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Cast-tape drying of tomato juice for the production of powdered tomato

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ABSTRACT

Cast-tape drying (CTD) is a process for producing dehydrated food powder. It consists of spreading a viscous fluid over a support whose lower surface is heated by water or steam. The aim of this study was to evaluate the kinetics of CTD for producing powder from tomato juice with and without maltodextrin, and to compare the physicochemical properties of this powder with those observed in powders produced by freeze-drying and spray drying. CTD time for the tomato juice–maltodextrin mix was longer (12 min) than the observed for pure tomato juice (8 min) to reach 0.03 g g^{-1} (dry basis). Adding maltodextrin to the juice increased the glass transition temperature and facilitated removing the dried flakes from the support. Powders with maltodextrin showed solubility higher than 95%. The dispersion time of powders containing maltodextrin obtained by spray-drying was higher (632 s) than the same parameter for powders from the other processes (less than 30 s). Powders from spray-dryer had lighter color than those from CTD, a spherical structure and tendency to agglomerate. Therefore, CTD of tomato juice with maltodextrin is a viable and technologically competitive alternative for producing tomato powders.

1. Introduction

Powder production is an alternative to extending the shelf life of some foodstuffs, leading to a product with good commercial value and easier handling, packaging, and transportation (Cuq et al., 2011). In particular for tomatoes, it is highly desirable to preserve their nutritional characteristics, such as the lycopene content; and sensorial aspects, such as color; as well as to provide technological aspects, such as the rehydration capacity. For human diet, tomatoes are the main source of lycopene, which is a thermolabile carotenoid with an effective antioxidant activity associated with reducing the risk of chronic diseases such as prostate cancer (Cohen et al., 1999; Hackett et al., 2004; Colle et al., 2010), and imparts the fruit's red color (Shi and Le Maguer 2000). Tomato powder can be used in soups, dressings, and condiments or, after reconstitution, as sauces for pizzas and pasta. In any of the foregoing uses, both red color and rehydration capacity are needful.

Drum, spray, freeze, and cast-tape drying are the main processes suitable to obtain powdered food (Tang et al., 2003; Goula and Adamopoulos, 2008; Liapis and Bruttini, 2006; Nindo and Tang, 2007; Pavan et al., 2012; Caparino et al., 2013; Castoldi et al., 2015; Zotarelli et al., 2015). However, the high sugar content of tomato juice leads to a relatively low glass transition temperature (T_g), which increases the product's stickiness mainly to metallic surfaces of drum and spray dryers, as a consequence of the high water content (early drying) or high temperature (later drying) (Tang et al., 2003; Goula and Adamopoulos, 2003; Goula and Adamopoulos, 2005a; Bhandari, 2007).

Sticking foodstuff reduces drying yields and productivity, promotes overheating, and results in a nutritionally depleted

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powder with undesirable sensorial characteristics (Boonyai et al., 2004; Bhandari, 2007; Chen and Özkan, 2007). Goula and Adamopoulos (2005b) observed lycopene losses between 8.1 and 20.9% for spray-dried tomato powder as consequence of the high inlet air temperature (110–140 °C) and the presence of oxygen and light. Adding carrier agents such as maltodextrin increases T_g values, minimizing this effect (Bhandari et al., 1993; Goula and Adamopoulos, 2008); however, it changes nutritional and sensorial aspects of the tomato powder. Goula and Adamopoulos (2008) dried tomato juice added with maltodextrin to produce a powder with reduced hygroscopicity and agglomeration and increased solubility.

Drying of food suspensions spread on rigid and flexible surfaces has received increased attention. Abonyi et al. (2002), Nindo et al. (2003), Abul-Fadl and Ghanem (2011), Pavan et al. (2012), Caparino et al. (2012), Castoldi et al. (2015), Zotarelli et al. (2015), Souza (2015), Celli et al. (2016), and Baeghbali et al. (2016) reported results on the drying of fruit pulps, coupled with a milling process, for producing powdered foods. Moreira et al. (2011), Moraes et al. (2013, 2015), Saini et al. (2012), and Tápia-Blácido et al. (2013) reported results on the use of this drying process applied to the production of protein- and starch-based films. Drying of fruit slices on a flexible film heated by water from its bottom has been also reported (Ochoa-Martínez et al., 2012; Ortiz-Jerez et al., 2015a,b; Ortiz-Jerez and Ochoa-Martínez, 2015).

Refractance window (RW) drying denominates processes that use films transparent to infrared radiation (polyester films, e.g. Mylar®). The bottom face of the film is heated by hot water, at temperatures no higher than 95 °C. The food suspension (e.g., fruit pulp) to be dried is spread on the upper face of the film and the evaporated water is exhausted during drying (Nindo and Tang, 2007). In order to provide the evaporation heat during the drying process, the bottom of the polyester film must be wholly touched by the hot water. Nindo and Tang considered that both, conductive and radiative heat transfer through the polymeric film are important. However, Zotarelli et al. (2015) and Ortiz-Jerez et al. (2015a,b) showed that the contribution of infrared radiation represents less than 3% of the total heat transfer, and that RW is controlled by heat conduction. Therefore, we assumed cast-tape drying (CTD) as a general denomination for dehydration processes in which a liquid food is cast in a thin layer onto a flat belt and dried.

Some powdered products obtained by CTD are carrot, strawberry (Abonyi et al., 2002), pumpkin (Nindo et al., 2003), tomato (Abul-Fadl and Ghanem, 2011; Castoldi et al., 2015), açaí berry (Pavan et al., 2012; Souza, 2015), mango (Caparino et al., 2012; Zotarelli et al., 2015), pomegranate (Baeghbali et al., 2016), and haskap berry (Celli et al., 2016). Tomato powder production by CTD was studied by Abul-Fadl and Ghanem (2011) by spreading tomato pulp over a flat glass plate, and by Castoldi et al. (2015) by spreading tomato juice over a RW system. Abul-Fadl and Ghanem (2011) used hot water (60, 75, and 90 °C) under a glass plate to dry tomato pulp between 1.0 and 1.5 mm thick. Compared with convective hot-air drying, they reported shorter drying time, lower costs, higher rehydration rate and solubility, and greater content of lycopene, ascorbic acid, and flavonoids. Castoldi et al. (2015) used hot water (65, 75, 85, and 95 °C) to dry 2- and 3-mm-thick pulp. The authors observed a relatively short dispersion time (below 9 s), solubility over 87%, and preserved luminosity values.

The objective of this study was to evaluate the kinetics of cast-tape drying for producing powder from tomato juice with and without maltodextrin, and to compare the physicochemical properties of this powder and those produced by freeze and spray drying.

2. Materials and methods

2.1. *Tomato juice*

Tomatoes (*Lycopersicon esculentum* Mill.) were purchased from the local market (Florianópolis, SC, Brazil) and selected for their soluble solids content (between 4.2 and 4.7 °Brix), which was measured in a manual refractometer (ATAGO, model PAL-BX/RI, Tokyo, Japan). After washing, the fruits were triturated (Arno, São Paulo, SP, Brazil) and filtered in a 16-mesh sieve to remove peel and seeds. This filtrate juice was the raw material for drying processes. Maltodextrin (10DE, Loremalt 2002, Lorenz, Quatro Pontas, PR, Brazil), when added to the tomato juice, was used at a ratio of 50% of the dry solids content.

2.2. *Cast-tape drying*

2.2.1. *Experimental device*

Fig. 1 shows a schematic of the experimental device for the CTD. It consisted of a hot water reservoir (0.8 m × 0.4 m × 0.05 m) and a thermostatic bath (Quimis, model Q214S, Diadema, SP, Brazil) operating in a closed system. Over the reservoir, a polyester film (Mylar® type D, DuPont, Wilmington, DE, USA) with 0.25 mm thickness was fixed ensuring that its entire bottom face continuously touched the hot water, while the top face was the support onto which the tomato juice was spread. Two exhaust fans provided the airflow over the juice. T-type thermocouples (IOPE, model A-TX-TF-R-30AWG, São Paulo, SP, Brazil) connected to a data acquisition system (Agilent, model 34970A, Bayan Lepas, Penang, Malaysia) measured air and hot water temperature.

2.2.2. *Drying procedure*

For all CTD experiments, circulating hot water temperature was maintained at 90 ± 2 °C and influx air conditions were 25.4 ± 1.0 °C (average ± standard deviation) and 57–67% relative humidity. Tomato juice was spread over the polyester film aided by a doctor blade (Tape Warehouse Fundição, model Doctor Blade Assembly, Morrisville, PA, USA) with a 2 mm gap. The experimental drying kinetics, i.e., moisture content (X [$g\,g^{-1}$ in dry basis]) vs. time (t [min]), of the tomato juice was determined by sampling with a metal spatula from three different points, mixing, and measuring the moisture content by gravimetry under vacuum at 70 °C (TECNAL, model TE-395, Piracicaba, SP, Brazil), according to the AOAC (2005). This procedure was performed in triplicate.

Sample temperature was measured by T-type thermocouples (IOPE, model A-TX-TF-R-30AWG, São Paulo, SP, Brazil) connected to a data acquisition system (Agilent, model 34970A, Bayan Lepas, Penang, Malaysia) inserted into the sample and by a thermographic camera (Flir, model T360, Täby, Sweden) placed 50 cm over the juice under drying. Thermographic images were analyzed with the help of a specific software (FLIR QuickReport 1.2 SP2, Täby, Sweden) assuming juice emissivity equal to pure water (0.96, Incropera et al., 2007) based on its high water content. The polyester emissivity (0.92) was determined according to the methodology proposed by Albatici et al. (2013) using the same thermographic camera and software.