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# Production of mango powder by spray drying and cast-tape drying

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ABSTRACT

The production of mango powder by spray drying and cast-tape drying, with and without the addition of maltodextrin was investigated. Moisture, particle size distribution, bulk density, particle density, porosity, morphology, total carotenoids content, water sorption isotherms, glass transition temperature and color of mango powders from both drying processes were compared. Powders resulting from cast-tape drying had irregular structure, different from the spherical structures showed by powders produced by spray drying. Cast-tape drying process resulted in powders with bulk densities of 0.8 g $cm^{-3}$ (with maltodextrin) and 0.7 g $cm^{-3}$ (without maltodextrin), higher than the observed for analogous powders produced by spray drying (bulk densities of 0.45 and 0.5 g $cm^{-3}$). Also, porosity of powders from cast-tape drying (below 60%) was lower than that of powders produced by spray drying. Mango powders produced by spray drying without maltodextrin showed the highest carotenoid concentration (113 μm of carotenoid $g^{-1}$ of dry mass). The state diagrams show that mango powders produced by spray drying exhibit slightly lower stability than those produced by cast-tape drying. Cast-tape drying is a suitable procedure for the production of mango powders and allows producing powders from whole fruit pulp, without the addition of maltodextrin.



## 1. Introduction

Mangoes are appreciated worldwide for its flavor and color, besides its nutritional value. According to estimates of the Food and Agriculture Organization of the United Nations, the world production of this fruit was approximately 42.1 million tons in 2012, concentrated in tropical regions of Asia and Latin America [1].

Mangoes are quite perishable and susceptible to injuries, requiring care during storage and commercialization [2]. Industrial processing of mango fruits can improve commercialization and consumption of this fruit as puree (or fruit pulp) and powdered products. The development of processes that result in new products, preserving nutritional and some fruit sensory characteristics is important to create alternatives for adding value and helping in reducing post-harvest losses. The production of mango dehydrated powder from fruit pulp is an alternative still underused, but with potential for generating intermediate processing products (business to business products), and even products to be marketed in retail stores to regular consumers. Fruit powder ingredients are convenient for the development of other industrial products and have lower transport and storage costs.

However, the production of high quality fruit powder must overcome some difficulties, as the hygroscopicity and the sticking characteristic of this high sugar content material. Literature reports the problems faced to produce fruit powders by spray drying (SD). Ripe fruits are rich in sugars and organic acids of low molecular weight that have low glass transition temperatures ($T_g$), at which the amorphous polymer undergoes a phase transition from the glass state to a rubbery state [3]. When they are dehydrated at temperatures above their $T_g$, the stickiness characteristic appears and causes their adhesion to the dryer walls, reducing yield and quality of the final product [4,5]. The addition of carrier agents to fruit juices (compounds with higher molecular weight) prior to drying process increases the $T_g$ of the mixture and has been widely used to reduce fruit pulp stickiness [6,3,7,8].

The literature reports studies on the production of mango powder by spray-drying, using carrier agents added to the mango pulp to be dried. Cano-Chauca et al. [7] reported the use of maltodextrin, Arabic gum and waxy starch at concentration of 12%. The authors also evaluated the effect of cellulose solution addition at different concentrations (0, 3, 6 and 9%) on the drying kinetics and powder characteristics. The addition of cellulose led to the formation of less sticky and less soluble crystalline particles. Cano-Higuita et al. [8] evaluated the influence of the addition of maltodextrin, skim milk and of a mixture thereof in the sorption isotherms of the mango powders produced by SD. They used ratios of 1:8,

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3:6 (dry basis) of mango pulp for maltodextrin and 1:4:4 of mango pulp for maltodextrin and skimmed milk. From the results of water sorption isotherm at 20 °C they reported that the formulation 1:8 was the less hygroscopic combination.

Alternative drying processes have been investigated for fruit powder production. Cast-Tape Drying (CTD) is a method suitable for food powder production. In fact, the drying process that has been reported as refractance window (RW) is a particular case of CTD. In this process, the solution to be dried is spread on a transparent polyester film, commercially known as Mylar (DuPont®), while its lower surface is in contact with hot water, which provides the heat for the product drying [9]. CTD applied to fruit and vegetable pulps results in films or flakes, but powdered products can be produced by grinding. An advantage of this drying process is the possibility of using moderate drying temperatures (60–80 °C) and relatively short drying times (some minutes) by selecting the thickness of the pulp layer to be dried. The use of this process for drying pulps of strawberry and carrot [10], pumpkin [11], açaí [12], mango [2,13,14] and tomato [15] has been reported in the literature.

Caparino et al. [2] evaluated the production of mango powder by different drying processes, i.e. refractance window (RW), freeze-drying (FD) and drum drying (DD), without the addition of carrier agents, and spray-drying (SD) with the addition of 0.25 kg of maltodextrin (10DE) per kg of dried mango solids. The physical properties of the resulted powders were compared. The authors reported that mango powders produced by RW without the addition of carrier agents showed better quality than those produced by SD and DD. Caparino et al. [13] reported moisture sorption, glass transition temperatures and microstructure data of mango particles, and their influence on the stability of powders produced by RW and FD. They observed similar water sorption properties from powders produced by both processes, with type III isotherms [16].

CTD process can be applied to fruit pulps without carrier agents. A fair comparison between CTD and SD processes and resulting products could be better if performed from processes without addition of carrier agents. However, studies on the SD of mango pulp without the addition of carrier agents were not found in the literature.

The aim of this study was to investigate the use of spray drying and of cast-tape drying for producing powders from mango pulp with and without maltodextrin. The physicochemical properties of powders from both processes were compared.

## 2. Material and methods

### 2.1. Mango fruits

Tommy Atkins mangoes used in this study were purchased in the local market, in Campinas-SP, Brazil. Fruits were selected according to their degree of ripeness, assessed from visual inspection and soluble solids concentration, determined with a manual refractometer with a 0–90°Brix range and 0.2°Brix resolution (Reichert, Model AR200, USA). The fruits were washed, peeled by hand and ground in a household blender (Arno, São Paulo, Brazil) for obtaining the mango pulp. Before the drying process, the pulp was sieved using a 16 mesh sieve, in order to retain large particles and fibers. Pulp soluble solids content was 17°Brix. Mango pulp was fractionated in 1 kg polyethylene containers and frozen until use.

### 2.2. Carrier agent

Maltodextrin MOR-Rex® 1910 (10DE) from Ingredion (Mogi Guaçu-SP, Brazil) was used as carrier agent, which is widely used for drying fruit juices by spray drying. Maltodextrin was added to the filtered pulp until complete dissolution.

### 2.3. Drying processes

Drying of mango pulp without maltodextrin was carried out using spray drying (SD) and cast-tape drying (CTD) processes. Each kilogram of mango pulp with moisture of 5.3 g $g^{-1}$ was mixed with 0.06 kg of maltodextrin (moisture 16.3 g $g^{-1}$) and 0.187 kg of water, in order to have a mixture with moisture of 4.7 g $g^{-1}$ before drying. The drying processes performed with mango pulp were named CTD-P and SD-P, while those processes with pulp added of maltodextrin were named as SD-M and CTD-M.

#### 2.3.1. Spray drying

A lab scale spray dryer (Buchi, B-290, Switzerland) with dehumidifier (B-296, Switzerland), was used for the production of mango powder with maltodextrin (SD-M) and without this carrier agent (SD-P). The equipment has a drying chamber (0.65 m × 1.10 m × 0.70 m) and a dual fluid nozzle atomizer type with orifice 0.7 mm in diameter and evaporation capacity of 1 L $h^{-1}$. A peristaltic pump was used for feeding the dryer with the mango pulp, at a flow rate of 0.42 L $h^{-1}$. The drying air flow was 35 $m^3$ $h^{-1}$ with inlet temperature of 150 °C. The outlet air temperature was monitored to observe its variation as a function of the pulp feeding.

#### 2.3.2. Cast-tape drying

A CTD lab-scale dryer was made using the same principle present in industrial equipment [9,11,14,17]. 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. A polyester film (Mylar® type D, DuPont, Wilmington, DE, USA), with 0.25 mm thickness, was fixed on the top of the reservoir frame, ensuring that the whole surface of film's bottom touched the hot water, while its top face was the support onto which the mango pulp was spread. Two exhaust fans provided the airflow over the pulp. The thickness of the Mylar film was chosen based on literature reports [11,14]. The mango pulp was spread over the Mylar film with the aid of a doctor blade, which allows the thickness of the spread pulp to be adjusted. Mango pulp and hot water temperatures were determined by T-type thermocouples (IOPE, model TF-TX-AR-30AWG, Brazil) connected to a data acquisition system (Agilent model 34970A, Malaysia). Water temperature was adjusted to 95 °C. The dried mango pulp was removed as films and flakes and milled in a Wiley type mill (TECNAL, ET 631/2 model, Brazil) during 2 min at 15,000 rpm.

### 2.4. Powder characterization

#### 2.4.1. Moisture and water activity

During drying, the evolution of the pulp moisture was determined by gravimetric method, using a vacuum oven (TECNAL, TE-395 model, Brazil) at 70 °C [18], from samples taken from the drier. The water activity ($a_w$) was determined in triplicate, using a water activity meter (Aqualab, Decagon Devices, USA).

#### 2.4.2. Hygroscopicity of the mango powders

The hygroscopicity of the mango powders was determined according to the methodology proposed by Cai and Corke [19], with modifications [20]. Approximately 1 g of dried sample was placed in a hermetic container at 25 °C, with a saturated NaCl solution, for creating a 75.3% relative humidity atmosphere. The samples were weighed after seven days and the hygroscopicity was determined and expressed in g of adsorbed water per 100 g of dry solid (100 g $g^{-1}$).

#### 2.4.3. Total carotenoids

Total carotenoids of fresh mango pulps and mango powders were determined according to the methodology described by Rodriguez-Amaya [21]. This methodology comprehends the extraction of carotenoids from the samples with acetone, followed by separation with