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Bottled water production using the condensed water from a concentrated orange juice plant

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ABSTRACT

Evaporated water is produced during the juice concentration process by separation of the condensed water in the evaporator. This evaporated water is fully, but poorly used, for example, washing fruits. Considering it as a fraction of the fruit itself, this study proposed its use as "fruit water" bottled for human consumption. Evaporated water samples were characterized according to the following parameters established by the Brazilian technical regulations for bottled water: inorganic, organic substances, pesticides, microorganisms, and physical properties. The results show that the only parameters that exceed the maximum permitted levels were apparent color and turbidity. Then, tests were conducted in laboratory and in pilot scale for evaluation of technology of the membrane separation process (MSP) for the purpose of reducing the apparent color of the evaporated water of citric juice to less than or equal to 5 units of Pt/Co and simultaneously the turbidity to less than or equal to 1 NTU. The ultrafiltration in cellulose membrane of 30 kDa at 1 bar pressure was effective in reducing the apparent color and turbidity of the recovered water from concentrate orange juice, with values below the maximum allowed by law, demonstrating that this water meets Brazilian quality requirements for human consumption.

1. Introduction

The concentrate orange juice industries use advanced technology and are one of the successful examples of the full use of an agricultural product. In addition to the frozen concentrated orange juice, they produce various byproducts including: pulp-wash (secondary juice), D-limonene, citrus pulp bran (pet food), so that practically any part of the fruit is discarded and become into byproducts of commercial value.

In this context, the evaporated water can be considered an exception because it is the largest volume generated in the processes, representing about 40% of the fruit in the industry. According to Yamanaka [24], it is fully used by the industries in many ways, including fruit cleaning/washing, extraction/recovery of solids residual of the pulp, water replacement in the process of peel essential oil recovery, calories recovery for use in boilers, floor, equipment and restrooms cleaning.

Whereas the concentrated orange juice is about six times in terms of soluble solids it can be estimated that for each kilogram of frozen juice concentrate are produced, theoretically, about 4.9 kg of evaporated water.

Evaporated water is produced during the concentration process. According to Tocchini et al. [21], the juice is concentrated in vacuum evaporator, with up to 8 stages and 6 effects, enabling energy savings. Water in vapor form is separated from the orange juice and serves as a heater for stages working at lower temperatures (higher vacuum), where it condenses.

Few articles were found in the literature on the recovery of evaporated water originating from juice concentrates, with the objective of identifying a use for this industrial byproduct.

DeStefano [9] registered his invention as a method for water recovery from fruit. By the patented method, fruit juice is extracted, and then the product is concentrated by removing water as vapor. According to the author, the water is recovered from the condensation of water vapor and can be bottled and sold.

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The author states that the method can be applied to various fruits such as orange, grapefruit, apple, cherry, grape etc. Then, he reports a characterization example of the obtained product by analyzing a sample, but without informing the fruit from which the water was recovered.

Moussi et al. [15] describes a water recovery method from the concentrated juice of fruits and/or vegetables. The author reports drinking water recovery from concentrated grape juice, characterizing this material before and after the sequence of treatment operations. Results of some chemical and sensory analyzes that prove the potability of the product are presented.

The objective of the present study was the chemical, microbiological and physical properties characterization of evaporated water from concentrated orange juice, produced by an industrial plant located in the state of São Paulo, to prospect the possibility of its use for human consumption through industrialization. For this, it was adopted as reference the Brazilian bottled-water regulations [3,4].

The experimental tests were conducted in laboratory and pilot scale, to evaluate the performance of membrane separation process technology using microfiltration and ultrafiltration for reducing apparent color of evaporated water to value equal or less than 5 units of Pt/Co and simultaneously the turbidity to value equal or less than 1 NTU.

In the following step of the study, evaporated water was processed and bottled in glass bottles. The final product was evaluated by physical, chemical, microbiological, sensory analysis, and the economic viability for an industrial plant (1000 L/h production capacity) was also estimated. These results will be reported in a following article in the writing phase.

2. Methodology

2.1. Raw material

The evaporated water, provided by Louis Dreyfus Commodities, a unit located in Engenheiro Coelho – SP, originated from the process of obtaining frozen concentrate orange juice (*Citrus sinensis*).

Ten samples were collected from a single point of industry line previously defined, which gathers the evaporated water after the last evaporation effect, in ten different dates of juice production along the *Citrus sinensis* orange crop, varieties: "Pera Rio", "Natal" and "Charmute" with "Natal" (blend) between September and October 2010, as shown in Table 1.

Table 1
Varieties of *Citrus sinensis* oranges processed on each of the ten dates of samples collection of evaporated water, in 2010.

Sample	1	2	3	4	5	6	7	8	9	10
Data ofcollection Varieties	September, 1st "Pera Rio"	September, 15th "Natal"	September, 22th "Natal"	September, 27th "Natal"	September, 29th "Natal"	October 6th "Pera Rio"	October 14th "Natal"	October 19th "Charmute" and "Natal"	October 21st "Natal"	October 27th "Natal"

2.2. Raw material characterization

The raw material was characterized by some analysis provided by the technical regulations for bottled water and ice described by ANVISA resolutions No. 274 [3] and No. 275 [4] pertaining to raw material under study, and other determinations as follows:

2.2.1. Inorganic substances

Antimony, arsenic, barium, boron, cadmium, chromium, copper, cyanide, lead, manganese, mercury, nickel, and selenium were quantified on an emission spectrometer with power inductively coupled plasma (ICP OES model VISTA MPX, Varian), while nitrate and nitrite by Standard Method 21,using the methodologies described by the American Public Health Association (APHA), in Eaton et al. [11].

2.2.2. Organic substances

1,1-Dichloroethene; 1,2,3-trichlorobenzene; 1,2,4-trichlorobenzene; 1,2-dichloroethane, benzene, vinyl chloride, dichloromethane, styrene, carbon tetrachloride, tetrachloroethene,