Original article

Addition of cashew tree gum to maltodextrin-based carriers for spray drying of cashew apple juice

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Summary This study involved an attempt to totally or partially replace maltodextrin DE10 (MD10) by cashew tree gum (CTG) as a drying aid agent in spray drying of cashew apple juice. The objective was to evaluate the impact of drying aid/cashew apple juice dry weight ratio (D/C, ranging from 3 to 5) and degree of replacement of MD10 with CTG (CTG_R, ranging from 0% to 100%) on ascorbic acid retention (AAR), hygroscopicity, flowability and water solubility of spray dried cashew apple juice powder. AAR was increased from 72.90% to 95.46% by increasing D/C from 3 to 5. CTG was shown as a promising maltodextrin replacer, being more effective than the latter to decrease powder hygroscopicity. The most adequate drying conditions (D/C = 5, $CTG_R \geq 50\%$) resulted in more than 90% of AAR, and produced a powder with good flowing properties and water solubility.

Keywords Cashew apple, cashew tree gum, gum arabic, powder fruit juices, spray drying, tropical fruits.

Introduction

In the last few decades, the food industries have been forced to change their products in order to answer to the requirements of the consumers concerning convenience, food safety, health benefits and sensory quality. An increasing demand for fruit juices has been observed, but most consumers do not have time to spend in preparing them, requiring ready-to-use or easy-to-prepare products.

The cashew (*Anacardium occidentale*) culture has a tremendous social-economical importance in Brazil, especially in the Northeastern region. The cashew itself is composed of the cashew nut (real fruit) and the cashew apple (pseudo-fruit). Thanks to its high ascorbic acid and phenols contents, cashew apples are considered as a good source of antioxidant compounds (Agostini-Costa *et al*., 2003; Assunção & Mercadante, 2003; Brito *et al*., 2007).

Juices, nectars and frozen pulps are the main products obtained from the cashew apple. Juices and nectars are costly to transport, because of their high weights (most of their composition being water), and frozen pulps require the additional costs related to an adequate cold chain. Juice powders are interesting exportation products, as they answer to consumer requirements, at the same time being cheap to transport and with a prolonged shelf life (Cano-Chauca *et al*., 2005).

Spray drying is a widely used technique to produce powders from liquid foods. However, drying of fruit juices into powder is difficult, especially because of the presence of low molecular weight sugars and acids, which have low glass transition temperature (T_g), being then very hygroscopic, because of their high molecular mobility above T_g (Roos, 1995; Jaya & Das, 2004). While under spray drying temperatures, they tend to stick to the walls of the drying chamber and can produce a paste-like structure instead of a powder (Bhandari *et al*., 1997; Dolinsky *et al*., 2000; Bhandari & Hartel, 2005). Some possible consequences are related to impaired product stability, decreased yields (because of stickiness on the drier chamber walls), and even operating problems to the spray drier (Bhandari *et al*., 1997).

The sticky behaviour can be avoided by the addition of drying aids, which are high molecular weight carbohydrates, such as maltodextrins, which decrease powder hygroscopicity, thanks to their T_g increasing effect (Bhandari *et al*., 1997; Bhandari & Hartel, 2005; Silva *et al*., 2006). Gum arabic has been reported to have higher T_g values than maltodextrin DE10 (MD10) (Collares *et al*., 2004), which suggests that it is probably more effective than the latter in reducing powder

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hygroscopicity. Moreover, gum arabic has been reported as being very efficient in flavour retention (Madene *et al.*, 2006; Galmarini *et al.*, 2008). On the other hand, gum arabic is expensive, which has motivated researchers to look for materials to replace it (McNamee *et al.*, 1998). Cashew tree gum (CTG), a complex water soluble heteropolysaccharide extracted from cashew tree (*A. occidentale*), has been identified as a very promising gum arabic replacer, due to its structural similarity to the latter (Zakaria & Rahman, 1996; De Paula *et al.*, 1998; Paula *et al.*, 2002). Such replacement, previously suggested by Owusu *et al.* (2005), could reduce costs and favour the cashew tree business, whose only high market value product is currently the cashew nut.

The objective of this study was to evaluate the influence of the drying aid/cashew apple juice dry weight ratio (D/C) and the degree of replacement of MD10 by CTG (CTG_R) on ascorbic acid retention (AAR) during spray drying, as well as on some properties of the final product (flowability, hygroscopicity and solubility), so as to define the most adequate conditions to obtain a spray dried cashew apple juice.

Material and methods

Cashew tree gum was extracted from a single cashew tree (Fortaleza, CE, Brazil) and purified by the method described by Torquato *et al.* (2004). MD10 and/or CTG in different proportions were added to whole cashew apple juice with 11.4% soluble solids (produced by Sucos Jandaia, Pacajus, CE, Brazil), according to a central composite design (Table 1), and homogenised for 1 min (tissue homogeniser AC 620/2; Ação Científica, Piracicaba, Brazil). The suspension was filtered in a stainless steel sieve (0.3-mm mesh) in order to avoid clogging of the atomiser. The spray drying was then conducted in a Mini Spray Dryer Büchi B-290 (Büchi Labortechnik AG, Flawil, Switzerland) under the following operational conditions: inlet temperature, 185 °C; outlet temperature, 90 °C; peristaltic pump rate, 840 mL h^{-1}; aspirator flow rate, 3.75×10^4 L h^{-1}.

The cashew apple powders obtained by each treatment were submitted to the following determinations: moisture content by the vacuum oven method (AOAC 1990), ascorbic acid contents by redox titration with 2,6-dichloroindophenol (AOAC 1990), water solubility (Eastman & Moore, 1984; modified by Cano-Chauca *et al.*, 2005), flowability (based on the angle of repose, as described by Bhandari *et al.*, 1998), hygroscopicity (Callahan *et al.*, 1982, modified by defining hygroscopicity as the moisture weight absorbed by 100 g of unpacked powder after 7 days of storage at 25 °C and 90% RH). The hygroscopicity values were not evaluated by their absolute values, because the powders were exposed to unreal abusive conditions (high RH, without the protection of a package), but instead the hygroscopicity was used to compare treatments. The whole juice from which the powders were obtained was submitted to determinations of ascorbic acid content and total solids, in order to calculate AAR based on cashew apple solids.

The results were analyzed by Response Surface Analysis, by using the software Minitab 15 (Minitab, State College, PA, USA), in order to consider the best possible conditions, that is to say, the most adequate ranges of variables so as to obtain a powder with the highest possible AAR, at the same time with good flowing properties and high water solubility. The process

Table 1 Experimental design (coded and actual values of the independent variables) and responses obtained from the experimental runs

D/C		CTG_R (%)		Responses			
Coded*	Actual	Coded*	Actual	AAR	ANG	HYG	WS
−1	3.3:1	−1	14.6	66.19	34.73	45.86	92.32
1	4.7:1	−1	14.6	81.12	26.73	40.71	95.18
−1	3.3:1	1	85.4	72.01	35.61	41.58	91.27
1	4.7:1	1	85.4	90.84	26.26	38.53	92.78
−1.41	3.0:1	0	50	72.90	36.59	45.56	93.09
1.41	5.0:1	0	50	95.46	23.96	41.00	93.03
0	4.0:1	−1.41	0	83.63	34.39	41.42	95.64
0	4.0:1	1.41	100	86.88	33.33	37.21	92.34
0	4.0:1	0	50	71.67	34.94	41.82	94.48
0	4.0:1	0	50	73.38	35.46	38.81	94.24
0	4.0:1	0	50	74.44	31.43	39.05	96.41

Mean values from triplicate analyses are shown.

D/C, drying aid to cashew apple juice dry weight ratio; CTG_R (%), degree of replacement of maltodextrin by cashew tree gum as drying aid; AAR, ascorbic acid retention during spray drying (%); ANG: angle of repose (°); HYG, hygroscopicity (g absorbed water/100 g powder in 7 days of storage at 25 °C and 90% RH); WS, water solubility (g powder/100 mL water).

*Coded values are according to the central composite design, ranging from −1.41 to 1.41 when one has two independent variables.

was then carried out under such conditions, in order to characterise the final product, in terms of moisture content, water activity (Aqualab CX-2; Decagon Devices, Pullman, WA, USA), ascorbic acid, total carotenoids (Higby, 1962) and total phenols contents (Folin-Ciocalteau method, described by McDonald *et al*., 2001).

Results and discussion

The experimental responses are presented in Table 1. Flowability and water solubility were observed to have satisfactory values in all conditions tested. All runs produced powders with a high water solubility (at least 90%) and without significant flowing problems according to the classification presented by Bhandari *et al*. (1998), who proposed that powders with angles of repose lower than 45° are free-flowing. So, flowability and water solubility were considered as non-limiting factors to the product quality in this study.

Figure 1 (contour plots for the experimental responses) and Table 2 were used to describe the behaviour of the responses. Table 2 presents the regression coefficients for the coded models. Except for water solubility, all models were significant ($P < 0.05$), with good determination coefficients (R^2 higher than 80%). The non-significance of the model for water solubility was not considered as a problem, as this property was taken as a non-limiting factor to the powder quality, as previously stated.

Ascorbic acid retention was increased by increasing drying aid:cashew apple ratios, suggesting that the drying aids had a protective effect on ascorbic acid. A decreasing degradation of ascorbic acid in presence of maltodextrin was previously reported by Hung *et al*. (2007) during freeze-drying. On the other hand, AAR was not significantly affected by the replacement of maltodextrin by CTG, although Righetto & Netto (2006) had observed that the partial replacement of maltodextrin by gum arabic favoured AAR during spray drying.

Hygroscopicity and flowability can be taken as correlated properties, because more hygroscopic powder will probably have more flowing problems related to the absorbed water (Fitzpatrick, 2005), because of the increased number of liquid bridges and capillary forces acting on the particles (Scoville & Peleg, 1981). Both properties are dependent on the powder T_g – the higher the T_g, the less hygroscopic and the more free-flowing is the powder. Higher drying aid concentrations decreased hygroscopicity and favoured flowability (i.e., decreased angles of repose), confirming the behaviour described in previous studies for hygroscopicity (Bhandari *et al*., 1993, 1997; Bhandari & Hartel, 2005; Quek *et al*., 2007; Silva *et al*., 2006) and flowability (Anselmo *et al*., 2006; Quek *et al*., 2007). Higher levels of replacement of MD10 by CTG decreased powder hygroscopicity, suggesting that CTG is more effective than MD10 to increase T_g values of the powders. Other studies about the CTG effects on T_g have not been found, but the similarity between CTG and gum arabic structures suggest that both must have similar T_g effects. So, this result may be compared to that reported by Collares *et al*. (2004), who indicated that the T_g increasing effect of gum arabic is higher than that of MD10. Although the degree of

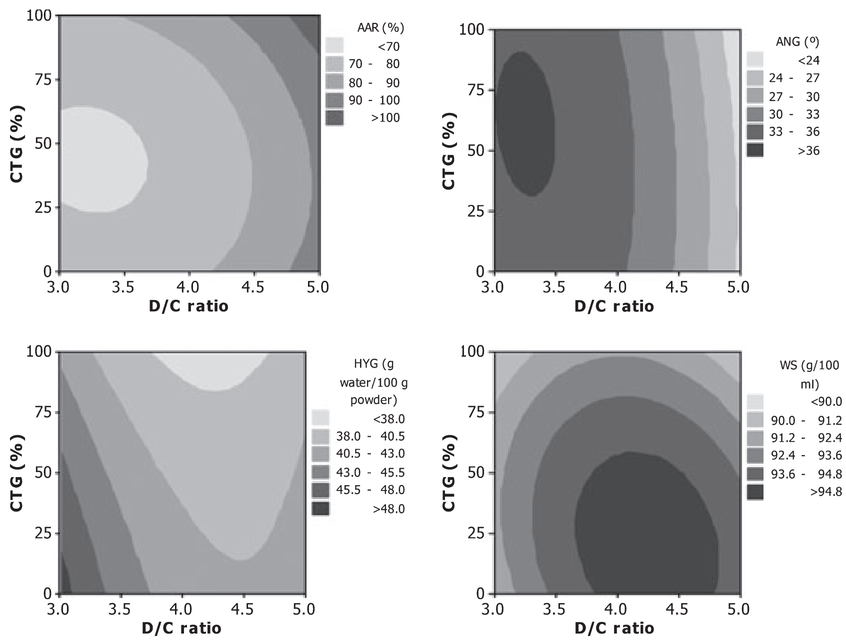

Figure 1 Contour plots representing the responses (AAR = ascorbic acid retention; ANG = angle of repose; HYG = hygroscopicity; WS = water solubility). D/C ratio: drying aid to cashew apple juice dry weight ratio; CTG_R: degree of replacement of maltodextrin DE10 by cashew tree gum.

Table 2 Regression coefficients for the equations representing the responses (based on coded values)

	AAR		ANG		HYG		WS	
Terms	**Coef**	**p**	**Coef**	**p**	**Coef**	**p**	**Coef**	**p**
Mean	73.20	<0.01	33.94	<0.01	39.89	<0.01	95.05	<0.01
D/C	8.23	<0.01	−4.40	<0.01	−1.83	<0.01	0.54	0.23
CTG_R	2.52	0.21	−0.14	0.82	−1.55	0.01	−1.02	0.05
$(D/C)^2$	3.70	0.14	−2.14	0.03	1.79	0.01	−1.16	0.06
$(CTG_R)^2$	4.24	0.10	−0.35	0.63	−0.20	0.69	−0.69	0.21
$D/C*CTG_R$	0.97	0.71	−0.34	0.69	0.52	0.39	−0.34	0.57
R^2	85.53%		93.26%		91.58%		75.44%	
$F_{regression}$	5.91		13.84		10.88		3.07	
P	0.04		<0.01		0.01		0.12	

AAR, ascorbic acid retention during spray drying; ANG, angle of repose; HYG, hygroscopicity; WS, water solubility; D/C, drying aid to cashew apple weight ratio; CTG_R, degree of replacement of MD10 by CTG .

replacement of MD10 by CTG did not significantly affect the flowability of the newly produced powders, its hygroscopicity reducing effect suggests that the flowability of the powders would probably be favoured by the replacement during storage, as less water is expected to be absorbed with time.

Although the model for water solubility was not significant, it can be considered as a tendency indicator. There seems to exist a tendency for water solubility to be impaired by increasing drying aid concentration, confirming results reported by Abadio *et al*. (2004) and Cano-Chauca *et al*. (2005), and also by increasing replacement of MD10 by CTG. Even though, as it was satisfactory within all experimental region, such tendencies were not considered for determining the best conditions.

Considering simultaneously all responses but solubility, the following conditions were established as those which provided a final product with the best possible combination of properties, within the conditions studied: drying aid to cashew apple dry weight ratio, 5:1, the drying aid having 50% CTG as a maltodextrin replacer. Under such conditions, the models predicted the following responses: AAR, 92.2%; angle of repose, 23.5°; and water solubility, 93.5%.

A spray dried cashew apple juice produced by using such conditions – that is to say, D/C ratio of 5, with a CTG_R of 50% – presented the following characteristics: moisture content, (1.16 ± 0.02)%; water activity, 0.284 ± 0.004; ascorbic acid, (224.24 ± 5.87) mg per 100 g; total carotenoids, (0.33 ± 0.02) mg per 100 g; and total phenols, (498.43 ± 9.59) mg per 100 g.

Conclusions

The drying aid agents were useful in spray drying of cashew apple juice, as increasing the proportion drying aid:cashew apple not only resulted in improved physical properties of the powder (that is to say, decreased its hygroscopicity and increased flowability), but also enhanced AAR during the process. The CTG was presented as a good drying aid agent, reducing the hygroscopicity of the spray dried cashew apple juice powder when compared with that produced by using MD10 as drying aid. When using a drying aid/cashew apple juice dry weight ratio of 5:1, CTG replacing maltodextrin in 50%, more than 90% of the ascorbic acid was retained during spray drying, and a powder with good flowing properties and water solubility was obtained.

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