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# Physicochemical, microbiological and nutritional quality of a tomato industrial by-product and its valorization as a source of oil rich in carotenoids

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## ABSTRACT

**Objective**: To valorize an industrial tomato byproduct from Northwest Mexico, based on the evaluation of its physicochemical, microbiological, and nutritional quality and it's potential as a functional ingredient to obtain a carotenoids rich oil.

**Design/methodology/approach**: Tomato by-product was collected from the food industry and oven-dried. The fresh and dry tomato by-product quality was evaluated through physicochemical, microbiological, proximal composition, dietary fiber, and minerals analysis. HPLC carotenoids analysis was performed from Soxhlet n-hexane extracted oil and dry-byproduct.

**Results**: The by-product showed 81 and 9.7% of humidity; 0.26 and 0.53% meq of citric acid for titratable acidity in fresh and dried, respectively, and 4.74 °Brix in fresh. Their color got paler due to the drying process, turning less red. The aerobic mesophylls, total coliforms, fungi and yeasts microbiological analysis in a fresh by-product (170, <10, <10 CFU $g^{-1}$, respectively) and dried (180, <10, ≤95 CFU $g^{-1}$, respectively), proved their acceptable microbiological safety. Their dietary insoluble (52%) and soluble (9%) fiber stands out, protein (14%), lipids (9.09%) content, as well as Mn> Zn> Fe> Cu, and K> P> Ca> Mg> Na. The carotenoids rich oil was 13 times more concentrated in lycopene (4.98 mg $g^{-1}$) and twice $\beta$-carotene (0.48 mg $g^{-1}$) content compared to the dry by-product from which it comes (0.38 mg $g^{-1}$ and 0.22 mg $g^{-1}$, respectively).

**Limitations on study/implications**: Great efforts were required to dry high amounts of the tomato industrial by-product.

**Findings/Conclusion**: The tomato industrial by-product from Northwest Mexico possesses suitable physicochemical, microbiological, and nutritional quality to be used as a functional ingredient to generate new products, for example, a carotenoid-rich oil.

Keywords: carotenoids, industrial by-product, quality, tomato oil, valorization.

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## INTRODUCCIÓN

Tomato (*Solanum lycopersicum*) is a world-wide vegetable production (182 million tons in 2017) (FAOSTAT, 2019). It is consumed fresh and processed. Annually, more than 40 million tons are destined to industry to produce juices, purees, ketchup, sauces and pasta; During its processing, by-products are generated, mainly consisting of skins and seeds, which constitute between 1.5 and 5% of the initial weight (FAO, 2016; Silva *et al*., 2019a). At a food processing industry in the northwestern region of Sinaloa, Mexico, which processes until thousand tons of tomatoes annually, up to 3,750 tons of by-product are generated, mainly used as livestock feed (La Costeña, personal communication).

The great antioxidant potential of industrial plant by-products has been described due to the quantity and quality of their bioactive compounds (Silva *et al*., 2019a; Urbonavičiené *et al*., 2018). The tomato by-product has important nutrition and health components, particularly carotenoids, fiber, vitamins, phenolic compounds and unsaturated fatty acids (Botinestean *et al*., 2014: Silva *et al*., 2019b). Also, plasma and liver cholesterol-lowering properties of tomato pomace and seed oil have been reported (Shao *et al*., 2013).

There are reports of the valorization of an industrial by-product of tomato using them to produce edible oil for salads, sauces and desserts; as an ingredient to improve the functional, sensorial quality and oxidative stability in bread, cookies and ice cream (Nour *et al*., 2015; Karthika Devi *et al*., 2016; Guerrero García Ortega, 2017; Mehta *et al*., 2018; Szabo *et al*., 2018; Matejová *et al*., 2019). However, in Mexico, there are no reports of the properties and quality of this by-product generated in the food industry, or of products made from it. The objective in this research was to value the tomato by-product of an industry in Northwest Mexico, from the evaluation of their physicochemical and microbiological quality as a by-product fresh and dried; in addition to its nutritional quality, dietary fiber and minerals, and its potential as a functional ingredient to obtain an oil rich in carotenoids. In such a way that this by-product can be used in the food, cosmetic or pharmaceutical industry.

## MATERIALS AND METHODS

From January to March 2018, two 20 kg samples of industrial tomato by-products: skin and seeds from scalding and pulping in the production of tomato paste, were collected at La Costeña® Company at Guasave, Sinaloa. The physicochemical and microbiological evaluation of the fresh by-product was carried out, followed by drying in a forced convection oven (D-20 Food Dehydrator Stainless Steel Shelves, model # 32750) at 55 °C for 120 min, until reaching water activity values (aw ) between 0.4 and 0.6 (Segoviano-León *et al*., 2020), then grounded for 1 min in a food mill (Mr. Coffee IDS-55). Flour of 1 mm particle size (18.47%), 0.707 mm (35.93%), 0.5 mm (28.93%), and 0.25 mm (16.67%) was evaluated in certified stainless steel sieves (TYLER); the flour was then stored in vacuum, in polyethylene bags at −20 °C and protected from light. The physicochemical, microbiological evaluation, proximal analysis and mineral content of the dry by-product were assessed. From the dry by-product, oil was extracted, which was then evaluated for its carotenoid content via HPLC, as well as the industrial dried tomato by-product.

### Microbiological analysis of the industrial by-product of tomato

The total coliforms were counted on a 3M Petrifilm plate (6410/6416/6443), fungi and yeasts on a 3M Petrifilm plate (6407/6417/6445) and 3M Petrifilm aerobic mesophiles (6400/6406/6442), following the NOM-113-SSA1-1994, NOM-111-SSA1-1994 and NOM-092-SSA1-1994, respectively. The results are reported as colony-forming units (CFU) per g of sample.

### Physicochemical evaluation of the industrial by-product of tomato

As a quality reference, the evaluation was done in the fresh samples, later dried to increase the shelf life and facilitate its handling. 1) Humidity, by the official method of the AOAC (1998) brought to constant weight at 105 °C, for 4 h in a forced convection oven (BINDER Thermo Fisher Scientific, Pittsburgh, PA, EU). 2) Total organic acids, NMX-F-102-S-1978 of titratable acidity for products made with fruits and vegetables, from 20 g of fresh and dry by-product grinding juice with 50 mL of distilled water titrated with NaOH 0.1 N. 3) Soluble solids, the °Brix of the juice obtained from the fresh by-product when pressed was assessed with a portable refractometer (Atago 3810 PAL-1). 4) CIELAB color (L *, a *, b *), 25 readings were taken from the fresh and dry samples without grinding, in Petri dishes with five reading points, using a Chroma meter CR-400 Konica Minolta colorimeter. 5) Proportion of skin and seeds, these were manually separated, and the weight of each portion was recorded from 100 g of dry by-product.

### Nutritional composition of the industrial by-product of tomato

Proximal analysis. Performed at a certified laboratory EURONutec, Nutec Group (AOAC, 1998). Dietary fiber analysis was done with the Sigma-Aldrich kit (TDF 100A) following the AOAC method 960.52 (1997).

Minerals. These were analyzed by wet digestion (Na, Ca, Mg, Fe, Mn, Cu, Zn, Mn) (Johnson & Ulrich 1959) and subsequent analysis by atomic absorption spectrometry. For K, the flamometric flame emission method was used with a flamometer (Buck Scientific PFP-7). P was evaluated with the vanadate-yellow molybdate method by acid digestion with a UV / visible spectrophotometer (Genesys Varían) at 470 nm.

Oil extraction. This was obtained in a Soxhlet with 2 g of the dry industrial by-product and 80 mL of hexane at 80 °C for 5 h (NMX-F-089-S-1978). The solvent was removed by rotary evaporation (Yamato, RE300) and forced convection oven (BINDER) at 55 °C for 1 h, for the residual. Oil yield was calculated by weight difference and stored at −20 °C, under a nitrogen gas atmosphere protected from light.

### Carotenoids from tomato industrial by-product and oil

These were extracted from the dried tomato by-products following the method by Silva *et al.* (2019b). 500 mg of by-product was mixed with 50 mL of food-grade ethyl acetate, homogenized and sonicated (Fisher Scientific FS20 Sonic Cleaner) for 20 min and stirring for 2 h at 200 rpm and 55 °C (protected from light). After centrifuging at 4000 g for 10 min at 20 °C (Sorvall ST16REI), the recovered supernatant was dried by rotary evaporation and stored at −20 °C. The carotenoids from the oil were extracted following the method by Gimeno *et al.* (2002), from 400 mg of oil mixed with 200 mg of ascorbic acid, 15 mL of absolute ethanol and 4 mL of KOH (76% m/v), then incubated by shaking for 30 min at 60 °C and 200 rpm. 5 mL of NaCl (2.5% m/v) and 7 mL of n-hexane: ethyl acetate solution (85:15 v/v) were added. The organic phase recovered was dried by rotary evaporation at 40 °C, and stored at −20 °C. For the determination of carotenoids by reverse phase HPLC, the extracts were resuspended in 1 mL of hexane and methanol, respectively. Carotenoids were identified based on reference standards: $\beta$-carotene and lycopene (Sigma Chemical Co., St. Louis, MO, USA), by DAD Dionex HPLC (DIONEX Ultimate 3000) with a diode array detector, Acclaim Polar column Advantage II (C18, 3 $\mu$m, 120 Å, 2.1 × 150 mm), at 452 and 471 nm; acetonitrile: methanol: methyl chloride (43:43:14 v/v/v; Sigma-Aldrich) as isocratic mobile phase and flow of 0.3 mL min$^{-1}$. The results were expressed in mg of lycopene and $\beta$-carotene g$^{-1}$ of the dried tomato by-product and the oil. For comparative purposes, a commercial cosmetic-type tomato seed oil (BRAND Aceites Vegetales AV) was also analyzed.

### Statistical analysis

The analyzes were performed by triplicate, expressing the mean of the replicates ± standard deviation. The proximal analysis was performed as an external service certified by Grupo Nutec.

## RESULTS AND DISCUSSION

### Physicochemical characterization

The physicochemical parameters of the fresh and dry by-products are shown in Table 1, they represent a reference of its initial quality and after being dried, the latter to increase its shelf life and facilitate its handling.

After drying, the final aw was 0.42, as reported by Segoviano-León *et al.* (2020) to preserve carotenoids. The soluble solids or °Brix determine the commercial quality of fresh tomato, due to their effect on sweetness, acidity and flavor intensity. The value obtained in the fresh by-product corresponds to the range established for different stages of tomato maturation (4.1 and 4.7 °Brix) (Hernández *et al.*, 2008) and the variety apple (4 °Brix) used for flour (Monsalve and Machado, 2007). The titratable acidity of the tomato by-product coincides with the early stages of maturation of fresh whole tomatoes and slightly lower than tomato variety apple (0.29 mg eq. Citric acid) at commercial maturity (Monsalve and Machado, 2007; Hernández *et al.*, 2008); and increases in

**Table 1**. Physicochemical parameters of industrial by-products of fresh and dried tomato.

| Parameters | Fresh by-product | Dry by-product |
|---|---|---|
| Moisture (%) | 81.3 ± 1.87 | 9.71 |
| Soluble solids (°Brix) | 4.74 ± 0.38 | nd |
| Titratable acidity (citric acid %) | 0.26 ± 0.03 | 0.53 ± 0.004 |
| Color L* | 41.18 ± 1.52 | 33.53 ± 3.25 |
| a* | 22.38 ± 1.01 | 16.1 ± 1.32 |
| b* | 27.75 ± 1.15 | 26.25 ± 3 |

nd: not determined.

the dry by-product because organic acids concentrate by water elimination. Color is another important quality aspect, it was affected by drying, reducing the intensity of the color red, becoming paler. Furthermore, the industrial by-product of dried tomatoes is made up of 40% seeds and 60% skin (epidermis), similar to other tomato by-products from Brazil (38.5 and 61.5%) and Tunisia (35% and 65%) (Silva *et al.*, 2019a; Kehili *et al.*, 2019).

### Microbiological analysis

The microbial account in the fresh and dried tomato by-product is shown in Table 2. Since there are no specifications for this product, the hygiene and sanitation practices in the preparation of food in fixed establishments were taken as a reference (NOM-093-SSAI-1994).

The results indicated that the microbial count of the fresh and dry by-product is lower than that specified in the Mexican standard, and that reported in dehydrated commercial tomatoes <10 to 22×104 CFU $g^{-1}$ of aerobic mesophiles and <10 to 18,000 CFU $g^{-1}$ of fungi and yeasts (Moreno *et al*. 2014), which is similar to that reported by Monsalve and Machado (2007) for dehydrated commercial tomatoes, which suggests that there is no bacterial contamination when drying in the stove; demonstrating that the industrial process that originates the tomato by-product and all the handling until drying takes place in favorable food safety conditions for its use.

### Nutritional quality of the industrial by-product of tomatoes

**Proximal analysis**. The tomato by-product (Table 3) presented reports similar content to that reported in Venezuela (Alvarado *et al.*, 2001) and was slightly lower than that in Brazil (50.74% fiber, 20.01% protein, 14.14% fat and 3.60% ash) (Silva *et al.*, 2019b).

**Dietary fiber**. Its high content of total dietary fiber of 67.32% (52.46% insoluble and 9.28% soluble) is outstanding, whose consumption has positive implications on health, and corresponds to the edible fraction resistant to digestion and absorption in the small intestine, this value represents 27 times more than of the contribution of fresh tomatoes (Abdullahi *et al.*, 2016). The recommendation for dietary fiber consumption is 19 to 38 g $d^{-1}$ (USDA, 2015; Quagliani *et al.*, 2016); Considering the tomato by-product as an ingredient, the addition of 20% to a food formulation would cover 50% of the daily recommended requirement.

**Minerals**. Zn and Fe stand out for their biological importance related to malnutrition. The macro K> P> Ca> Mg> Na and micro minerals Mn> Zn> Fe> Cu of the industrial tomato by-product are presented in Table 3. Except for Ca, the tomato by-product of Caracal and Romania tomatoes has a high minerals content: K, Mg and Na (3.03, 0.21 and 0.067 g 100 $g^{-1}$, respectively), in addition to Zn, Fe, Mn and Cu (63.3, 56.3, 13.5 and 11.5 mg $Kg^{-1}$, respectively) (Nour *et al*. 2018). However, it is higher in P, K, Ca, Mg and Cu than the by-product of red tomato mixed with immature green tomato (King & Zeidler, 2004) and 10 times higher in P and Ca, and 28 times more in Na, in comparison fresh tomato of various varieties (Fragni *et al.*, 2018).

### Extraction of oil and carotenoids from the by-product of dried tomato and oil

The yield of the oil extraction *via* the Soxhlet method with n-hexane was 8.23 g 100 $g^{-1}$ of dry by-product, this value corresponds to the range (3 and 15 g 100 $g^{-1}$) reported by Vági *et al.* (2007) from an industrial tomato by-product.

**Table 2**. Microbiological quality of industrial by-product of fresh and dried tomato.

| | Fresh by-product | Dry by-product | Reference NOM-093-SSAI-1994 |
|---|---|---|---|
| Aerobic mesophiles (CFU/g) | 170 | 180 | 150,000 |
| Total coliforms (CFU/g) | <10 | ≤10 | 100 |
| Yeast and mold (CFU/g) | <10 | ≤95 | nr |

nr: not referenced.

**Table 3**. Proximal analysis and mineral content of industrial tomato by-product*.

| Composition | g 100 $g^{-1}$ | Macronutrients g 100 $g^{-1}$ | | Micronutrients mg $kg^{-1}$ | |
|---|---|---|---|---|---|
| Ash | 3.82 | P | 0.27 | Fe | 3.41 |
| Crude fibre | 32.80 | K | 0.43 | Cu | 2.55 |
| Lipids | 9.09 | Ca | 0.12 | Zn | 5.71 |
| Moisture | 9.71 | Mg | 0.07 | Mn | 7.47 |
| Crude protein | 14.86 | Na | 0.04 | | |
| Carbohydrates/NFE | 29.72 | | | | |

*dry basis; NFE: nitrogen free extract.

The lycopene content (4.98±0.09 mg $g^{-1}$) and $\beta$-carotene (0.48±0.002 mg $g^{-1}$) of the oil was 13 and 2 times the content of dried tomato by-product (0.38±0.15 and 0.22±0.087 mg $g^{-1}$, respectively); as well as 3.8 and 2.8 times higher than lycopene (1.31±0.04 mg $g^{-1}$) and $\beta$-carotene (0.17±0.04 mg $g^{-1}$) of the cosmetic-type commercial tomato seeds oil. It was six times higher in lycopene and three times lower in $\beta$-carotene than the oil obtained from another industrial tomato by-product (Machmudah *et al.*, 2012). When compared to palm oil, which is recognized to be carotenoids rich (1.385 mg $\beta$-carotene $g^{-1}$ oil) but lack lycopene (Sampaio *et al.*, 2013), it contains a third of $\beta$-carotene, but is a peculiarly lycopene-rich oil, although there are no values for its recommended daily intake (RDI), it has been suggested that the intake of 4 and 4.4 mg $d^{-1}$ of $\beta$-carotene for men and women and lycopene >6.46 mg $d^{-1}$, reduces cancer risk (Institute of Medicine, 2000).

## CONCLUSIONS

The industrial by-product of tomato from Northwest Mexico has an adequate physicochemical and microbial quality with high nutritional value based on its of dietary fiber content, protein and minerals, which can be used as a functional ingredient for the production of new products. It is a source for obtaining a unique oil rich in lycopene, in addition to $\beta$-carotene, which offers a potential use to generate gourmet oil or new products with important health benefit properties. This work contributes to the valorization of the industrial by-product of tomato from the northwest region of the country, considered the main production area of *Solanum lycopersicum* in Mexico.

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