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QUALITY ATTRIBUTES AND PARTICLES DEPOSITION OF SPRAY DRIED FRUCTANS OF BLUE AGAVE JUICE

ATRIBUTOS DE CALIDAD Y DEPOSICIÓN DE PARTÍCULAS DEL SECADO POR ASPERSIÓN DEL JUGO DE AGAVE AZUL

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Abstract

The blue agave juice is a natural source of fructans and dietary fibers, which have great interest in food industry as a functional additive. The aim in this work was to increase the yield, reducing the wall deposition and it improves the quality attributes in spray drying of blue agave juice. Total powder yields were increase when its changes were made in the outlet temperature, atomizer speed and airflow. Maximum reduction of deposition and best yield were found at inlet temperature of 198 ºC, outlet temperature of 80 ºC, airflow of 720 m^{3}h^{-1} and atomizer speed of 30,000 rpm.

Keywords: spray drying, quality attributes blue agave juice, deposition, fructans.

Resumen

El jugo de agave azul es una fuente natural de fructanos y fibras dietéticas, que representa un gran interés en la industria alimentaria como ingrediente funcional. El objetivo de este trabajo fue incrementar el rendimiento, reducir la deposición en la pared del secador y mejorar los atributos de calidad en el secado por aspersión de jugo de agave azul. El incremento en el rendimiento total de polvo se obtuvo cuando se hicieron cambios en la temperatura de salida, velocidad de aspersión y flujo de aire. La reducción máxima de la deposición y el mejor rendimiento fueron encontrados a temperatura de entrada de 198 ºC y temperatura de salida de 80 °C, con un de flujo de aire de 720 m^{3}h^{-1} y con una velocidad de aspersión de 30,000 rpm.

Palabras clave: secado por aspersión, atributos de calidad, jugo de agave azul, deposición, fructanos.

1 Introduction

The blue agave (*Agave tequilana* Weber var. azul) is an economically important crop in the state of Jalisco, México, for the production of tequila. However, blue agave juice is also to make honey and fructans (FOS) employed. FOS was recently identified in agave as a highly branched molecule showing a wide degree of polymerization (DP) ranging from 3 to 29 units with (2-1) and (2-6) linkages of both internal and external fructose (López *et al*., 2003). FOS in blue agave has allowed making more products than just tequila (Michel *et al*., 2015; Alvarado *et al*., 2014; Mancilla and López, 2006). FOS can in various food products be used as an alternative sweetener, a texture modifier, and a fat substitute (Matusek *et al*. 2009). FOS stimulates growth of bifidobacteria, increases Ca^{2+} absorption and decreases blood triglycerides levels (Urías *et al*. 2007; Cani *et al*. 2004; Chandalia *et al*. 2000). As a result, there has been considerable interest in using FOS as a food additive due to its prebiotic and other health protective effects.

Spray drying (135-195 ºC) inulin from chicory under a high temperature process resulted in a significant degradation of FOS ranging from 20 to 100% (Matusek *et al*. 2009; Böhm *et al*. 2005) and it was found that thermal treatment of inulin leads to a degradation of the long fructose chains (Böhm *et al*. 2005). The functional activity of FOS was lost due heat treatment (Huebner *et al*. 2008). An alternative method to minimize the loss of functional properties is to microencapsulate FOS by spray drying, thus optimizing the processing conditions (Gibbs *et al*. 1999). Spray drying is

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the most commonly used encapsulation method in the food industry (Bayram *et al*. 2008; Carrillo *et al*., 2011; Perez *et al*., 2015). Hence, the influence of the main process variables, such as temperature, atomizer speed, airflow, feed flow, nature of the food and its geometry, drying aids types and total solids concentration in a solution play an important role, affecting changes in bulk properties (González *et al*. 2009; Woo *et al*. 2008; Luna *et al*. 2005). Studies have reported the best drying conditions of inulin: feed temperature at 25 °C, atomized at 210 °C, with 5% of the maximum pump speed, resulting in a white powder composed of smooth spherical particles of several morphologies (Toneli *et al*. 2010). This means that FOS or inulin could endure high temperatures of 186 to 214 ºC with drying aids (Nogueira *et al*. 2002). Studies reported the effects of various spray dryer operating variables on tomato powder and concluded that moisture content, solubility and bulk density decreased with an increase in drying temperature, but there was an increase in the solubility and bulk density when the airflow increased (Goula *et al*. 2004). In addition, an increased atomizer speed resulted in increased bulk density and average time of powder wettability and decreases particle size, moisture content, and insoluble solids of orange powder (Chegini and Ghobadian, 2005). However, there is another problem that occurs in the spray drying process, which it is the deposition of drying particles along the internal dryer wall, particularly in sugar-rich foods, which tend to be sticky (Bhandari *et al*. 1992; Ozmen and Langrish, 2003). Many researchers have tried to overcome this problem by adding additives to the materials (Bhandari *et al*. 1992; Ozmen and Langrish, 2003; Woo *et al*. 2007; Woo *et al*. 2008; Langrish and Wang, 2009; Wang and Langrish, 2010).

The purposes of this study were to evaluate the effect of spray drying conditions of blue agave juice on bulk properties, as well as to identify the treatment that could reduce the deposition problem on the spray-drying wall.

2 Materials and methods

2.1 Blue agave juice

Agaveros Industriales de Jalisco in Jocotepec, Jalisco, Mexico, provided blue agave juice. Blue agave juice was from a single production batch obtained, using 4 tons of six to seven-year-old agave plants pines. The juice was in filter press pilot (Didatec Tech®, AFP101, France) filtered and standardized at 20 ºBrix, and frozen at -18 °C. The soluble solids of blue agave juice were from 95% FOS, 4% fructose and 1% glucose constituted.

2.2 Spray drying

A spray dryer Minor^{tm} for pilot scale production (GEA Niro A/S, Søborg, Denmark) with cylindrical section of the drying chamber of 1.2 m in diameter and 1.0 m of height was used for the spray drying process in all experimental treatments. The conical section was 0.7 m in height with 0.3 m in bottom diameter outlet. The rotating disc atomizer has twenty-four annular 4 × 3 mm orifices on an 18 mm thick disc of 0.10 m of diameter. Feed flow rate is controlled by a peristaltic pump of variable flow (Watson Marlon, 504U) connected to a flexible plastic tube inside one container and liquid-fed inlet of the atomizer. The outlet temperatures were varied at 70 and 80 °C, atomizer speed at 20,000 and 30,000 rpm and airflow was at 720 and 810 m^3h^{-1}. Inlet temperature was constant in all treatments at 195 ºC. Powder products were in a receiver at the bottom of the drying chamber (large) and a receiver at the bottom of the cyclone (fine) collected. The spray-dried powder samples were in their respective glass flasks weighed and packed (4.0 L).

2.3 Powder physicochemical analysis

2.3.1. Moisture

Powder moisture content was determined by placing approximately 2 g of sample on a tray of 2.5 cm of diameter into an oven at 100 ± 2 ºC for 2 to 3 h up to constant weight and was expressed in terms of the wet basis percentage ($100 \times kg_{water}\ kg^{-1}_{wet\ powder}$) (Nollet, 2004).

2.3.2. Water activity

Water activity of blue agave juice powder was measured at 25 ºC in 1 g samples using an Aqualab 3TE (Decagon, Pullman, WA, USA) calibrated by LiCl solutions at known concentrations.

2.3.3. Bulk density

A 100 ml glass graduated cylinder was with 20 g (± 0.15 g) of sample filled, and gently dropped into a rubber mat from a height of 15 cm for 40 times (Chegini and Ghobadian, 2005; Roustapuor *et al*.

2009; Al-Kahtani and Hassan, 1990). Bulk density was calculate dividing the weight of the powder by the volume occupied in the cylinder (g ml^{-1}) (Goula *et al*., 2004). All samples were in duplicate made.

2.3.4. Solubility

Solubility determination of the spray-dried powder was by the addition of 4.5g material to 25 ml of distilled water at 26 ºC performed. The mixture was agitated with a magnetic stirrer (brand Cimarec, SP131015, Thermo Scientific, 50-60 Hz, 0.2 A. Waltham, MA, USA) set at position 5 (150 rpm) and the dissolving time was recorded (Nogueira and Park, 2002; Roustapuor *et al*. 2009).

2.3.5. Hygroscopicity

Approximately 1 g of powder was evenly on petri dishes (9 cm diameter) spread to allow a high surface area between humid air and powder. Samples of each powder in the dishes were in desiccators placed under the following conditions: 25 ºC and 85% relative humidity using HNO_3 solution. A 10 min interval to optimize moisture sorption was selected (Roustapuor *et al*. 2009). Hygroscopicity was based on the equilibrium moisture content and was determined by the weight increase per gram of solid powder after 90 min (Goula *et al*. 2004; Roustapuor *et al*. 2009).

2.4 Particle morphology

Powder samples were to sample stubs attached, using double-sided tape. The samples were sputter coated with gold using a Polaron sputter coater E5100 and then examined using a JSM-5300 LV scanning electron microscope (JEOL, USA) at a magnification of 1000 × and 20-30 kV.

2.5 Powder yields

Agave powder yields in percentage (%) were determined dividing the final weight of powder by the initial weight of juice. The fine and large particles yields were individually by weighing each container powder determined (drying chamber and cyclone) and dividing them by the initial weight of juice. The total powder weight was equal to the sum of weights from fine and large particles.

2.6 Determination of mono, di and fructooligosaccharides composition in the powders

The presence of mono, di and fructooligosaccharides en the powder were determined qualitatively by high-performance anion-exchange chromatography (HPAEC) on a Dionex ICS 5000 chromatography system equipped with a pulsed amperometric detector (PAD), using a Dionex PA200 column (0.4 × 5 cm; Dionex, USES). The columns were first equilibrated at 35 °C with 100 mM NaOH at flow rate of 0.5 mL·min-1 during 10 min before the injection of 30 μL of each aliquot of diluted powder. The fructooligosaccharides were eluted with a gradient of 600 mM sodium acetate in 100 mM NaOH and only 100 mM NaOH. 1-kestose (DP3), 1,1-kestotetraose (DP4) and 1,1,1-kestopentaose (DP5) (Megazyme, Bray, Ireland) and inulins of chicory (Sigma, USA) were used as fructan standards. Standard solutions of glucose, fructose and sucrose were obtained from Sigma (St. Louis, Missouri, USA).

2.7 Determination of amount of deposition

The amount of deposition was on samplers collected, adopting the experimental method by past researchers (Sandripour *et al*. 2012). The samplers were mainly in the cylindrical section placed. The cylindrical section of spray dryer was equipped with two black cardboard strips samplers of (1.0 × 0.8 m) that were placed along the length of the spray chamber. The samplers were installed at a height of 0.2 m and in opposite direction of the spray chamber, considering the axisymmetric geometry. At the end of each experimental run, the samplers were removed and divided at three different heights 0.2, 0.6 and 0.8 m from the dryer roof. Afterwards, all divided samplers were weighed to determine the amount of deposition. The divided samplers were also analyzed to determine moisture (%) and water activity of the deposited powders on the strips.

2.8 Experimental design and statistical analysis

The experiments were conducted using a full factorial design of experiments 2^3 along with two controls (TW1 & TW2). Ten experiments with one replicates were performed. The controls were not treated with carrier agent, but all the other samples in the factorial design were treated with the addition of 0.1 % whey protein of T01 and T08 (Table 1). Table 1 shows all experiments and controls of full factorial designs. Whey protein WPC-80 (protein 80 % minimum) was in America Alimentos S.A. de C.V. Company purchased.

The results illustrate the means for four replicates (two replicates for each test of the experimental design). Statistical analyses were using statistical software MINITAB (Release 14.10) performed. Statistical significance was determined by a multiple analysis of variance (MANOVA) at p values of <0.05.

3 Results and discussion

3.1 Spray drying of blue agave juice

The processing conditions and response variables for all experiments in pilot spray drying are in Table 2 shown. In all the experiments, agave powder had a tendency to stick to the internal stainless steel surfaces of the drying chamber, with or without whey protein as carrier agent; according with other authors (Adhikaria *et al*. 2003; Kudra, 2003). This significantly affects yield, the amount of product collected, as well as some sensory and bulk characteristics (Wang and Langrish, 2010; Finney *et al*. 2002).

3.2 Powder physicochemical analysis

The values of moisture content of blue agave juice powder at different drying conditions are in Table 2 reported, where moisture content varied from 0.040 - 0.055 $kg_{water}\ kg^{-1}_{dry\ matter}$. The spray drying conditions showed significant difference in moisture content between the treatments with or without carrier agent.

Table 1. Complete random design with independent variables.

Treatments	Independent Variables			Sample
	Atomizer speed	Outlet temperature	Air flow	
	rpm	°C	$m^3\ h^{-1}$	
TW1	20000	70	720	Just agave juice
TW2	30000	80	810	Just agave juice
T01	20000	70	720	Agave juice with Whey
T02	30000	70	720	Agave juice with Whey
T03	20000	80	720	Agave juice with Whey
T04	30000	80	720	Agave juice with Whey
T05	20000	70	810	Agave juice with Whey
T06	30000	70	810	Agave juice with Whey
T07	20000	80	810	Agave juice with Whey
T08	30000	80	810	Agave juice with Whey

Note: The inlet temperature was in the range of 198-194°C without control.

Table 2. Responses for dependent variables studied

Treatments	Dependent variables									
	a_w		Bulk density		Hygroscopicity		Moisture		Solubility	
		s	$kg\ L^{-1}$	s	$kgkg^{-1}_{db}$	s	$kg_{water}kg^{-1}_{dry\ matter}$	s	h	s
TW1	0.380^{ab}	0.05	528^{c}	0.04	1.120^{b}	0.05	0.055^{a}	0.022	0.132^{c}	0.013
TW2	0.332^{b}	0.01	502^{c}	0.12	1.063^{c}	0.02	0.052^{a}	0.011	0.125^{c}	0.019
T01	0.340^{b}	0.02	588^{a}	0.00	1.079^{c}	0.01	0.040^{b}	0.006	0.133^{b}	0.017
T02	0.350^{b}	0.02	541^{b}	0.00	1.064^{c}	0.04	0.045^{a}	0.006	0.189^{a}	0.031
T03	0.348^{b}	0.01	548^{b}	0.01	1.298^{a}	0.24	0.046^{b}	0.015	0.203^{a}	0.041
T04	0.339^{b}	0.01	556^{a}	0.00	1.040^{c}	0.04	0.046^{ab}	0.006	0.170^{a}	0.035
T05	0.329^{b}	0.07	646^{a}	0.03	1.094^{c}	0.02	0.044^{b}	0.004	0.174^{a}	0.013
T06	0.340^{b}	0.01	556^{a}	0.00	1.127^{b}	0.04	0.044^{b}	0.007	0.119^{c}	0.033
T07	0.414^{a}	0.10	572^{a}	0.02	1.093^{c}	0.02	0.049^{a}	0.003	0.148^{ab}	0.025
T08	0.341^{b}	0.05	521^{c}	0.09	1.114^{b}	0.01	0.045^{b}	0.009	0.143^{c}	0.022

The values of water activity of blue agave juice powder at different drying conditions are in Table 2 reported, where water activity varied from 0.332 to 0.414. There was significant difference in water activity between the treated samples (TW2, T01, T02, T03, T04, T05, T06 and T08), except T07 and TW1 (Table 2).

Bulk density increases with the addition of carrier agent improve particle morphology (Walton, 2000). Thus, spherical particles will pack better and will have the highest bulk densities with all other factors being equal (Gadelha *et al*. 2009). According to Table 2 the lowest values for bulk density were achieved for the highest level of airflow, atomizer speed and temperature.

In the spray drying of agave juice, 70 and 80 ºC, output air temperatures showed a significant effect on bulk density (Table 2). Normally, a significant effect on bulk density is associated with a change in the particle morphology (Walton, 2000) and a greater tendency for the particles to be hollow (Chegini and Ghobadian, 2005; Gadelha *et al*. 2009).

The higher values in solubility when is worked at low airflow were found, as shown in Table 2. However outlet air temperature and atomizer speed shower the significant effect on solubility values only when is worked at high airflow. The addition of carrier increase the solubility. This results differs from the other spray drying studies, but it may be due to the nature of blue agave juice, which contains mainly FOS (Goula, Adamopoulos and Kazakis, 2004; Chegini and Ghobadian, 2005; Müller *et al*. 2000).

The treatment T03 was the high value the hygroscopicity showed (1.298 kg kg^{-1} db). Table 2 it can be seen that by using carrier agent and low airflows an increase in outlet air temperature has a significant effect and when was worked at high outlet air temperatures, an increase atomizer speed also shows a significant effect. However, by increasing the airflow, the outlet air temperature showed no significant effect, but if increased atomizer speed showed a significant effect.

3.3 Particle morphology

Microphotographs confirmed the results regarding wide morphology distributions for all samples; in general, the microphotographs showed that the spray-dried powders are spherical particles (Fig. 1 and 2). This characteristic leads to free flow, water activity and moisture and is important for the application of spray-dried powders as an intermediary food product (Rosell, Santos and Collar, 2009). A change in outlet temperature resulted in appreciable change in morphology of the particles (Fig. 1). However, large particles in spray drying samples with whey protein-treated carrier agent developed smooth capsules with detectable signs of breakage and agglomeration (Fig. 2), which probably resulted from water evaporation (Palmieri *et al*. 1999; Reineccius, 2004). The higher atomizer speed and airflow did no result in agglomeration (Fig. 1), but all powders developed a multicare capsule (Gibbs *et al*. 1999), which is characteristic of FOS (Woo *et al*. 2008). Spray draying blue agave juice without whey protein-treated carrier agent exhibited spherical sharing without smooth or agglomeration problems (Fig. 2). Thus, FOS of blue agave juice could be used as carrier agent because the spherical particles developed, shows stability in dried particles and have the highest bulk densities (best packing) (Del Nobile *et al*. 2003).

3.4 Powder yields

There was a significant difference between fines, large and total particles yields (Fig. 3). The carrier agent resulted in an increase in fine and total powder yields. This results are good because is recovery the higher account of fine powder in the cyclone showed better efficient in the spray drying. The effect of temperature and airflow on product recovery by analysis of the residual accumulation was determined. Some fine particles that resulted may not have been by a high airflow recovered, because a final spray dryer cyclone may have resulted in deposition problems on the cyclone wall.

3.5 Identification of mono-, di- and oligosaccharide

The chromatographic profiles at different stages of the hydrolysis process was obtained by high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD) of the blue agave juice powders compared with standard chicory inulin shown in Fig. 4 and 5. HPAEC-PAD has been widely used for the analysis of fructans because it allows the observation of short and long linear fructans up to a DP of about 30. This technique has been previously to describe the carbohydrate profile of agave fructans applied (Arrizon *et al*. 2010; Waleckx *et al*. 2008).

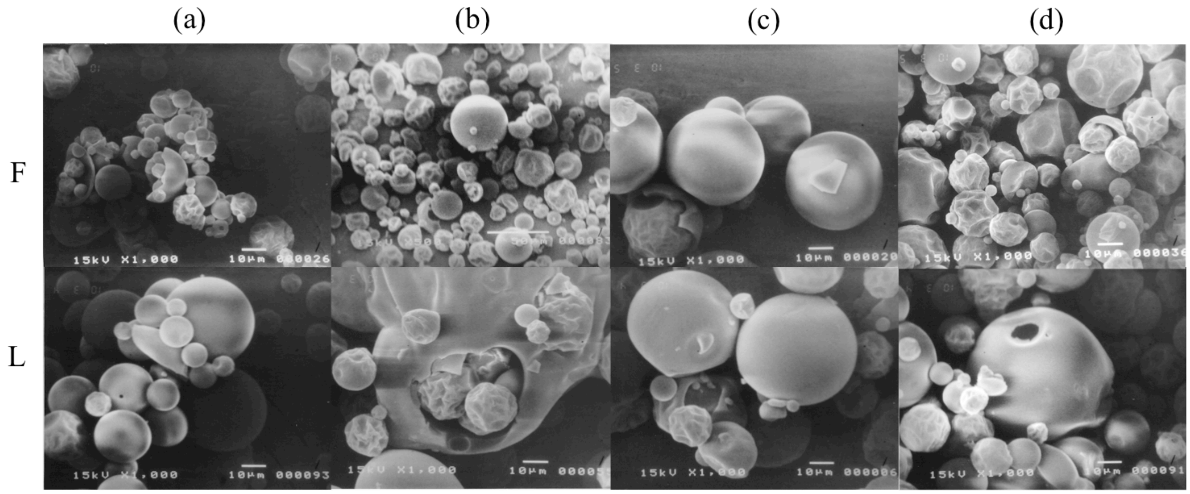

Fig. 1. Micrographs of drying juice of the blue agave juice with and without carrier agent and dry fine (F) and dry large (L) particles: (a) with carrier agent at 70ºC, 20,000 rpm and 720 m^3 h^{-1}, (b) without carrier agent at 70ºC, 20,000 rpm and 720 m^3 h^{-1}, (c) with carrier agent at 80ºC, 30,000 rpm and 810 m^3 h^{-1} and (d) without carrier agent at 80ºC, 30,000 rpm and 810 m^3 h^{-1}.

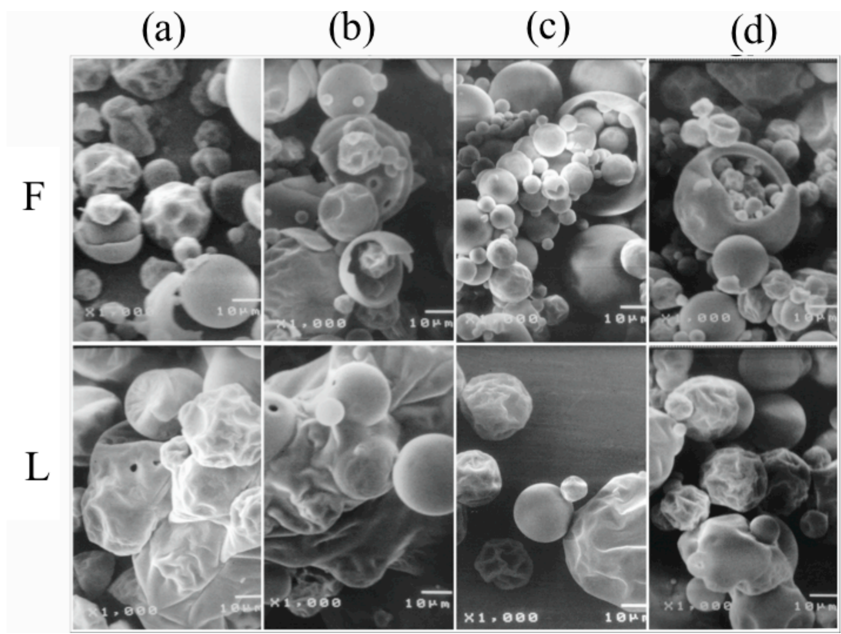

Fig. 2. Micrographs of final powder of blue agave juice with additives at different operating conditions on fine (F) and large (L) particles: (a) 70ºC, 20,000 rpm and 720 m^3 h^{-1}, (b) 80ºC, 20,000 rpm and 720 m^3 h^{-1}, (c) 70ºC, 30,000 rpm and 810 m^3 h^{-1}, (d) 80ºC, 30,000 rpm and 810 m^3 h^{-1}.

In this work we can observe that powders of blue agave juice obtained by spray drying at low outlet air temperature, low airflow and low spray rate increased hydrolysis of agave fructans. This increase was when we compared the treatments observed to the same operating conditions with and without the use of a carrier agent. By increasing the airflow rate, outlet air temperature and speed of rotation, the same behavior is also observed because the carrier agent helped get less hydrolysis of the agave fructan. This work shows fructans of varying DP and linkage structure in each from blue agave juice powders.

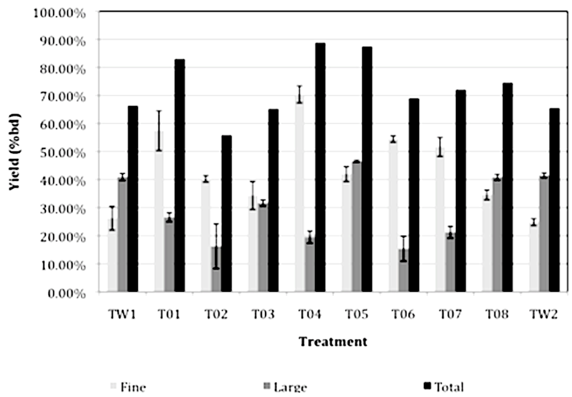

Fig. 3. The effect of spray drying conditions on the fine, large and total particles yields of the *Agave tequilana* juice.

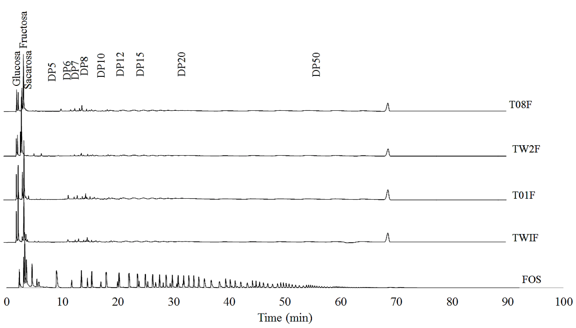

Fig. 4. HPAEC-PAD profiles of Agave fructans powders spray dried with carrier agent compared to elution time of inulin standard.

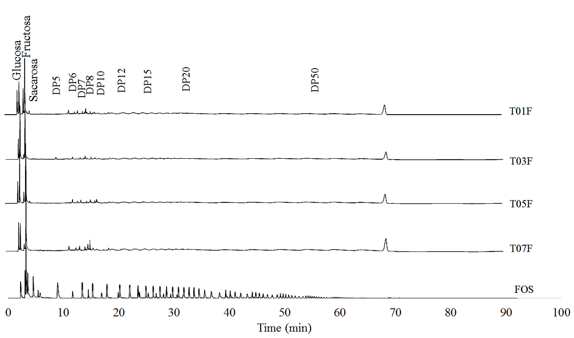

Fig. 5. Chromatographic profiles of Agave fructans powders obtained by spray drying without carrier agent compared with inulin standard.

The glucose, fructose, sacarose and kestose were in samples identified. The presence of inulin-type fructans was in our samples confirmed. Furthermore, we can assume that almost all of the peaks eluted after 7 min were fructans. Both Fig. 4 and 5, the agave fructans, for instance, comprises approximately 90% fructose chains with a DP of 7-11 and only 5% agave fructans with a DP over 25. This mixture of fructose and fructans may have functional features and used both as sweetener and as prebiotic. From a structural point of view, due to the complex structure of agave fructans, this hydrolytic process results in a mixture of inulin and non-inulin fructans whose prebiotic properties require evaluation. Nevertheless, a recent study describes the potential prebiotic activity of the whole agave fructans (Gomez *et al*. 2010). To relate the degree of hydrolysis with fructose as well as fructans production and distribution, the total area of products with retention times was in the range of 7?55 min quantified and plotted as a function of the standard. These results are in Fig. 4 and 5 shown, where it may be observed between 7 and 35 min, the fructans production is optimal in all treatments with and without carrier agent.

3.6 Amount of deposition in spray drying

The amount of deposition on the dryer wall showed significant differences (Fig. 6) at different drying conditions and elevations of the cylindrical section of the spray dryer. Although small agglomerates were in all the cylindrical part of the spray drying formed, they were mainly in the middle section distributed (Fig. 6). These results contrast with other food products with high carbohydrate content that was evenly distributed on the bottom plate of cylindrical spray drying (Woo *et al*. 2008; Giese, 2000). However, the depositing particles were also wetter at the top (near the atomizer) (Woo *et al*., 2008). Fig. 6 illustrates the particles distribution in kg m-2 at all elevations of the cylindrical section of the spray dryer, as well as the effect of drying conditions on the deposition. Deposition was mainly located in the central belt of the middle section, at 0.350 and 0.525 m of the cylindrical section and no depositions were found at the conical section of the spray dryer (Woo *et al*. 2008). Reduction of the deposition on the cylindrical wall occurred at outlet temperature of 80 ºC, atomizer speed of 30,000 rpm and airflow of 720 m^3h^{-1} (treatment T04), but when temperature increases and atomizer speed decreases at a constant air speed and viz., wall deposition increases. On the other hand, treatments T02 and TW1 presented the highest amount of deposition with 0.898 kg and 0.845 kg in stick particles, reducing overall yield (Wang & Langrish, 2003). This increase in fraction of deposition could be due a higher chance to escape from the core flow of formed droplets (Giese, 2000).

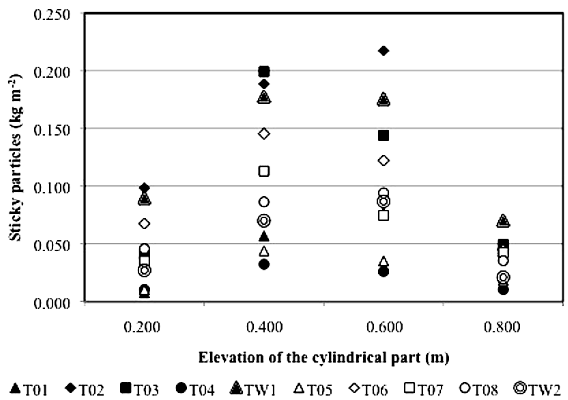

Fig. 6. The amount of deposition on samplers collocated in the dryer wall at different drying conditions of blue agave juice.

Therefore, this increase in fraction of deposition at the top and middle section are mainly due to formation of viscous immobile liquid brigges (Woo *et al.* 2008). Although the deposition problem is also related to glass transition temperature, especially for sugar-rich foods, it is suggested that this problem is also due to that agave powders are mainly composed of high-molecular weight carbohydrates, but sensitive to high temperatures that allow release of low molecular weight carbohydrates. Fig. 6 shows the difference between treatments with (T01 and T08) and without (TW1 and TW2) carrier agent. Carrier agent addition in treatment T01 significantly decreases deposition in TW1 with the same spray drying conditions. However, T08 and TW8 showed no significant difference on the amount of deposits at different heights of the spray-drying chamber.

The variation of moisture content and water activity of droplets along the length of chamber at different operative conditions are in Fig. 6 depicted. Moisture content at each height is the average of moisture content of deposited particles at different points from the contour of spray drying chamber in that height. As depicted in Fig. 6, moisture content of each treatment showed no significant difference at different heights, as well as among treatments with or without carrier agent. T04 treatment had the lowest moisture of < 0.01 kg_{water} $kg^{-1}_{dry\ matter}$, while T08 and TW8 treatments had the highest moisture of > 4 kg_{water} $kg^{-1}_{dry\ matter}$. Water activity at different heights of the spray-drying chamber can be seen, starting from 0.2 m of roof height, meaning that water activity is greater at 0.4 m than 0.8 m (Fig. 6).

Conclusions

Results show that all operating conditions significantly affect some bulk properties of powder. Outlet temperature affected bulk density as well as particle morphology, whereas airflow affected powder solubility. A change in outlet temperature represented a significant difference on morphology of particle. However, large particles in spray drying samples with whey protein-treated as carrier agent had smooth capsules with detectable signs of breakage and agglomeration. Yields ranged from 25-70%, 15-45% and 55-90% for fine, large and total yields respectively. There was a significant accumulation of the amount of deposition at various elevations of the cylindrical section of the drying unit in all trials. Highest concentrations of deposition, as well as the highest values of powder moisture and water activity, occurred at middle elevation (0.4 m). Optimal operating conditions for the best bulk and physicochemical properties as well as the lowest deposition were at an outlet temperature of 80 ºC, atomizer speed of 30,000 rpm and airflow of 720 m^3h^{-1}, resulting in the better total yield at 90% and in the lower deposition problem < 0.05 kg m^{-2}. Further research is required to find the stability/mobility diagram of agave powders to provide guidelines for their handling to avoid stickiness, as well as decrease or recover deposited particles.

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