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Potential of figs from cultivars grown in subtropical regions for canning purposes

Abstract – The objective of this work was to evaluate the influence of fig (*Ficus carica*) cultivars grown in subtropical regions on the physicochemical, rheological, and sensorial characteristics of the canned figs. Fresh fruits of the cultivars were analyzed for length, diameter, unit mass, total soluble solids, total titratable acidity, pH, total soluble solids/total titratable acidity ratio, and color. Canned figs were evaluated for titratable acidity, pH, color, texture profile, and sensory characteristics. The different physicochemical characteristics of the fresh figs influenced those of the obtained canned fruits. The canned figs from 'Lemon' and 'Pingo de Mel' presented the lowest and highest pH, respectively, whereas those from 'Troiano' showed the highest total titratable acidity. As for color, after processing, the canned figs, in general, presented a more greenish and darker color than the fresh fruits. The canned figs from 'Brunswick' and 'Troiano' had the lowest acceptance, whereas those from 'Bêbera Branca' and 'Roxo de Valinhos', the greatest. Less acid and softer canned figs are more widely accepted, which can be obtained from all cultivars, except from Brunswick and Troiano.

Index terms: *Ficus carica*, processed fruits, rheological characteristics, sensorial quality.

Potencial de figos de cultivares cultivadas em regiões subtropicais para elaboração de doce em conserva

Resumo – O objetivo deste trabalho foi avaliar a influência de cultivares de figueiras (*Ficus carica*) cultivadas em regiões subtropicais nas características físico-químicas, reológicas e sensoriais dos doces de figos em conserva. Os frutos frescos das cultivares foram analisados quanto a comprimento, diâmetro, massa unitária, sólidos solúveis totais, acidez total titulável, pH, relação sólidos solúveis totais/acidez total titulável e cor. Os figos em conserva foram avaliados quanto a acidez titulável, pH, cor, perfil de textura e características sensoriais. As diferentes características físico-químicas dos figos frescos influenciaram as dos frutos em conserva obtidos. Os figos em conserva de 'Lemon' e 'Pingo de Mel' apresentaram os menores e os maiores pH, respectivamente, enquanto os de 'Troiano' apresentaram a maior acidez total titulável. Em relação à cor, após o processamento, os figos em conserva, no geral, apresentaram coloração mais esverdeada e escura que o fruto fresco. Os figos em conserva obtidos de 'Brunswick' e 'Troiano' tiveram a menor aceitação e os de 'Bêbera Branca' e 'Roxo de Valinhos', a maior. Figos em conserva menos ácidos e mais macios são mais amplamente aceitos, o que pode ser obtido de todas as cultivares, exceto de Brunswick e Troiano.

Termos para indexação: *Ficus carica*, frutas processadas, características reológicas, qualidade sensorial.

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Introduction

The fig (*Ficus carica* L.) tree is historically one of the most exploited fruit trees since ancient times and is among the most cultivated species in the countries of the Mediterranean coast, especially in Turkey, Algeria, Morocco, and Egypt (FAO, 2017). In subtropical regions, some of the grown cultivars have potential to be commercially exploited, as already occurs in Brazil, in a relevant way in regions with subtropical climate (Pio et al., 2019).

Currently, the Roxo de Valinhos cultivar is the only one commercially exploited in subtropical regions (Dalastra et al., 2009; Souza et al., 2014a; Silva et al., 2017). This cultivar is characterized by its rusticity, high vigor, and reasonable fruit yield, and its fruits can be used both for fresh consumption and for industrial processing (Souza et al., 2014a). Despite the acknowledged potential of this cultivar, it is still necessary to introduce new cultivars to diversify the present single-variety cultivation, as well as to identify cultivars that can be used to produce high-quality processed figs in these regions.

In general, figs are characterized by their high moisture content of 82.2%, are considered as a great source of carbohydrates – of which the principal sugars are soluble, responsible for their sweet taste –, and present high perishability, making their fast transportation to the centers of consumption necessary. The main causes of losses in fig quality are inadequate harvest and packing, as well as the lack of standardization in the classification of the product (Caetano et al., 2017). One way to increase consumption and also the value of the final product is processing foods in the form of jelly, jam, preserve, or canned fruits.

In the world market, dried figs are widely marketed and appreciated for their high quality – large fruit size, light color, soft texture, longer shelf life, as well as better taste retention and a more attractive appearance (Chimi et al., 2008; Sen et al., 2010). Since several fig cultivars are available for the diversification of the fig culture, it is necessary to evaluate which one of them is the most suitable for processing in the form of canned fruits.

The objective of this work was to evaluate the influence of the fig cultivars grown in subtropical regions on the physicochemical, rheological, and sensorial characteristics of the canned figs produced with their fruits

Materials and Methods

The figs processed as canned fruit were obtained from eight fig cultivars: Bêbera Branca, Brunswick, Lemon, Mini Figo, Pingo de Mel, Roxo de Valinhos, Três num Prato, and Troiano. The still-green figs were harvested in the orchard of the fruit sector of Universidade Federal de Lavras (UFLA), located in the state of Minas Gerais, Brazil.

The experimental design was completely randomized, with 16 treatments – 8 cultivars to pick fresh figs from and 8 canned figs obtained from these cultivars. Considering that the analyses were done in triplicates, the total number of samples was 48.

After harvest, fruits were selected for size and uniformity and were immediately transported to the postharvest laboratory of UFLA. There, the fruits with physical or microbiological damages were discarded and the remaining ones were sanitized with chlorinated water and had their skin mechanically removed. The later procedure was done with the aid of a machine, consisting of a box with a low-rotation shaft, which removes skin due to the friction between the fig and small stones; salt was used to remove fruit latex. Subsequently, the fruit were stored in the cold until processing as canned fruit.

Eight canned-fruit formulations were prepared in the laboratory for processing of vegetable products of UFLA; the only difference among them was the used fig cultivar.

The fruits were cooked in the open copper pan with a gas burner for 5h30min. After cooling, the water was changed, and the fruits remained the same until the following day. Subsequently, for processing, 70% water and 30% sugar were added to 120 fig units, followed by cooking. When the soluble solids reached 60 °Brix, heating was stopped; total soluble solids (TTS) were determined using the RT-82 portable refractometer (HighMed: Soluções em Tecnologia de Medição Ltda., Tatuapé, SP, Brazil). The hot canned figs were placed in sterile glass jars, cooled to room temperature, and stored at 7°C until the moment of analysis.

The fresh fruits and canned figs were analyzed in three replicates at the postharvest laboratory of UFLA. Fresh fruits were analyzed as to length, diameter, unit

mass, TSS, total titratable acidity (TTA), pH, TSS/TTA ratio, and color (L*, Chroma, and °Hue). The canned figs from the different fig cultivars were evaluated for titratable acidity, pH, color (L*, Chroma, and °Hue), texture profile, and sensorial characteristics.

Fruit length and diameter were measured with the aid of the digital caliper (Kingtools, São Paulo, SP, Brazil), and average fruit weight was obtained by weighing each fruit individually on the AUX220 semi-analytical scale (Shimadzu do Brasil, Barueri, SP, Brazil).

TTA, TSS, and pH values were determined according to the analytical standards of Instituto Adolfo Lutz (Zenebon et al., 2008). Color was obtained by the method described in Gennadios et al. (1996). L*, Chroma, and °Hue values were determined using the CR-400 colorimeter (Konica Minolta Business Solutions do Brasil Ltda., São Paulo, SP, Brazil) with CIELab standards and D65 illuminant, with L* ranging from 0 (black) to 100 (white).

The texture profile analyses of the canned figs, specifically of the fig fruit, were performed in penetration mode under the conditions described by Souza et al. (2014c): pretest speed of 1.0 mm s^{-1}, test speed of 1.0 mm s^{-1}, posttest speed of 1.0 mm s^{-1}, time interval between penetration cycles of 10 s, distance of 40 mm, and compression with a 6.0-mm diameter cylindrical aluminum probe using the TA-XT2i texture analyzer (Stable Micro Systems Ltd., Surrey, United Kingdom); the fruit samples were compressed by 30%. The rheological parameters analyzed were hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness (Friedman et al., 1963). Hardness measures the force required to achieve a given deformation (Friedman et al., 1963; Vliet, 1991), whereas adhesiveness is the work necessary to overcome the forces of attraction between a contact surface and the surface of the evaluated food (Vliet, 1991). Springiness determine how fast the deformed material returns to its original condition after the removal of the deformation force, respectively, whereas cohesiveness is the extent to which the material can be distended before breaking irreversibly. Gumminess determines the energy required to disintegrate a semisolid food to the point of being swallowed, and the mixture reflects the energy required to chew a solid food to this point (Vliet, 1991). Finally, chewiness is the amount of energy required to simulate the chewing of a semisolid sample to a constant state of swallowing.

The sensory analysis was carried out at the sensory analysis laboratory of UFLA, in compliance with the local ethics committee, approval number 1,091,594; there, an acceptance test was performed with 90 consumers, during two days. The evaluated characteristics were: color, flavor, consistency, and overall liking, using a 9-point hedonic scale (1, extremely dislike; and 9, extremely like). Each taster received a fig unit from each of the formulations (four per day) and was informed not to eat the whole sample but only enough for the evaluation. The samples were served in 50-mL plastic cups, coded with three digits, in a balanced order.

The univariate statistical analysis was used to compare both the different fig cultivars, regarding their physical and physicochemical attributes, and the different canned fruits, as to their physicochemical, rheological, and sensorial characteristics. Means were compared by Tukey's test to verify if samples differed significantly at 5% probability.

In order to better visualize the sensorial acceptance by the consumer, a three-way internal preference map was generated by the parallel factor analysis (Parafac) (Nunes et al., 2011). The Parafac model was optimized by using the value of core consistency diagnostics (Concordia) to choose the number of factors (Bro, 1997; Nunes et al., 2011). Data were analyzed with the SensoMaker, version 1.8, software (Pinheiro et al., 2013).

Results and Discussion

As for the size and weight parameters of the different fig cultivars, Três num Prato showed the greatest average length of 45.29 mm and Troiano the greatest average diameter, reaching 31.44 mm (Table 1). The unit weight among the cultivars ranged from 4.75 for Mini Figo to 16.53 g for Roxo de Valinhos. It should be noted that, regarding the consumption of fresh fruits, those with a greater caliber are more attractive to the consumer.

The TSS content varied from 2.00 to 5.00 °Brix, TTA from 0.40 to 1.20 citric acid per 100 g, pH from 4.53 to 5.89, and the TSS/TTA ratio from 2.45 to 5.75. These parameters are extremely important because they help to define the best destination for the consumption of

the fruits: in the form of fresh fruit or, after processing, in the form of jelly, preserve, or canned fruits (Curi et al., 2016).

The degree Brix is largely associated with the presence of sugars and organic acids; the higher the content of these nutrients, the higher the Brix. This result may be explained by the higher temperatures of subtropical environments, which, together with higher photoperiods, provide fruits rich in SS (Maro et al., 2014), making them sweeter and generally more attractive to consumers (Curi et al., 2017b). 'Mini Figo' and 'Troiano' stood out for having higher SS contents.

According to Paiva et al. (1997), acidity is one of the parameters that affect the classification of fruits based on flavor. Fruits with acidity levels ranging from 0.08 to 1.95% are classified as mild flavored, which is normally the most accepted by the consumer for fresh fruits. It should be highlighted that all the evaluated cultivars fall into this group (Table 1).

The TSS/TTA ratio is one of the most used ways to estimate fruit flavor (Antunes et al., 2010; Maro et al., 2013). Despite being considered adequate to determine fruit quality, this relationship is influenced by climatic conditions, especially by luminosity and temperature (Curi et al., 2017a). The higher values obtained for this variable are attributed to the high SS contents and low acidity levels of the fruits; the higher this ratio, the greater the sweetness of the fruit in relation to its acidity, which results in a greater sensorial acceptance. Mini Figo stood out for presenting a higher ratio of 5.75 (Table 1), showing that this cultivar has high sweetness and low acidity, which probably reflects in an optimal sweet-acid balance.

Regarding the color of the different fig cultivars, L* varied from 26.54 to 31.19, Chroma from 5.98 to 14.08, and °Hue from 84.93 to 102.64. 'Lemon' stood out because of its greater chromaticity, which indicates color intensity, suggesting that the fruits of this cultivar were of a more intense green, compared with the other ones. 'Mini Figo' stood out due to its greater °Hue, resulting in a more greenish tonality (Table 1).

In the case of the canned figs obtained from the different fig cultivars, pH ranged from 5.55 to 6.56 for Lemon and Pingo de Mel, respectively. To prepare canned fruit, the pH of the fruit must be in balance with sugar, in order to facilitate the formation of the necessary gel. The acidity of the canned figs varied from 0.01 to 0.03 g citric acid per 100 g, which is considered low.

A significant difference was observed for all color parameters, except for Chroma. L* ranged from 15.18 to 19.55, Chroma from 0.43 to 1.99, and °Hue from 75.99 to 211.99 (Table 2). In general, when compared with fresh fruits, the canned figs presented a more greenish color and were darker, possibly due to the water evaporation and the reactions that occur during heating, such as the chemical (Maillard) reaction between amino acids and reducing sugars that usually requires the addition of heat and that gives browned food its distinctive flavor.

The canned figs obtained from 'Brunswick' showed the highest values for hardness and springiness, of 5.88 and 0.64, respectively (Table 3). Those obtained

Table 1. Average length (AL), average diameter (AD), unit weight (UW), total soluble solids (TSS), total titratable acidity (TTA), pH, TSS/TTA ratio, and color (L*, Chroma, and °Hue) of figs (*Ficus carica*) from cultivars grown in subtropical regions[(1)].

Cultivar	AL (mm)	AD (mm)	UW (g)	TSS (ºBrix)	TTA (%)[(2)]	pH	TSS/TTA ratio	L*	Chroma	°Hue
Bêbera Branca	44.75ab	22.25ab	10.61abc	2.00b	0.80ab	5.85a	2.45b	26.65a	9.73abc	93.77bc
Brunswick	33.18c	23.87b	7.73bc	3.00ab	0.60b	5.46bc	4.76ab	26.54a	7.90bc	96.26ab
Lemon	33.40c	28.69b	9.14bc	4.00ab	1.20a	4.53d	3.23ab	30.79a	14.08a	79.96c
Mini Figo	25.97d	19.75b	4.75c	5.00a	0.90ab	5.48bc	5.75a	26.91a	7.55bc	102.64a
Pingo de Mel	31.52c	22.41b	9.84abc	2.60b	0.50b	5.59abc	5.09ab	27.08a	10.58ab	94.18bc
Roxo de Valinhos	41.04b	28.34b	16.53a	2.30b	0.40b	5.76ab	4.83ab	27.14a	9.69bc	95.21bc
Três num Prato	45.29a	29.18ab	12.53ab	2.30b	0.70ab	5.89a	3.03ab	31.19a	7.30bc	84.93bc
Troiano	42.12ab	31.44a	11.99abc	5.00a	1.00a	5.27c	4.95ab	29.96a	5.98c	96.32ab
CV (%)	4.52	4.09	29.48	22.11	24.63	2.16	23.53	9.02	16.67	5.55

[(1)]Mean values followed by equal letters, in the columns, do not differ by Tukey's test, at 5% probability. [(2)]In gram of citric acid per 100 g fresh weight.

from 'Pingo de Mel' had greater adhesiveness (13.62) and cohesiveness (0.65), whereas those elaborated with 'Troiano' showed the highest values for gumminess (2.99) and chewiness (2.00). In summary, the canned fruits produced from 'Brunswick' are more firm, rigid, adhesive, and elastic, while those from 'Troiano' are gummier.

Several factors may explain the varying texture of the canned fruits prepared from the different fig cultivars. The amount of sugar present in each cultivar, pH, and acidity can influence gelling and, consequently, the texture of the final product (Souza et al., 2014b). In addition, aspects such as moisture content and the chemical composition of the fruit may also change texture, as it may affect cooking time, yield, and, therefore, the moisture content of the processed product (Curi et al., 2017c).

The analysis of variance showed a significant difference among the canned fruits obtained from the different fig cultivars regarding taste, consistency, and overall liking. In general, for the canned fruit formulations, there was a great sensory acceptance of all sensory characteristics evaluated, with average scores ranging from the hedonic terms “liked slightly” to “liked very much” (Table 4). However, the canned figs obtained from Brunswick and Troiano presented a lower consumer preference (Table 4 and Figure 1), whereas those from all other cultivars showed a similar sensorial acceptance. Among the most accepted formulations, the canned fruits elaborated with 'Bêbera Branca' and 'Roxo de Valinhos' presented the highest averages of acceptance, with scores varying from the hedonic terms “moderately liked” to “liked very much”.

The canned figs obtained from 'Brunswick' and 'Troiano', which were less sensorially accepted, were characterized by a higher acidity (Tables 2 and 3). Those obtained from 'Brunswick' had the lowest pH, whereas those from 'Troiano', the highest TTA and greatest hardness and gumminess. In this way, it can

Table 2. pH, total titratable acidity (TTA), and color (L*, Chroma, and °Hue) of canned fig formulations produced with figs (*Ficus carica*) from cultivars grown in subtropical regions[(1)].

Cultivar	pH	TTA[(2)]	L*	Chroma	°Hue
Bêbera Branca	6.47ab	0.01c	19.55a	1.91a	94.21ab
Brunswick	5.83d	0.01c	16.81bcd	1.37a	135.47ab
Lemon	5.55e	0.02b	18.69ab	1.72a	75.99b
Mini Figo	6.30bc	0.01c	18.80ab	0.53a	211.99a
Pingo de Mel	6.56a	0.01c	18.68bc	0.64a	166.19ab
Roxo de Valinhos	6.11c	0.01c	15.18d	0.77a	140.04ab
Três num Prato	6.22bc	0.01c	17.64bc	0.43a	141.90ab
Troiano	5.59de	0.03a	16.14cd	1.99a	103.22ab
Coefficient of variation (%)	1.52	28.87	4.54	16.67	21.78

[(1)]Mean values followed by equal letters, in the columns, do not differ by Tukey’s test, at 5% probability. [(2)]In grams of citric acid per 100 g fresh weight.

Table 3. Rheological parameters: hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness of canned fig formulations produced with figs (*Ficus carica*) from cultivars grown in subtropical regions[(1)].

Cultivar	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness
Bêbera Branca	4.07abc	10.58ab	0.64a	0.55ab	2.25abc	1.45ab
Brunswick	5.88a	5.27c	0.64a	0.49ab	2.88ab	1.86a
Lemon	4.68abc	4.72c	0.72a	0.60ab	2.83ab	2.07a
Mini Figo	3.34abc	3.84c	0.71a	0.60ab	1.98abc	1.41ab
Pingo de Mel	2.76cd	13.62a	0.52a	0.65a	1.65abc	0.99ab
Roxo de Valinhos	1.94d	3.87c	0.55a	0.45b	0.88c	0.48b
Três num Prato	2.29cd	7.59bc	0.71a	0.63ab	1.46abc	1.05ab
Troiano	5.12ab	3.25c	0.68a	0.59ab	2.99a	2.00a
Coefficient of variation (%)	26.97	23.01	15.95	10.93	23.52	27.15

[(1)]Mean values followed by equal letters, in the columns, do not differ by Tukey’s test, at 5% probability.

be inferred that consumers prefer less acid and softer canned figs. As these characteristics can be easily altered by adjusting processing, in general, all studied fig cultivars are suitable for preparing canned fruit.

Table 4. Sensory characteristics of canned figs produced with figs (*Ficus carica*) from cultivars grown in subtropical regions[(1)].

Cultivar	Color	Taste	Consistency	Global impression
Bêbera Branca	7.83a	7.19a	7.42a	7.23a
Brunswick	6.97a	5.89c	6.47b	6.24b
Lemon	6.79a	6.83ab	6.90ab	6.81ab
Mini Figo	6.62a	6.33bc	6.81ab	6.43b
Pingo de Mel	6.80a	6.51abc	7.00ab	6.72ab
Roxo de Valinhos	6.93a	7.31a	7.33a	7.27a
Três num Prato	6.88a	6.68abc	7.00ab	6.98ab
Troiano	6.47a	6.18bc	6.58b	6.42b

[(1)]Mean values followed by equal letters, in the columns, do not differ by Tukey's test, at 5% probability.

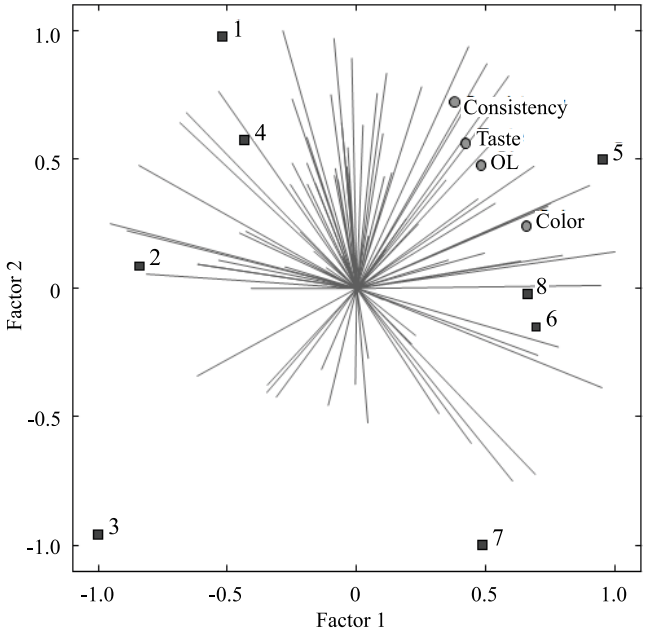

Figure 1. Three-way internal preference map generated by the parallel factor analysis, representing consumer preference for the sensory characteristics color, taste, consistency, and overall liking (OL) used to evaluate the canned fig formulations produced with figs (*Ficus carica*) from eight cultivars grown in subtropical regions: Roxo de Valinhos (1), Mini Figo (2), Troiano (3), Três num Prato (4), Bêbera Branca (5), Lemon (6), Brunswick (7), and Pingo de Mel (8).

In this study, it was verified that, besides Roxo de Valinhos, several other fig cultivars are suitable for canned fruit processing. This would give the Brazilian fig producers other options for cultivation, which would no longer be limited to a single cultivar. Other factors such as adaptation, susceptibility to pests, production cost, and yield should also be taken into account to determine the most interesting cultivars for industrialization.

Conclusions

1. Fig (*Ficus carica*) cultivars grown in the evaluated subtropical regions produce fruits with different physicochemical and rheological characteristics, and all of them have potential to be processed as canned figs with good acceptance by the consumer.

2. Canned figs with less acid and softer fruits are more widely accepted, which can be obtained from all cultivars, except from Brunswick and Troiano.

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