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Research Article

Sensory and Biochemical Characterization of Novel Drinks Based on Tomato Juice

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Abstract: In these last years, consumers' choices are being directed towards healthier food and beverages with an increasing demand for functional products. In this study, we investigated the sensory and biochemical properties of novel drinks based on tomato juice. To this purpose, different blends were formulated mixing fresh tomato juice with other fruit juices and nectars in different proportions and then assayed to investigate their sensory (panel test), compositional and biochemical characteristics. Our results indicated that it is possible to formulate tasty drinks based on tomato juice with improved nutritional properties. The combinations of red fruits/tomato (60/40 v/v) and red fruits/orange/tomato (40/30/30 v/v/v) showed a sugar content lower than those of different soft drinks on the market including energy drinks, and suitable lycopene levels as well. Interestingly, the blended red fruits/orange/tomato had a greater number of polyphenols and vitamin C, a softer tomato flavour and high sensory appreciation. High pasteurization (90ºC, 7 min), performed to increase storability, did not significantly affect sensory and biochemical properties of drinks. These achievements may be useful to modulate tomato flavour release and consumer acceptability of novel drinks based on tomato juice.

***Keywords*:** functional beverage, soft drink, lycopene, polyphenols, tomato flavour, high pasteurization

1. Introduction

The global tomato processing market is aided by the rising production as well as consumption of processed tomatoes. 42 million tonnes of processed tomatoes were consumed globally in 2019, with an expected consumption of 51 million tonnes in 2025 [1]. However, the global tomato juice market is limited in comparison to that of other tomato-based products, i.e. peeled, chopped, puree and tomato paste, which are leading products on international trade [1-2]. In addition, tomato juice consumption is very limited in comparison to that of other soft drinks with lower nutritional properties such as energy drinks, which are very popular among young consumers despite their low nutritional value [3-4].

The high interest in energy drinks is mainly linked to their likable taste, stimulating effect and purpose to boost physical performance. In fact, these soft drinks are formulated with the aim to provide the consumers with a "plus"

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of energy through a combination of stimulants and sugars (e.g. caffeine, herbal extracts, B vitamins, amino acids and sugar derivatives) [5-6]. Caffeine and sugars can reach concentrations of 35 mg and 15.6 g per 100 mL of energy drink, respectively [7]. Chronic caffeine consumption may provoke health concerns related to central nervous system, cardiovascular, gastrointestinal and renal dysfunction [5-6, 8]. Sugar levels in energy drinks are comparable to those of other common sugar-based beverages associated with increasing body weight and obesity in young people (including children) and adults [7]. The absence of caffeine as well as the wide range of minerals and adequate sugar amounts contained in tomato and other fruits make their juices an optimal source for drinks aiming to support physical performance and promote energy recovery as much as energy drinks. Moreover, tomato is one of the major sources of lycopene and a good source of vitamin C and several antioxidant molecules which may provide tomato juice with functional properties [9-10]. Lycopene and vitamin C, in presence of other micronutrients, may have a synergistic effect on preventing certain type of cancer (lung, stomach, prostate, breast, pancreas, etc.) [9-10].

If we focus on commercial data, there was an increase in soft drink demand with a world market share of 3.2% in 2013 against that of 2.9% in 2008 with potential growth of 216.74 billion dollars during 2020-2024 [3-4]. Interestingly, consumers are increasingly demanding for functional products with positive effects on health among which there are also examples of soft drinks based on tomato juice such as fermented or aromatic beverages [10-12]; a trend confirmed by Zhu et al. [13] in their study on consumer preference and willingness to pay for tomato juice. The study results showed that tomato juices with fresh aroma notes and better taste will encourage consumers' purchase intent.

Thereby, the present research aimed to investigate the sensory and functional properties of some novel drinks based on fruit juices, including tomato juice, as potential new proposals on soft drinks market. Since in literature similar studies, including that performed on Physalis (*Physalis peruviana L.*) juice by Rabie et al. [14], have suggested that pasteurization may preserve the valuable attributes of juices (e.g. ascorbic acid and total phenolic), we decided comparing the sensory and biochemical data obtained for raw and pasteurized blends. In addition, both caloric intake and sugar content of the novel drinks were compared to those of some energy drinks on the market.

2. Materials and methods

2.1 *Materials*

Tomato juice used for drink production was made from fresh tomato fruits of the round cluster variety (deep red colour tomatoes with strong green parts and sweet taste. Normally used for salads and juices). Fruit juices and nectars were the following commercial products: a) 100% orange (Skipper Zuegg, local market) and b) red fruits (strawberry, red grapes, black cherry, red currant, cranberry; Skipper Zuegg, local market).

Gallic acid standard, Folin-Ciocalteu and 2,4,6-Tri(2-pyridyl)-s-triazine (TPTZ) reagents were purchased from Sigma (St Louis, MO, USA), ascorbic acid standard, dichlorophenolindophenol, metaphosphoric and acetic acids were purchased from Panreac (Barcelona, Spain). Fehling A and Fehling B reagents were purchased from J.T. Baker Chemicals (Deventer, Holland). Carrez I and Carrez II, water, acetone, methanol, hexane, 2,2'-azinobis-(3-ethylbenz-thiazoline-6-sulfonic) diammonium salt (ABTS), Tetrahydrofuran (THF), butylatedhydroxytoluene (BHT), methylene chloride, potassium persulfate and ammonium sulphate reagents, lycopene (purity ≥ 85 g 100 g^{-1}) and 2-octanone standards were purchased from Sigma-Aldrich (Steinheim, Germany).

2.2 *Preparation and formulation of drinks*

Tomato fruits were washed, cut in small pieces and chopped using a mixer. The fresh juice was roughly filtered through a 0.32 mm fine mesh steel strainer (Paderno, Novara, Italy) to remove peels and seeds and then blanched (65°C, 5 min) to produce a softer texture (pectinase activation). Hence, tomato juice was mixed with commercial fruit juices and nectars in the following proportions: red fruits/orange/tomato (40/30/30 v/v/v; 30/40/30 v/v/v; 30/30/40 v/v/v), orange/tomato and red fruits/tomato (20/80 v/v; 40/60 v/v; 50/50 v/v; 60/40 v/v; 80/20 v/v). Among them, two combinations were selected through a preliminary sensory test: red fruits/tomato (60/40 v/v) (S1) and red fruits/orange/tomato (40/30/30 v/v/v) (S2). The other combinations were rejected because of their low global appreciation (< 4) and high tomato flavour (> 7). Aliquots of these blends were also subjected to high pasteurization by autoclaving (90°C, 7 min) with the purpose to assess how pasteurization process may affect the sensory and biochemical properties of drinks.

2.3 *Panel test*

Panel test was carried out to adopt different protocols by a panel of 10 judges (5 men and 5 women) recruited among students, researchers and professors from the University of Zaragoza, Faculty of Veterinary [15-17]. The panel evaluated the following attributes: global intensity (flavour perception), tomato flavour, red berry fruit flavour, orange flavour, sweet taste, sour taste, bitter taste and global appreciation. The intensity of each attribute and the global appreciation of the tested blends were indicated on a 10 points scale (attribute intensity: 0 = low intensity, 10 = high intensity; global appreciation: 0 = not appreciated, 10 = very appreciated). Raw and pasteurized samples were prepared 1 h before the evaluation and coded with random numbers. They were served at 4°C temperature in random order. The panel was provided with unsalted crackers and water to clear palate between sample tasting.

2.4 *Sample preparation for biochemical analyses*

The aqueous and organic extracts of drinks were obtained according to the method reported by Djuric and Powell [18] with slight changes. 1 mL of each blend was mixed with 0.5 mL of water and centrifuged (4000 g × 5 min). The pellets were washed with 0.5 mL of water twice and the supernatants were combined to yield the aqueous fraction (AF). The pellets were then washed four times with 1 mL of acetone/methanol (7/3, v/v), using vigorous vortexing and sonication. After centrifugation, the supernatants were combined to yield the organic fraction (OF).

For total polyphenol compound and vitamin C analysis, 10 mL of each sample were subjected to homogenization and 1/10 dilution with water. After stirring, the samples were assayed directly without centrifugation.

For sugar determination, since sugar solutions must have a sugar concentration between 0.5 and 1 g 100 mL^{-1}, 5 mL of each sample were diluted 20 times with water. Then, the samples were subjected to defecation in order to eliminate interfering substances (i.e. tannins and pectins) by using Carrez reagents.

2.5 *Total polyphenol compounds*

The analysis of total polyphenol compounds was performed according to Singleton and Rossi [19] using the Folin-Ciocalteau colorimetric method. The total phenolic content was determined by using a calibration curve performed with gallic acid and expressed as mg of gallic acid per L of solution. The analyses were carried out in triplicate for each sample.

2.6 *Lycopene content*

In order to extract lycopene from drink OFs, 4 mL of each fraction were mixed with 10 mL of hexane. The solutions were stirred and thus left to stand for 15 min. Hence, 2 mL of the hexane phases containing lycopene were dried under nitrogen and then mixed with 1 mL of THF. The lycopene content was determined by High Performance Liquid Chromatography (HPLC) analysis following the procedure of De Sio et al. [20] with appropriate changes. The analysis was performed on an Agilent 1100 Series coupled with a Diode array UV-Vis detector. Data were collected at 472 nm. The column was a reverse-phase Phenomenex Ultracarb ODS30 (7 µm, 250 mm × 4.6 mm). The injection volume was 50 µL. The elution was performed with a linear gradient of methanol/water 95/5 (v/v) containing BHT 0.1 g 100 mL^{-1} (eluent A) and methylene chloride containing BHT 0.1 g 100 mL^{-1} (eleunt B). The flow rate was 1.0 mL min^{-1}. The gradient, starting at sample injection, was from 5% B in A to 70% B in A in 35 min. A calibration curve was prepared using different concentrations of lycopene standard. The analysis was made in triplicate and the results were expressed in mg of lycopene per L of solution.

2.7 *Antioxidant activity*

The antioxidant activity was measured by ABTS analysis according to the method reported by Re et al. [21]. Briefly, ABTS reactive was dissolved in 5 mL of water to obtain a concentration of 7 mmol L^{-3}. Then, 88 µL of 2.45 mmol L^{-3} potassium persulfate solution was added to form the radical cation $ABTS^{+}$. The mixture was stored in the dark at 4-6°C for 12-16 h before use. The $ABTS^{+}$ stock solution was diluted with ethanol to reach an absorbance of 0.70 ± 0.02 at 734 nm (25°C). A calibration curve was prepared in diluting Trolox in ethanol by using concentrations from 4.5

to 30 μg mL^{-1}. The analysis was carried out after exactly 2.5 minutes of sample addition and the absorbance was read at 734 nm by using a spectrophotometer mod. UV-1601 (Shimadzu Italia, Milan, Italy). For each dilution, the percentage of inhibition was calculated using the formula $A_{734}\% = (1 - A_f/A_0)*100$, where A_0 was the absorbance of blank sample and A_f was the absorbance after 2.5 min. The inhibition percentage was plotted as a function of Trolox concentrations. The antioxidant activity of the samples was calculated from the ratio of linear regression coefficient of the analyte and that of the Trolox. The analysis was made in triplicate and the results were expressed in mg of Trolox equivalent per Liter of solution. The free radical scavenging ability of the drink extracts and Trolox against $ABTS^+$ free radical was evaluated mixing 100 μL of extracts with 1000 μL of $ABTS^+$ methanolic solution. After 2.5 minutes of incubation at room temperature in the dark, the absorbance was measured at 734 nm.

2.8 *Vitamin C content*

The vitamin C content was determined by the titration method of Lees [22]. To carry out the analysis, the following reagents were used: a dichlorophenolindophenol solution (50 mg 100 mL^{-1}); an ascorbic acid stock solution (5 mg 500 mL^{-1}); a solution containing 15 g of metaphosphoric acid in 40 mL of acetic acid; and 450 mL of water. A calibration curve was prepared using different concentrations of ascorbic acid. The titration proceeded with an indophenol solution until a pale pink coloration persistent for at least 5 seconds. Then, the milliliters of solution used in the titration were pinned. The vitamin C content was calculated by the amount of mg of ascorbic acid on 100 mL of sample using a calibration curve. The analysis was made in triplicate and the results were expressed in mg of ascorbic acid per L of solution.

2.9 *Sugar content*

The sugar content was measured by Fehling method. The titration was made in triplicate and the results were expressed both in kcal L^{-1} and g L^{-1}.

2.10 *Volatile compounds*

The volatile compound composition was determined by dynamic headspace-solid phase microextraction (SPME)-GC/MS analysis using the method reported by Lisanti et al. [23] modified as follows. 25 mL of each blend was placed in a 50 mL glass bottle together with 25 mL of a saturated solution of ammonium sulphate in order to avoid changes of volatile components due to the action of endogenous tomato enzymes. Then, 50 μL of a water solution of 2-octanone (5.2 mg L^{-1}) (internal standard) were added. Afterwards, the samples were subjected to magnetic stirring (30°C, 15 min) in order to facilitate the extraction of volatile components. The SPME fiber was inserted through the cap septum into the headspace of samples for 30 min at 30°C. The SPME device (Supelco Co., Bellefonte, PA, USA) was equipped with an 85 μm carboxen/polydimethylsiloxane (CAR/PDMS) fiber coated with a 1 cm length stationary phase. Volatile compound thermal desorption was carried out by exposing the SPME fiber in the injector for 10 min. The fiber was previously conditioned at 300°C for 2 h. Before each analysis, a blank test was performed to prevent the release of undesirable compounds. Volatile compounds were analysed by using a GC Agilent Technologies model GC 6890N (Santa Clara, CA, USA) coupled with a mass spectrometer MS 5973N equipped with HP-5MS capillary column (30 m × 0.25 mm i.d.; with 0.25 μm film thickness) (JandW Scientific, Folsom, CA, USA). The temperature was set at 40°C for 5 min followed by an increase of 3°C min^{-1} up to 140°C and, then, increased to 300°C at 30°C min^{-1} for 1 min. The injector was kept at 300°C. Helium was used as carrier gas (1.0 mL min^{-1}) [24]. Compound identification was performed by comparing retention times and mass spectra obtained by analysing pure reference compounds under the same conditions. Moreover, the identification was confirmed by comparing the mass spectra with those of the NIST database. In a few cases, the pure chemical standard was not available, thus the compounds were labelled as tentative (t). Mass spectra were recorded at 70 eV. The peak area of each compound was normalized with respect to the area of the internal standard peak. Each sample was analysed in triplicate.

2.11 *Statistical treatment of data*

Significant quantitative differences among the samples were determined for each compound by performing a one-way analysis of variance (ANOVA). Tukey's test was used to discriminate among the mean values of the variables. Differences were considered significant at $p < 0.05$. Data elaboration was carried out using XL Stat (version 2009.3.02), an add-in software package for Microsoft Excel (Addinsoft Corp., Paris, France).

PLS analysis was performed on lycopene, total polyphenols (mg L^{-1}), antioxidant activity (mg L^{-1}), vitamin C (mg L^{-1}), sugars (g L^{-1}), volatile compounds (µg L^{-1}) and sensory data to observe the main differences among the proposed drinks.

3. Results and discussion

Sensory profiles of S1 and S2 are reported in Table 1. After heat treatment, the sensory attributes of pasteurized samples (PS1 and PS2) did not change significantly compared to those of raw samples (RS1 and RS2). However, PS2 was associated with higher bitter taste, lower sweet taste and lower global appreciation. These changes were probably due to chemical reactions of sugars triggered by the high temperature (i.e. Mallard's reaction) [25]. As expected, S2 showed a tomato flavour significantly lower than that of S1, either before or after pasteurization. The small perception of this attribute in S2 was associated mainly to its lower amount of tomato juice (only 30 mL 100 mL^{-1}). Again, the absence of orange juice in S1 explains its smaller orange flavour and sour taste compared to S2. Although global appreciation of RS2 was higher than that of RS1, this difference was not significant after the thermal treatment.

Table 1. Average values of sensory attributes of raw (RS1, RS2) and pasteurized (PS1, PS2) blends

Attributes	Samples			
	RS1	PS1	RS2	PS2
Global intensity	7.1a	6.1a	6.4a	6.8a
Tomato flavour	6.5a*	5.4a	4.3a	4.7a
Red berry fruit flavour	5.3a	5.9a	5.4a	5.7a
Orange flavour	0.6a	1.5a	4.6a*	5.5a*
Sweet taste	6.3a	6.7a	6.5a	5.4a
Sour taste	2.5a	3.2a	4.3a*	4.9a
Bitter taste	1.5a	0.9a	1.1a	2.1a
Global appreciation	4.7a	5.3a	6.5a*	5.5a

Values followed by different letters and asterisks are significantly different ($p < 0.05$). Letters indicate differences between raw and pasteurized samples. Asterisks indicate differences among raw samples (RS1 vs RS2) and pasteurized samples (PS1 vs PS2)

Table 2 reports the results of biochemical analyses performed on tomato-based drinks. The two raw blends showed high contents of lycopene and polyphenols, as well as higher antioxidant activity. Interestingly, the heat treatment did not significantly alter the content of the above-mentioned functional compounds. In agreement with Giovannucci [9],we may hypothesize that the biochemical properties of S1 and S2 resulted quite stable after the thermal treatment because of the simultaneous presence of antioxidants (i.e. lycopene) and other micronutrients (i.e. minerals). These molecules can produce synergistic interactions able to preserve the functionality of polyphenols and carotenoids. As already reported by Dewanto et al. [26], also in this case, the lycopene content was increased after pasteurization (Table 2). This data is consistent with the ability of lycopene to increase its bio-accessibility following the thermal treatment [27]. Unlike sugar content decreased by 27.1 % and 25.9 % in S1 and S2, respectively. The sugar content decrease may be the result of chemical reactions (i.e. Mallard's reaction) induced by high pasteurization [25].

Table 2. Lycopene (mg L^{-1}), antioxidant activity (mg L^{-1}), total polyphenols (mg L^{-1}), vitamin C (mg L^{-1}) and sugars (kcal L^{-1} and g L^{-1}) of tested combinations before (RS1, RS2) and after high pasteurization (PS1, PS2)

Attributes	Samples			
	RS1	PS1	RS2	PS2
Lycopene (mg L^{-1})	188.9 ± 1.8b*	230.9 ± 2.0a*	132.8 ± 4.3b	149.6 ± 3.1a
Antioxidant activity, AF (mg L^{-1})	8229.4 ± 680.6a	7813.7 ± 849.9a	8437.2 ± 552.1a	6705.2 ± 611.9b
Antioxidant activity, OF (mg L^{-1})	762.0 ± 106.7a	730.2 ± 114.2a	1042.8 ± 103.3a*	872.2 ± 103.6a
Total polyphenols (mg L^{-1})	275.9 ± 23.6a	277.5 ± 23.8a	339.6 ± 12.2a*	362.1 ± 11.9a*
Vitamin C (mg L^{-1})	95.7 ± 0.2a	46.3 ± 0.5b	105.5 ± 0.8a*	100.4 ± 0.4b*
Sugars[a] (kcal L^{-1})	283.1 ± 0.1a*	206.3 ± 0.2b*	272.8 ± 0.2a	202.16 ± 0.1b
Sugars (g L^{-1})	74.5 ± 0.1a*	54.3 ± 0.2b*	71.8 ± 0.2a	53.2 ± 0.1b

Values followed by different letters and asterisks are significantly different ($p < 0.05$). Letters indicate differences between raw and pasteurized samples. Asterisks indicate differences among raw samples (RS1 vs RS2) and pasteurized samples (PS1 vs PS2). All the analyses were made in triplicate. [a]Kilocalories were calculated using the method described by Southgate and Durnin [28].

From a nutritional point of view, the two combinations provided satisfactory results. In fact, they showed a lower caloric intake (Table 2) compared with different energy drinks on the market (Table 3). These findings indicated that a drink based on fruit juices, including tomato juice, can be healthier than energy drinks, which are usually associated to a low nutritional value and a high caloric intake.

Table 3. Sugar content of different energy drinks used as comparison

Energy drinks	Sugar content[a]	
	Kcal L^{-1}	g L^{-1}
Go&Fun green	414.2	109.0
Red bull	421.8	111.0
Monster	421.8	111.0

[a]Data related to sugar content of reported energy drinks were collected on the market. Kilocalories were calculated using the method described by Southgate and Durnin (1970) [28].

The different volatile composition of S1 and S2 may explain their different sensory profiles (Table 4). In fact, RS2 showed a lower concentration of typical fresh tomato volatile compounds, such as 6-methyl-5-hepten-2-one, that is responsible for tomato-like flavour, or ethyl butanoate, hexanal and *trans*-2-hexenal, that are responsible for fresh-cut grass [29-33]. We may hypothesize that the lower amount of tomato volatile compounds associated to RS2 was mainly due to the major dilution of this blend, which has one more ingredient (orange juice) compared to RS1. The orange juice enriched the volatile composition of RS2 increasing the concentration of some esters [34]. These molecules contributed to mask the tomato odour, making the flavour more appetizing. In the same blends, new volatile compounds were found after high pasteurization. Most of these molecules (i.e. pentanal, *trans*-2-pentenal, nonanal, decanal, benzyl acetate, dimethylsulfide) were identified as being mainly responsible for sensory profile change of pasteurized drinks [35-37]. They contributed to make the tomato flavour more intense (higher perception of cooked tomato) and the taste more biting.

Table 4. Volatile compounds (μg L^{-1}) of the tested blends before (RS1, RS2) and after high pasteurization (PS1, PS2)

Compound (μg L^{-1})	RS1	PS1	RS2	PS2
Pentanal	ND	9.8 ± 3.9	ND	ND
trans-2-Pentenal	ND	ND	ND	14.4 ± 1.0
Hexanal	1707.5 ± 274.6b	1025.0 ± 316.5a	1174.9 ± 213.1a	904.6 ± 243.2a
Furfural	12.5 ± 0.7	ND	41.7 ± 3.3*b	21.7 ± 3.8a
trans-2-Hexenal	460.1 ± 90.7a	753.7 ± 206.2a	436.5 ± 117.3b	700.4 ± 39.2a
Heptanal	27.7 ± 2.4*b	2.8 ± 1.6a	17.9 ± 4.9a	18.2 ± 3.9a
Nonanal	ND	36.1 ± 5.8	ND	ND
Decanal	ND	ND	ND	3.1 ± 0.5
2,4-Hexadienal (E, E)	59.2 ± 11.6b	26.0 ± 9.3a	64.8 ± 2.4	ND
cis-2-Heptenal	109.2 ± 9.6*b	68.7 ± 11.0a	83.8 ± 4.8b	53.8 ± 1.2a
trans-2-octenal	ND	13.0 ± 3.5	70.1 ± 11.4b	35.3 ± 1.7a
1-Penten-3-one	51.8 ± 1.8a	58.6 ± 31.2a	91.7 ± 10.5*a	76.6 ± 31.8a
6-Methyl-5-hepten-2-one	135.9 ± 29.2a	198.8 ± 42.4a	97.1 ± 30.9a	151.1 ± 2.8a
Menthone (t)	31.9 ± 6.6*a	45.2 ± 7.8a	19.9 ± 1.8a	28.0 ± 6.3a
Carvone (t)	3.5 ± 0.0	ND	12.9 ± 1.3*a	11.3 ± 1.5a
trans-Geranylacetone (t)	4.7 ± 1.8b	9,9 ± 0.7a	9.6 ± 2.0*a	8.9 ± 0.8a
α-Terpineol	6.6 ± 0.0a	3.6 ± 0.1a	6.2 ± 0.9b	24.6 ± 2.9a
Ethyl acetate	43.0 ± 7.3a	39.8 ± 17.2a	25.5 ± 10.6a	34.0 ± 3.7a
Ethyl hexanoate	102.1 ± 11.8*a	123.7 ± 8.6a	61.9 ± 6.5a	63.4 ± 2.4a
Isoamyl acetate	27.8 ± 4.0*a	39.8 ± 13.1a	11.5 ± 1.3a	17.8 ± 5.8a
Ethyl butanoate	253.5 ± 2.0*a	318.9 ± 129.5a	155.1 ± 56.8a	186.7 ± 12.0a
cis-3-hexenyl acetate	11.9 ± 2.7a	15.5 ± 0.8a	12.2 ± 1.6a	4.0 ± 0.0a
Benzyl acetate	ND	5.3 ± 1.8*	ND	ND
Isoamyl n-butyrate	39.8 ± 1.2	ND	ND	ND
Linalool	14.3 ± 0.2a	6.6 ± 1.6a	74.8 ± 4.6*b	63.2 ± 0.8*a
2-Ethylfuran	24.6 ± 2.7*b	16.0 ± 2.2*a	14.2 ± 4.5a	14.7 ± 0.9a
2-Methylfuran	ND	ND	14.2 ± 4.5a	17.0 ± 11.9a
Limonene	Tr	Tr	1549.0 ± 543.6a	1628.2 ± 22.8a
2-Isobutylthiazole	16.7 ± 5.9a	12.0 ± 2.1a	15.5 ± 5.7a	9.6 ± 5.4a
Dimethylsulfide (t)	ND	15.2 ± 5.3*	ND	17.3 ± 5.9*

Values followed by different letters and asterisks are significantly different ($p < 0.05$). The asterisks indicate differences among raw samples (RS1 and RS2). Letters indicate differences between raw (RS1, RS2) and pasteurized (PS1, PS2) samples; ND = not detected; Tr = traces; (t) = The volatile compounds were tentatively identified.

Relationships between the sensory properties and chemical data related to S1 and S2 were established by PLS analysis (Figure 1). Global intensity and tomato flavour, which closely characterize RS1, were positively associated to sugar content and aromatic molecules typical of tomato (i.e. ethyl acetate, hexanal, heptanal, *cis*-2-heptenal). After the heat treatment, PS1 was positively correlated to sweet taste and esters as it should be a beverage based on red fruits. RS2 was positively associated with sour taste, red berry fruit flavour and aromatic molecules (i.e. esters and lactones). Unlike PS2 showed orange flavour and bitter taste more prominent. These attributes were positively correlated to total polyphenols, vitamin C content and antioxidant capacity. These data confirm our hypothesis that thermal treatment may stabilize the functional properties (total polyphenols and antioxidant activity) of tested beverages without significantly alter their sensory properties.

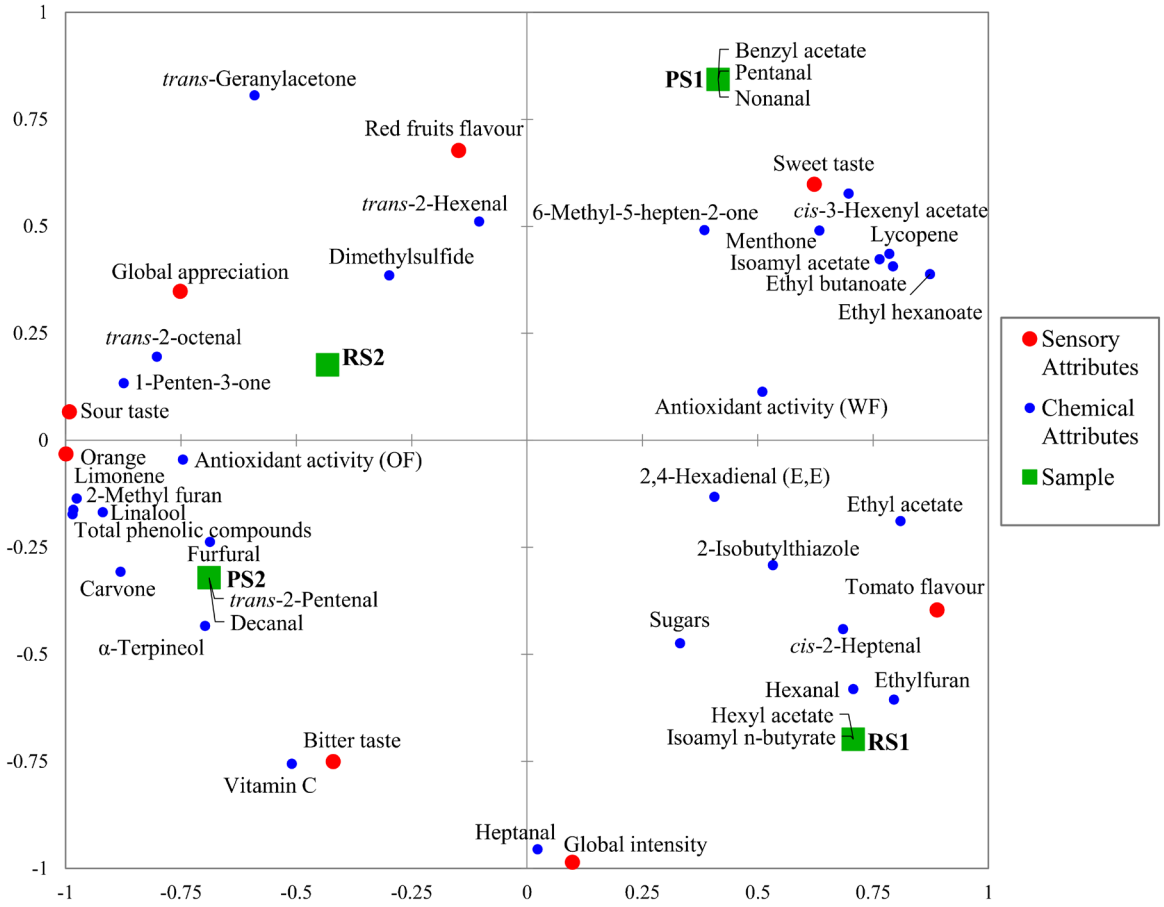

Figure 1. PLS analysis of tomato-based drinks performed on lycopene (mg L^{-1}), total polyphenols (mg L^{-1}), antioxidant activity (mg L^{-1}), vitamin C (mg L^{-1}), sugars (kcal L^{-1}), volatile compounds (µg L^{-1}) and sensory data, before (RS1, RS2) and after high pasteurization (PS1, PS2)

4. Conclusions

In conclusion, the produced juice blends may likely to provide a better flavour as results of the simultaneous presence of aromatic compounds from different fruit sources, with nutritional and biochemical properties very similar to those of starting juices. Particularly, the two formulated tomato-based drinks showed sugar contents lower than those of different energy drinks on the market. S1 reported a suitable lycopene concentration, but the high tomato flavour can make this combination less appreciated. S2 showed high concentrations in total polyphenols and vitamin C. Interestingly, S2 was associated with a softer tomato flavour and high global appreciation. Moreover, high pasteurization (90ºC, 7 min) did not significantly affect sensory and biochemical properties of drinks.

These achievements might be useful to modulate tomato flavour release and consumer acceptability in the formulation of novel drinks based on tomato juice. Further studies are needed to confirm our findings and better understand how the industrial manufacturing process, as well as the storage conditions, can change the drink chemical composition and thus their sensory characteristics.

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