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Acceptability and antioxidant properties of a semi-dried and smoked tomato product

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Abstract

Tomatoes (*Lycopersicon esculentum*) are good sources of antioxidants, such as lycopene, which have been shown to be beneficial for health. Careful drying of tomatoes can concentrate antioxidants and provide a tasty food product that can help to reduce the incidence of cancers and cardiovascular diseases. Semi-drying to a final dry matter content of 20% at 40°C followed by smoking was used to produce a new tomato product. Colour, pH, titratable acidity and lycopene, vitamin C and total phenol content and antioxidant activity of two tomato cultivars (Caluna and Toronto) were determined on fresh, dried or smoked samples and on final products made from the two different cultivars. The pH of the fresh and final products were very similar (overall mean 4.43±0.02) while the titratable acidity of the final product increased to a mean of 1.24% citric acid compared to the fresh tissue mean of 0.47% citric acid. The drying process increased the extracted lycopene content from a mean of 94.4 mg/100 g DM in the fresh tomatoes to 126.4 mg/100 g DM in the semi-dried tomatoes. In contrast, the total phenols were reduced from a mean of 255 mg GAE/100 g DM in the fresh tomatoes to a mean of 214 mg GAE/100 g DM in the semi-dried tomatoes. The mean vitamin C content of the fresh tissue was 313 mg/100 g DM with 32 mg/100 g DM retained in the dried tissue. The overall mean antioxidant capacity of the dried product was increased by the drying and processing treatments to a mean of 2373 ABTS (µM Trolox/100 g DM). Measurement of the colour of the dried products showed the typical red colour of the tomatoes was retained during processing. Panellists evaluated three tomato products made from the cultivars Caluna and Toronto for appearance, colour, taste and overall acceptance. In contrast to many commercial products, the colour of the new tomato products was similar to the original fresh tomatoes. Panellists preferred the dried and smoked Toronto product sprayed with white vinegar. A new smoked tomato product containing health promoting antioxidants was produced.

Key words: *Lycopersicon esculentum*, semi-drying, antioxidants, sensory evaluation.

Introduction

Tomatoes have been identified as an important functional food as they contain a number of antioxidants such as carotenoids (e.g. lycopene), phenolic compounds and ascorbic acid [1-4], in addition to meeting basic nutritional requirements [5]. Tomatoes are an important part of Mediterranean diets where they appear to protect people from cardiovascular disease. However, the protective effect has also been credited to a variety of other foods such as fruits, vegetables, olive oil and red wine [6-7]. Overall, antioxidants present in fruits and vegetables [8] are considered to be the main beneficial effect. The beneficial dietary components of some of these Mediterranean foods include carotenoids in fruits and vegetables, monounsaturated fat and polyphenolic compounds in olive oil and flavonoids in red wine [9-11]. Tomatoes and tomato products also contain high levels of antioxidants which help prevent oxidative damage that is hazardous for humans [12, 13] and they are considered to be important functional foods because they appear to prevent or delay the onset of chronic diseases. Studies have shown that regular consumption of tomatoes and processed tomato products is related to a reduced risk of various chronic diseases such as cancers, especially prostate cancer [9, 14-17] and coronary heart diseases [18, 19].

Cooking tomatoes often has a negative influence on the nutritional properties of tomatoes. It is thought that the cooking can affect levels of the antioxidants, for example, frying tomatoes has been reported to cause significant reductions in ascorbic acid, total phenolic content and antioxidant activity [1]. Drying provides one of the oldest and most effective means of preserving foods from spoilage. Once dry, many foods can be stored successfully for years without refrigeration, if appropriately packaged [20]. As dried tomatoes can be kept for considerable lengths of time they are a valuable product because they can be bought when prices are seasonally low and then stored after processing. The recognized health benefits of tomatoes and tomato products also enhance the value of these products. Nevertheless, processing and health value are not always compatible because many nutrients can be destroyed during processing.

The drying temperatures used to produce commonly available dried products have often caused chemical and enzymatic reactions that can lower the levels of nutrients present, e.g. vitamin C and antioxidants such as lycopene [21], degrade flavour compounds and hence alter colour and flavour [20]. Heating and then drying tomato products under different processing conditions may cause degradation of lycopene, the principal colour component responsible for the distinctive deep-red colour of ripe

tomatoes and tomato products [22-26]. Tomatoes and tomato products are major dietary sources of lycopene and are important not only because of the colour it imparts but also because of its recognized health benefits [20, 27, 28].

In most instances, conditions that contribute to loss of cellular integrity cause a decline in phytochemical content but there are important exceptions where processing and/or cooking, in fact, increases the availability of phytochemicals in fruits and vegetables [29]. Studies have shown that heat processing of tomatoes and tomato products causes lycopene to change into the *cis* form which, in turn, increases its bioavailability [30]. Shi and Le Maguer [23] found that food processing such as cooking or heating may improve lycopene bioavailability by breaking down cell walls and weakening the bonding forces between lycopene and the tissue matrix, thus making lycopene more digestible and enhancing isomerisation. These observations indicate that due to the generation of different *cis*-isomers, the bioavailability of lycopene may be enhanced in natural lycopene containing food products that include a thermal treatment during production. If health benefits are correlated with the uptake of *cis*-lycopene, thermal processing methods should be optimized to provide an increased content of *cis*-isomers in vegetable and fruit products [31].

Air-drying at a lower temperature is reported to have little effect on the lycopene content of tomatoes [23, 32-34]. The total phenolics and carotenoids of tomato have been reported to be reasonably stable during processing under high temperatures, and thermal processing has been reported to release more bound phenolics due to the breakdown of cellular constituents [35].

Smoking is a commonly used processing method in the fish industry. It is generally agreed that phenolic compounds are the major agents involved in the preservation and organoleptic properties of smoked products [36]. The relative concentrations of phenolic compounds in products depend on the nature of the wood used for smoking [37], the method of smoking, pyrolysis temperature and the smoking process [38]. Iliadis *et al.* [39] also found that the smoked taste has a high consumer overall acceptance in smoked foods such as mackerel. Although an increasing number of products are being smoked to preserve them, no recorded data has been found for smoked tomatoes.

The challenge, therefore, is to produce a processed tomato product retaining all the essential characteristics of fresh tomatoes. This includes an attractive red colour, high concentration of antioxidant compounds and a good tomato taste. A recent paper published by Toor *et al.*[40] showed it is possible to produce semi-dried tomatoes that retain both a bright red colour and high levels of antioxidants. In this study it is proposed to use the same low temperature drying process [32] followed by smoking in order to produce an appealing bright red-coloured product while retaining high levels of antioxidants in the tissue.

Materials and Methods

Source of samples and initial processing: Tomato cultivars (Toronto, De Ruiter Seeds CV, Bergschenhoek, The Netherlands) and Caluna (Rijk Zwaan Nederland B.V., De Lier, The Netherlands) used for these experiments were grown in a commercial greenhouse located in Springston, Canterbury, New Zealand (43°39'S, 172°25'E) using a hydroponic system. The tomatoes were harvested at Maturity Stage 5 as defined by the California Tomato Commission [41]. The tomatoes were washed for 1 minute in a solution of 0.2% Divosan hypochlorite (JohnsonDiversey New Zealand Limited, Papatoetoe, Auckland) and then cut into halves longitudinally across the middle. To accelerate drying and avoid water retention under the skin, several holes were made in the skin with a small spike. The tomatoes were then sprayed with a solution (1 L white or balsamic vinegar; containing 200 g sodium chloride; 200 g sucrose (Pam's Products Ltd., Mt Roskill, Auckland)) and 1 g potassium sorbate (Formula Foods Corporation Ltd., Sockburn, Christchurch), to prevent bacteriological growth and assist with drying, then allowed to stand for five minutes before being dried on a metal grid (13 mm x 13 mm). Weights (200 g) were put on top of the tomatoes which were placed in drying cabinet set at 40°C with an air flow of 0.05 m^3/s. After drying to 19.3±1.7% dry matter (DM), the tomatoes were smoked for 5 minutes in a 10 L capacity smoke box using Manuka (*Leptospernum scoparium*) sawdust. The smoked semi-dried tomatoes were then placed in glass jars, canola oil added and the jars flushed with nitrogen gas before being sealed with a metal lid.

Quantitative analysis: The dry matter (DM) content of the fresh and processed tomatoes was determined by drying representative tomato samples in a 105°C oven for 24 hours [42].

CIELAB colour measurements were performed in triplicate on the flesh of representative samples of the fresh and processed tomatoes using a Minolta Chroma Meter (model CR-210, Minolta Camera Co. Ltd. Osaka, Japan), consisting of an 8 mm diameter measuring area with a diffuse illumination/0° viewing angle. A standard white tile (L* 98.07, a*-0.23, b*1.88) was used to calibrate the colorimeter.

For the measurement of pH, titratable acidity and ascorbic acid fresh tomatoes were homogenized directly and the dried tomato samples were diluted to 5 ml with deionized water. Ten g of each homogenate was used for analysis.

The pH and titratable acidity were determined using a Metrohm 670 titroprocessor (Metrohm Herisau, Switzerland) that measures the amount of 0.1 M NaOH required to neutralize the tomato acids. The titratable acidity was expressed as g citric acid/100 g DM.

The ascorbic acid content of the tomatoes and tomato products were measured by titration with phenolindo-2,6-dichlorophenol (DPIP) (Sigma-Aldrich Ltd, Palmerston North, NZ) using a Metrohm 670 titroprocessor (Metrohm Herisau, Switzerland) [42]. One g of homogenate was mixed with 40 ml of buffer (1 g/L oxalic acid and 4 g/L anhydrous sodium acetate in water made up to 1 L) and titrated against a dye solution containing 295 mg/L DCPIP and 100 mg/L sodium bicarbonate.

For lycopene analysis, 4 g of the freshly homogenized tomato samples were weighed into light-proof tubes. The extraction method was adapted from the method of Sharma *et al.* [43]. A 20 ml aliquot mixture of hexane-acetone-ethanol (2:1:1, v/v/v) was added to the sample and the tubes mixed on a rotary mixer for 30 minutes. Five ml of water was added and the tubes were shaken and centrifuged at a very low speed (58 rcf) for 5 minutes. The hexane (AR, Sigma-Aldrich Ltd, Palmerston North, NZ) layer was collected in a new tube and the residual layer was re-extracted four times to ensure complete extraction of lycopene. The absorbance of the combined hexane layers was measured at 472 nm by a spectrophotometer (Unicam Helios Beta, Pye Unicam, Cambridge, UK) using hexane as a blank. The specific extinction

coefficient K of 3450 L/cm/g was used to calculate the total lycopene content of the extracts [44]. The results were expressed as mg lycopene/100 g DM.

For analysis of water soluble antioxidants, 4 g of the freshly homogenized tomatoes was extracted in 10 ml 80% acetone (AR, Sigma-Aldrich Ltd, Palmerston North, NZ) on a rotary mixer in the dark for 4 hours at 4°C and centrifuged at 2726 rcf for 10 minutes. All samples were extracted in triplicate and the supernatant was used to measure the antioxidant activity and total phenolic content.

The total phenolic content was measured according to a method adapted from Spanos *et al.* [45]. A standard curve (ranging from 0 to 50 µg gallic acid per assay) was prepared by making a 0.5 mg/mL solution of gallic acid in 80% acetone. To 500 µL of appropriately diluted sample or standard, 1 mL of 0.2 M Folin-Ciocalteau reagent (Merck Ltd, Palmerston North, NZ) and 1 mL of 7.5% w/v sodium carbonate in water were added. The samples were vortexed and incubated for 15 min at 45°C before being cooled to room temperature and vortexed again before the absorbance was measured at 765 nm in a Unicam Helios Beta spectrophotometer (Pye Unicam, Cambridge, UK). Two replicates from each extraction were measured. The results were expressed as gallic acid equivalent (GAE)/100 g DM.

The radical scavenging capacity (antioxidant activity) of the tomato sample extracts was measured using the modified ABTS (2,2'- azinobis-3-ethylbenzothiazoline-6-sulfonate, Sigma-Aldrich Ltd, Palmerston North, NZ) radical decolourisation assay adapted from Miller and Rice-Evans [46]. The ABTS solution was incubated at 30°C and diluted with 5 mM phosphate buffered saline (Sigma-Aldrich Ltd, Palmerston North) to reach an absorbance of 0.700 at 734 nm using UV-visible recording spectrophotometer (Shimadzu UV2100, Shimadzu Corporation, Kyoto, Japan) with a temperature-controlled cell holder. Standard curves were prepared using 0.5 mM Trolox® (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid, Sigma-Aldrich Ltd, Palmerston North, NZ) in 5 mM phosphate buffered saline diluted to final concentrations ranging from 0 to 200 µM/mL Trolox. ABTS solution (1 mL) was added to 100 µl of standard or sample and vortexed for 10 seconds. The decolourisation caused by reduction of the cation by antioxidants from the sample was measured at 734 nm and values were taken 5 minutes after initial mixing. The Trolox equivalent activity (TEAC) in the samples was expressed as µM Trolox/100 g DW.

Sensory analysis: Sensory evaluation of three processed samples (Toronto tomato halves sprayed with balsamic vinegar, dried and smoked; Caluna tomato halves sprayed with white vinegar, dried and smoked and Toronto tomato halves sprayed with white vinegar, dried and smoked) was undertaken using a consumer-type panel comprising eighty two staff and students from Lincoln University. The tomatoes were presented on a white plate and panellists were asked which product they preferred with regards to colour and overall appearance (on a five-point scale where 1 = like very much to 5 = dislike very much). The panellists were then asked taste the samples and to score their overall acceptance (on a seven-point scale where 1 = like very much to 7 = dislike very much) of the three tomato products. They were then asked to comment on any differences they observed between a fresh tomato and the processed samples as well as two commercially available dried products.

Statistical analysis: All the results from the chemical analyses were analysed using the Minitab Version 14 statistical software (Minitab Ltd, Coventry, UK). One-way ANOVA was carried out to determine the differences between the four stages of processing and the two cultivars. A Fisher test at 95% confidence was used to make the different groupings between the results. The Friedman test (ISO/DIS 8587.2) was used to analyse the sensory evaluation results and the average ranking of the panellists.

Results and Discussion

Preliminary studies showed that tomatoes sprayed with balsamic vinegar produced a dried tomato that had a much darker colour than tomatoes sprayed with white vinegar. As the objective of this experiment was to retain as far as possible the original bright red colour of the fresh tomatoes, these samples were not analysed for CIE colour or chemical and antioxidant analysis but they were retained for consumer sensory analysis.

Colour changes of semi-dried tomato product during processing: Processing the two tomato cultivars resulted in significant changes in the L* values (Table 1); the drying process lowered the brightness by nearly two units ($P<0.01$), but smoking did not change the L* value any further. Overall, the Toronto products had a higher L* value than the Caluna products ($P<0.001$); both values were much higher than those of commercially dried tomato samples (Sébastien Veillet, pers. comm.).

The a* value which is a measure of the redness of the tissue, increased during processing with the highest values being observed after drying and smoking, with Caluna showing higher

Table 1. CIELAB L*a*b* colour analysis of fresh, semi-dried and smoked Caluna and Toronto tomatoes (mean ± SE).

Cultivar	Process	L*	a*	b*	a*/b*	Chroma $(a^{*2} + b^{*2})^{0.5}$
Caluna	Fresh	38.3 ± 0.3^{b}	27.7 ± 0.4^{b}	18.2 ± 0.2^{a}	1.52 ± 0.02^{d}	33.1 ± 0.4^{b}
	Dried	36.7 ± 0.4^{a}	31.2 ± 0.4^{c}	20.4 ± 0.3^{b}	1.53 ± 0.03^{d}	37.3 ± 0.3^{d}
	Smoked	36.1 ± 0.6^{a}	30.6 ± 0.4^{bc}	21.7 ± 0.5^{c}	1.41 ± 0.04^{c}	37.5 ± 0.4^{d}
	Final product	36.9 ± 0.3^{a}	29.0 ± 0.5^{b}	19.0 ± 0.5^{ab}	1.53 ± 0.03^{d}	34.6 ± 0.7^{b}
Toronto	Fresh	39.9 ± 0.5^{c}	24.5 ± 0.3^{a}	18.3 ± 0.2^{a}	1.34 ± 0.02^{b}	30.6 ± 0.3^{a}
	Dried	38.0 ± 0.3^{b}	29.7 ± 0.4^{b}	21.4 ± 0.2^{c}	1.39 ± 0.02^{bc}	36.6 ± 0.4^{c}
	Smoked	38.2 ± 0.3^{b}	29.9 ± 0.4^{b}	23.6 ± 0.3^{d}	1.27 ± 0.02^{a}	38.1 ± 0.3^{d}
	Final product	39.0 ± 0.9^{c}	26.4 ± 0.6^{a}	20.0 ± 0.5^{b}	1.32 ± 0.03^{b}	33.1 ± 0.7^{b}
Source of variability	df					
Cultivar	1	***	***	***	***	**
Process	3	**	***	***	**	***
Cultivar x process	1	ns	**	*	ns	***

Values with different superscripts in a same column are significantly different ($p<0.05$ ns = non-significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

a* values than Toronto (P<0.001). The combination of a lower L* value and higher a* value resulted in a darker red colour for Caluna compared to Toronto. The b* value evaluates the yellowness of the product. The highest values (P<0.05) were found just after smoking as the Manuka sawdust used to smoke the tomatoes had deposited a thin yellow layer on the tomato surface. The Toronto tomato products were more orange compared to Caluna products (P<0.001), as demonstrated by a higher b* value. As Caluna products have higher a* values and lower b* values than Toronto products the a*/b* ratio is much higher in Caluna, which reflects the redness of the product. With a final a*/b* ratio of 1.32 the Toronto product looked more red-orange while the Caluna final product appeared darker red.

Chroma has been related to overall consumer acceptance [47]. Maximum chroma values for both cultivars were reached after smoking. The addition of oil reduced the chroma values by 3 to 5 units (P<0.05).

One objective of this experiment was to retain the bright red colour of the fresh tomatoes during processing in order to make the final product attractive to consumers. Table 1 shows that the CIE values for final product values were very similar to the original fresh tomatoes with sometimes higher a* values (P<0.05). Overall, the chroma values of the two final products were very similar. Since the most important criteria that can influence consumer choice is chroma [47] and as the chroma values of these products were higher than those found for commercial products currently available on the market, consumers may be more attracted to these semi-dried products.

Chemical analysis during processing of a semi-dried tomato product: The pH values (Table 2) of the fresh and final products were very similar (overall mean 4.43±0.02) and lower than that considered to be a critical point above which bacteria growth occurs. Both the spraying with vinegar and the drying increased the concentration of natural organic acids. The titratable acidity of both cultivars increased greater than two fold (P<0.05) after drying, the final mean value was 1.24% citric acid/100 g DM. Titratable acidity level may be an important criterion in consumer acceptance of the products because a high value correlates to an acceptable acidic taste.

Lycopene analysis showed a large range of values (from 90 to 130 mg/100 g DM) similar to the values of Shi and Le Maguer [23] who found that lycopene concentration in tomatoes can range from 10 to 200 mg/100 g DM. More recently, Garcia *et al.* [48] reported values up to 250 mg/100 g in California-grown tomatoes. In this experiment there was an apparent increase in lycopene content on a DM basis after processing as was also observed previously [49]. This increase is most likely to be due to improved extraction and recovery resulting from increased disruption of the cellular matrix allowing lycopene to be more easily extracted after drying and processing. This suggests that lycopene was not destroyed during processing at low temperatures. The lycopene levels in the two final products (mean 126.5 mg/100 g DW) were higher than those found in similar dried commercial products (data not shown). As the lycopene content of tomatoes changes over the year, even higher values could be expected for tomatoes harvested during summer and at the very last stage of ripeness.

The semi-dried products contained a small amount of vitamin C (mean 32 mg/100 g DM). The two main stages of the processing

Table 2. Chemical and antioxidant activities of fresh, semi-dried and smoked Caluna and Toronto tomatoes (mean ± SE).

		Chemical analyses			Antioxidant analyses			
Cultivar	Process	Dry matter (%)	pH	Titratable acidity (% citric acid/100 g DM)	Lycopene (mg/100 g DM)	Vitamin C (mg/100 g DM)	Total phenols (mg GAE/100 g DM)	Antioxidant capacity - ABTS (µM trolox/100 g DM)
Caluna	Fresh	5.5	4.37 ± 0.01	0.49 ± 0.01^{a}	90.8 ± 2.2^{a}	310 ± 11.6^{d}	189 ± 7.1^{b}	2842 ± 80^{d}
	Dried	16.4	4.50 ± 0.01	1.08 ± 0.01^{b}	117.0 ± 3.5^{d}	73 ± 1.9^{b}	150 ± 1.5^{a}	2049 ± 199^{b}
	Smoked	19.4	4.37 ± 0.01	1.41 ± 0.01^{d}	123.7 ± 1.7^{d}	76 ± 7.5^{b}	272 ± 3.1^{c}	3901 ± 109^{c}
	Final product	19.4	4.46 ± 0.01	1.26 ± 0.01^{c}	122.8 ± 1.2^{d}	28 ± 7.1^{a}	213 ± 1.4^{b}	2519 ± 218^{c}
Toronto	Fresh	5.1	4.36 ± 0.01	0.45 ± 0.01^{a}	98.1 ± 1.0^{b}	316 ± 15.7^{d}	221 ± 4.3^{b}	2520 ± 396^{c}
	Dried	16.8	4.55 ± 0.02	0.90 ± 0.01^{b}	104.2 ± 1.9^{c}	120 ± 3.2^{c}	160 ± 1.7^{a}	1531 ± 208^{a}
	Smoked	20.6	4.43 ± 0.01	1.16 ± 0.01^{c}	92.4 ± 1.3^{a}	144 ± 4.4^{c}	210 ± 5.7^{b}	2309 ± 101^{b}
	Final product	20.6	4.42 ± 0.01	1.22 ± 0.01^{c}	130.1 ± 1.5^{e}	36 ± 2.0^{a}	216 ± 3.5^{b}	2228 ± 162^{b}
Source of variability		df						
Cultivar		1	ns	***	*	***	**	***
Process		3	ns	***	***	***	***	***
Cultivar x process		1	ns	***	***	***	***	***

Values with different superscripts in the same column are significantly different (p<0.05) ns = non-significant, * p < 0.05, ** p < 0.01, *** p < 0.001.

responsible for vitamin C losses were the drying process (P<0.001) and storage in oil (P<0.001). Even though drying was performed at low temperatures, the air flow could easily oxidize the vitamin C. On a wet matter basis, losses ranging between 45 and 65% of vitamin C were observed. These were similar to the values reported by Chang *et al.* [50] who found that 56 and 61% of vitamin C was lost on a WM basis after 8 h drying (2 h at 80°C followed by 6 h at 60°C).

Total phenols and total antioxidant activity: Drying reduced the level of total phenols in the tomato samples (P<0.001) with the Toronto tomatoes appearing to be more sensitive to processing than Caluna. The smoking stage significantly increased (P<0.001) the total phenol content of the final product derived from Caluna. This indicates that wood smoke made a contribution to the phenol content of the final product. The total phenol contents of the final products (mean 215 mg GAE/100 g DW) were very similar to each other and to the original fresh tomatoes (mean 205 GAE/100 g DM).

The phenol content in fresh tomatoes has been reported to range from 300 to 400 mg GAE/100 g DM [40, 51] but the values found in this study were lower (mean 205 mg GAE/100 g DW). Toor *et al.* [40] reported changes over a year starting from 169 mg GAE/100 g DW and rising to 579 mg GAE/100 g DW, the lowest values corresponding to tomatoes grown in winter and early spring, the period of this study. In contrast to the results of our study, Gahler *et al.*[51] reported an increase of 44% in total phenolic content on a fresh weight basis during drying at high temperatures (180 to 220°C for 45 min), and Chang *et al.*[50] reported increases below 30% after processing at average temperatures (80 and 60°C for 8 h) with a 190% increase after drying at a low temperature (40°C for 20 h).

The total antioxidant activity also changed considerably during processing. There was a decrease during the drying process (P<0.001) and then the smoking process led to an increase in the total antioxidant activity. The total antioxidant activity of the raw tomato (mean 2681 ABTS, μM Trolox/100 g DM) was very similar to that of the final products (mean 2374 ABTS, μM Trolox/100 g DM).

Sensory evaluation - colour: The results presented in Table 3 confirm that the tomatoes sprayed with balsamic vinegar gave a darker-coloured final product that was not appreciated by the panellists when compared to the two cultivars sprayed with white vinegar. The colour of the semi-dried and smoked Toronto product was the most preferred cultivar but the mean ranking value was not significantly different from Caluna processed in the same way.

Sensory evaluation - overall appearance: The Toronto white vinegar-treated tomatoes got the highest mean ranking (mean 2.20) for overall appearance by the panellists (Table 3), Caluna was the next most appreciated product. Toronto tomatoes prepared with balsamic vinegar had a mean value of 3.06 which was the least appreciated of the three samples evaluated.

Sensory evaluation - overall acceptance of taste: No significant differences could be observed when the panellists evaluated the taste of the three semi-dried and smoked products (Table 3). The panellists appeared to prefer the taste of the tomatoes that had been treated with white vinegar (mean overall acceptance value for Toronto and Caluna, 1.84), the average taste score for Toronto treated with balsamic vinegar was only marginally higher (2.12).

Table 3. Mean score of three semi-dried and smoked tomato products based on their appearance and average ranking for colour, taste and overall acceptance.

	Toronto with balsamic vinegar	Toronto with white vinegar	Caluna with white vinegar
Colour	2.61	1.64	1.75
Overall appearance	3.06	2.20	2.39
Overall acceptance (taste)	2.12	1.84	2.04

The panellists were then encouraged to write comments about the samples they had evaluated. The semi-dried products were described as "looking fresher" than the others and "still (containing) a lot of moisture." As processing the semi-dried tomatoes did not alter the shape of the tomato this may have positively influenced many of the panellists. Nevertheless, some panellists appeared to prefer commercially prepared tomato products perhaps because this was "what they expected from dried tomatoes". These panellists may have been regular consumers of dried tomatoes and were used to their dark-brown colour instead of the red colour of the semi-dried products made in this study.

Conclusions

This study presents a new method of producing semi-dried tomatoes which retained a low pH and a juicy texture. The combination of drying at 40°C for 20 hours and smoking for 5 minutes produced a final product containing a mean DM of 19.3±1.7%. Processing retained most of the attributes of fresh tomatoes, especially the colour; the process retained most of the antioxidants naturally present in fresh tomatoes and also some vitamin C (mean 32 mg/100 g DM). The smoking process gave a taste that was appreciated by the panellists. Sensory evaluation showed that the final product sprayed with white vinegar was most liked by panellists. Overall, these tomato products have the potential to be a healthy, nutritious and colourful functional food to add to the diet.

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