction in SS as a function of the increase in irrigation water salinity was higher in fruits subjected to F1 - 100 g L^{-1} NaCl, F2 -100 g L^{-1} $CaCl_2$ and F3 - 100 g L^{-1} KCl, with reductions of 71.42, 75.72, and 60.62%, respectively, at the highest level of water salinity (4.3 dS m^{-1}) compared to those subjected to ECw of 0.3 dS m^{-1}. The decrease in SS contents is associated with the fact that sugars are the first substrates consumed during the fermentation process. This situation may be related to the consumption of D-glucose and D-fructose by microorganisms in fruits kept in the different formulations of lactic fermentation (Campara et al., 2021). In addition, the increase in irrigation water salinity may also have led to an increase in the Na/K ratio, causing nutritional imbalance in the plant, and consequently in the processes of synthesis and translocation of carbohydrates (Melo et al., 2014).

The vitamin C content of fresh cherry tomato fruits (Figure 3B) was higher in plants irrigated using water with electrical conductivity of 1.3 dS m^{-1} and for formulations F1 and F2 (19.44 and 17.15 mg $100g^{-1}$ of pulp); for F6, the highest value (12.65 mg $100g^{-1}$ of pulp) was obtained at ECw of 2.3 dS m^{-1}. On the other hand, the vitamin C content of fruits subjected to the formulation F3 decreased linearly, with a reduction of 17.03% per unit increase in ECw. It is worth pointing out that fruits subjected to the formulations F1 and F2 resulted in vitamin C contents higher than the values recommended for table tomatoes (14.06 mg $100g^{-1}$ of pulp). For fruits preserved in F4 ($y = 8.3999 - 0.5611^{ns}x + 0.17^{ns}x^2$ $R^2 = 0.15$) and F5 ($y = 7.4278 + 0.8703^{ns}x - 0.1509^{ns}x^2$ $R^2 = 0.38$) formulations, there was no satisfactory fit to the data, so they were not included in Figure 3B.

The decrease in vitamin C content may be related to changes in the translocation of photoassimilates, due to the stress caused by excess salts in irrigation water (Lima et al., 2020b). It is important to highlight that vitamin C is quite unstable and can be enzymatically transformed by oxidative reactions into its reversible form (dehydroascorbic acid) and/or irreversible form (2,3-diketogulonic acid), which may cause reduction in vitamin C in the fruit (Ramos et al., 2013).

Similarly, the flavonoid contents of cherry tomato fruits (Figure 4A) also had the highest values under preservation with formulations F1 and F2 and associated with ECw of 1.8 (9.45 mg $100g^{-1}$ of pulp) and 0.3 dS m^{-1} (8.00 mg $100g^{-1}$ of pulp), with reductions of 48.04 and 49.20% when plants were irrigated with ECw of 4.3 dS m^{-1}, respectively. The data of tomato fruits preserved in the F3 formulation were not adequately described by the tested regression models ($y = 5.4784 + 0.115^{ns}x$, $R^2 = 0.07$). On the other hand, in fruits under the formulations F4, F5 and F6, the flavonoid contents were reduced by water salinity by 8.67, 5.55, and 9.28% per unit increase in ECw, respectively. Reductions in the FLA content of cherry tomato fruits subjected to lactic fermentation formulations and with increased ECw may be associated with delayed fruit deterioration. During the ripening process of vegetables, chlorophyll is degraded, while there is synthesis of other pigments such as flavonoids (Takahashi et al., 2018).

The anthocyanin contents of cherry tomato fruits (Figure 4B) in the formulations F1 and F2 increased by 24.61 and 43.97% in plants grown under irrigation with water of 4.3 dS m^{-1} compared to those under ECw of 0.3 dS m^{-1}. On the other hand, cherry tomato fruits under lactic preservation in formulations F3 and F6 had reductions of 0.0939 and 0.3161 mg $100g^{-1}$ of pulp and in plants subjected to ECw of 4.3 dS m^{-1} compared to those produced under low salinity of irrigation water (0.3 dS m^{-1}), respectively. For fruits kept under the formulations F4 ($y = 0.6677 - 0.0343^{**}x$, $R^2 = 0.24$) and



ns, *, **, - Respectively not significant and significant at $p \leq 0.05$ and ≤ 0.01 by F test
Brine formulations: F1 - 100 g L^{-1} NaCl, F2 -100 g L^{-1} $CaCl_2$, F3 - 100 g L^{-1} KCl, F4 - 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$, F5 - 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl, and F6 - 50 g L^{-1} NaCl + 50 g L^{-1} KCl

Figure 4. Flavonoids - FLA (A) and anthocyanins - ANT (B) of fresh cherry tomato fruits as a function of the interaction between the salinity levels of irrigation water - ECw and lactic fermentation brines

F5 ($y = 0.618 - 0.005^{ns}x$, $R^2 = 0.02$), there was no satisfactory fit of the tested regression models. Several factors interfere in the stability of anthocyanins, and pH stands out as a limiting factor in their chemical stability, so the stability of anthocyanins is higher under acidic conditions (Modesto Junior et al., 2016), which is confirmed by the increase in the titratable acidity of cherry tomato fruits preserved in formulations F1 and F2 (Figure 4B).

Conclusions

1. Lactic fermentation brines promote higher titratable acidity and soluble solids of cherry tomato fruits under irrigation water salinity.

2. Irrigation using water with electrical conductivity of 2.3 dS m^{-1} promotes higher soluble solids/titratable acidity ratio in cherry tomato fruits preserved in the formulations with 50 g L^{-1} NaCl + 50 g L^{-1} KCl and 50 g L^{-1} $CaCl_2$ + 50 g L^{-1} KCl.

3. The highest moisture contents were found in fruits preserved with 100 g L^{-1} $CaCl_2$ and 50 g L^{-1} NaCl + 50 g L^{-1} $CaCl_2$.

4. Brine formulations for lactic preservation containing 100 g L^{-1} NaCl and 100 g L^{-1} $CaCl_2$ promote higher contents of vitamin C and flavonoids in cherry tomato fruits, regardless of the salinity of irrigation water.

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