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SPRAY DRYING OF UNFERMENTED COCONUT SAP OR SWEET TODDY INTO AN AMORPHOUS POWDER

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Abstract
This study was carried out to convert unfermented coconut sap or the sweet toddy into powder form through spray drying using maltodextrin (DE 10) as the drying aid. Three different formulations of sweet toddy: maltodextrin (70%: 30%, 80%: 20% and 90%:10%) were spray dried at inlet and outlet temperatures of 165 °C and 65 °C, respectively. Powder recovery in a pilot scale spray dryer was used as a measure of the ease of spray drying for a given formulation. The spray dried sweet toddy powder was characterized for moisture content, water activity, crystalline-amorphous nature, particle morphology, sugar profile and the keeping quality. The best powder recovery (56.35±2.90%) was obtained for the formulation of sweet toddy: maltodextrin in the ratio of 80%:20%. The moisture content and water activity value of the spray dried coconut sweet toddy powder were 1.24±0.01% and 0.29±0.00, respectively. It was interesting to note that both the moisture content and the water activity of sweet toddy powder did not vary significantly (p>0.05) on storage of one year. X-ray diffraction studies revealed that the spray dried sweet toddy powder was amorphous. The scanning electron micrograph of spray dried coconut sweet toddy powder showed that the particles were spherical in shape. The sugar profile of this sweet toddy powder showed that it had a total sugar content of 66.1±0.04% out of which 32.7±0.02% was sucrose, 22.4±0.01% was glucose and 11.0±0.01% was fructose.

Keywords: unfermented coconut sap, sweet toddy, spray drying, stickiness, drying aid.

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1. INTRODUCTION

The sweet toddy or the unfermented coconut sap is the liquid that oozes out of the coconut inflorescence which is used to prepare coconut treacle, jaggary and golden syrup. The fresh unfermented sweet toddy contains 15-18 % (w/v) sugar mainly in the form of sucrose (Athputharaja, Samarajeewa and Widanapathirana, 1980). Sweet toddy undergoes fermentation almost immediately by a group of heterogeneous micro-organisms, probably originating from the indigenous flora of palm trees, the atmosphere or the tapping equipment. It is essential that sap is preserved from spontaneous fermentation with the addition of anti-ferments such as 'Hal' (*Vateria copalifora*) bark if the sap is used to produce jaggary, treacle and golden syrup. It is reported that the anti-ferments delay the fermentation process only by 14 to 15hrs (Athputharaja, Samarajeewa and Widanapathirana, 1980). However, if sweet toddy is preserved for prolonged periods, it can be used to make treacle, jaggary and golden syrup at any period of time. One such preservation method is spray drying.

Spray drying is a well-established and widely-used method for transforming a wide range of liquid food products into powder form (Adhikari et al., 2009a; Adhikari et al., 2009b; Jayasundera et al., 2010). Spray dried food powders can be stored at ambient temperature for prolonged periods without compromising the powder stability (Jayasundera et al., 2011a). They are also cheaper to transport and easier to handle in manufacturing plants. Spray drying is economical compared to freeze drying as the latter is a batch process with long processing time and is also six times as expensive as spray drying in terms of operational cost and nine times as expensive as spray drying in terms of capital cost (Chavez and Ledeboer, 2007; Santivarangkna, Kulozik and Foerset, 2007). Spray drying has many applications, particularly in the food, pharmaceutical and agrochemical industries (Vega, Goff and Roos,

2005; Bhandari et al., 1993; Adhikari et al., 2007; Maa, Nguyen and Hsu, 1998; Maa and Hsu, 1997). However, one prevalent problem in spray drying is the stickiness that occurs when sugar-rich foods are spray dried. The stickiness results in depositions onto the internal dryer wall and unacceptable clumping of particles. Both of these lead to inferior product quality and economic loss (Bhandari and Howes, 1999; Ozmen and Langrish, 2003).
To minimize the stickiness problem, both process-based and material science-based approaches are used. Process-based approaches include the mechanical scraping of the wall of the drying chamber, introduction of cold air at the bottom of the chamber and the use of low temperature/low humidity air. An example of the material science based approach involves the addition of drying aids such as corn starch, gum Arabic and maltodextrin to reduce the stickiness of the powders (Downton, Flores-Luna and King, 1982; Werner et al., 2007).
However, no studies have been carried out to convert unfermented coconut sap or the sweet toddy into an amorphous powder due its inherent stickiness. Therefore, this study was aimed at spray drying sweet toddy into an amorphous powder with the addition of maltodextrin (DE 10) as a drying aid and to characterize the powder with respect to moisture content, water activity value, crystalline/amorphous nature, sugar profile and the keeping quality.

2. MATERIALS AND METHODS

Materials

Maltodextrin DE 10 (food grade) was imported from Qingyuan Foodstuff Company Limited, China. Unfermented coconut sap (sweet toddy) was collected at Bandirippuwa Estate, Lunuwila, Sri Lanka.

Methods

Solution preparation

Three different formulations of sweet toddy: drying aid (70%: 30%, 80%: 20% and 90%:10%) were prepared by heating the solutions at 45±5^{o}C and gently agitating them with a magnetic stirrer and subsequently spray dried.

Powder production

Spray drying of solutions was carried out on a pilot scale spray-dryer (L-8, Ohkawara Kakohki Co Ltd., Yokohama, Japan) with a water evaporating capacity of 1L/hr. The inlet and outlet temperatures were maintained at 165^{o}C and 65^{o}C, respectively. The powders were collected from cyclone and the cylindrical part of the dryer chamber by lightly sweeping the chamber wall (Bhandari, Datta and Howes, 1997). The yield was calculated as the ratio of the mass of solids collected to the mass in feed solution on a dry basis. Depending on the powder recovery the best formulation was selected for further studies.

Moisture

Moisture content of spray dried sweet toddy samples was determined according to standard oven method (AOAC, 1999).

Water activity (a_w*}*

Water activity of powder samples was determined by using Hygro-thermometer data logger (water activity meter). The temperature was maintained at 24.5± 0.5^{o}C.

X-ray diffraction

X-ray diffraction (XRD) studies were carried out on a Rigaku Ultima IV diffractometer with CoKα1 radiation. Diffractograms were taken between 8^o and 50^o (2θ).

Scanning electron microscopy (SEM)

Surface morphology of powder samples were observed by using LEO (LEO 1420VP) SEM operated at an accelerated voltage of 5.49kV and the current of 2.387A at a working distance of about 20mm. The samples were gold plated by using gold sputter.

Sugar profile

Sample preparation

One gram of sweet toddy powder was dissolved in 50ml of water. It was filtered through 0.45μm syringe and injected to HPLC system (Shimadzu LC -10AS single pump, Shimadzu Corporation, Japan).

HPLC conditions
Twenty micro liters of diluted sweet toddy sample were injected onto a Supelco Gel C 610H analytical column, (300mm x 7.8mm), Supelco, USA at a temperature 30^{o}C with a flow rate of 1.0 ml/min. Mobile phase was 0.1% H_3PO_4 (BDH, UK) and detection was carried out on a Shimadzu RID-10A, Shimadzu Corporation, Japan. All injections were made in triplicate.

Keeping quality
The spray dried sweet toddy powder packed in triple laminated aluminium pouches was evaluated for the changes in moisture content and water activity at monthly intervals for a period of one year at ambient conditions (30±2^{o}C).

Statistical analysis
All results were statistically analysed by one-way analysis of variance (ANOVA). Differences were considered significant for $p < 0.05$.

3. RESULTS AND DISCUSSION

Powder recovery
Figure 1 shows the visual observation of coconut sweet toddy powder.

Figure 1. Spray dried sweet toddy powder

The recovery of spray dried sweet toddy powder was determined (Figure 2). A zero powder recovery was observed in the case of formulation of sweet toddy: drying aid in the ratio of 90:10 since all sugar solids in the formulation were lost as wall deposits. This indicates that 10% of drying aid was not sufficient to overcome stickiness. However, when the drying aid percentage was increased from 10% to 20% and 30% the total recoveries rose to 56.35±2.90% and 57.8±1.85%, respectively. This is an indication of a successful spray drying trial as 50% recovery is taken to be a benchmark for a successful spray drying (Masters, 1991). Statistical results revealed that there was no significant difference (P>0.05) between the recoveries of sweet toddy: drying aid in the ratio of 80:20 and 70:30. Therefore, the formulation with the lower percentage of drying aid (20%) was selected for further analysis.

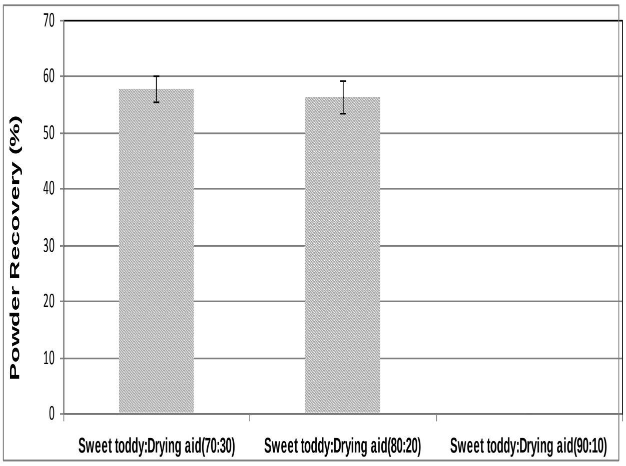

Figure 2. Recovery of sweet toddy in spray drying trials

Crystalline/amorphous nature of spray dried sweet toddy powder

It can be seen from the X-ray diffractogram provided in Figure 3 that spray dried sweet toddy powder was amorphous which may be due to very rapid evaporation and particle formation process (Jayasundera et al., 2011b). The scanning electron micrograph (Figure 4) showed that particles of sweet toddy: drying aid (80:20) powder were mostly spherical. The morphology of these particles apparently gives a good indication of the amorphous and crystalline nature of powders, spherical particles being amorphous in nature and hexagonal being crystalline (Ando et al., 2007).

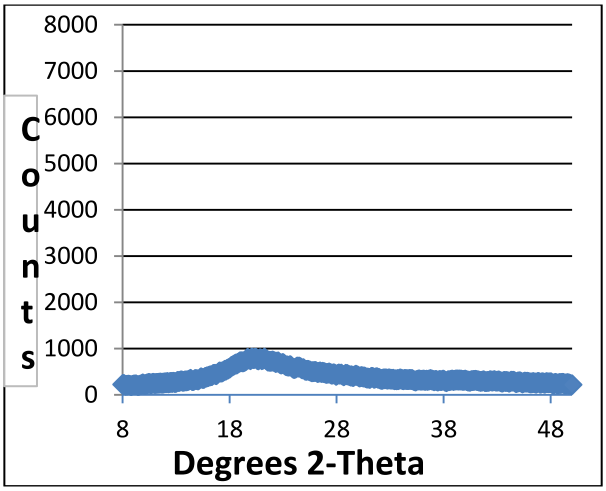

Figure 3. XRD pattern of sweet toddy powder

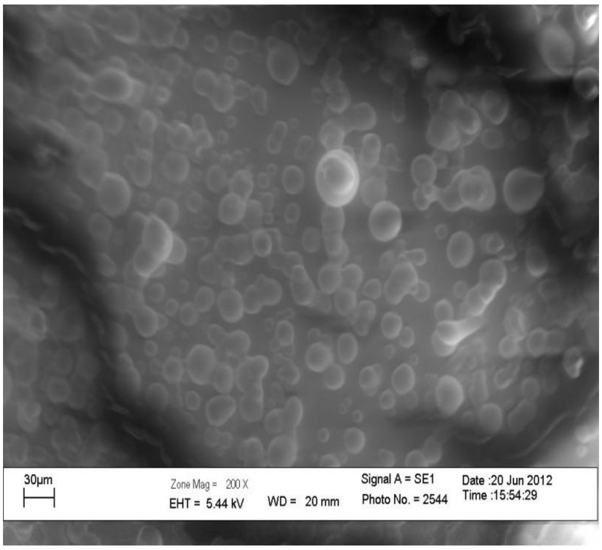

Figure 4. Scanning electron micrograph of spray-dried sweet toddy

Sugar profile

The sugar profile of the sweet toddy powder showed that it had a total sugar content of 66.1±0.04% out of which 32.7±0.02% was sucrose, 22.4±0.01% was glucose and 11.0±0.01% was fructose (Figure 5).

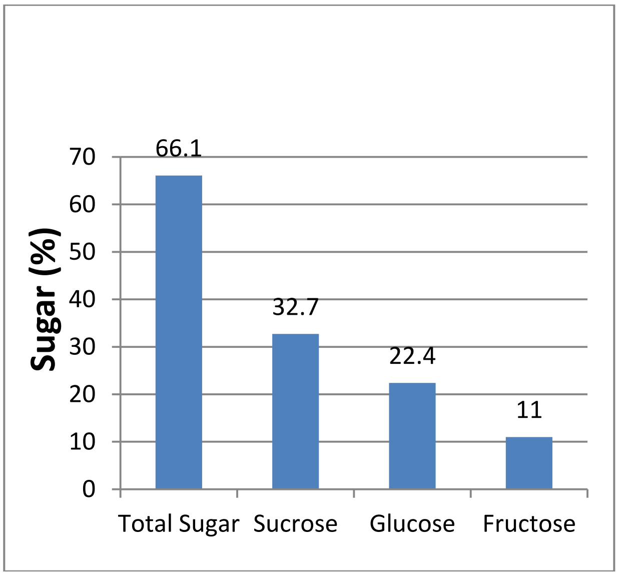

Figure 5. Sugar profile of spray-dried sweet toddy

Moisture content, water activity and keeping quality of spray dried sweet toddy

Table 1 shows the moisture contents and a_w values of spray dried sweet toddy on storage. The initial moisture content and a_w value of the spray dried coconut sweet toddy powder were 1.64±0.12% and 0.28±0.00, respectively. The moisture content varied between 1.64±0.12% and 2.55±0.10% during the storage of one year. One of the characteristics of spray dried products is the low moisture content which is less than 5% (Masters, 1991). Therefore, moisture content of sweet toddy powder is well within the range. Water activity is a very important index for spray dried powder as it determines the shelf life of powder produced. Water activity measures the activity of free water in a food system which is responsible for any biochemical reaction. Higher water activity indicates that there is more free water available for biochemical reactions and thus the shelf life is shorter. Any food powder with a_w less than 0.6 is microbiologically stable (Goula and Adamopoulos, 2005; Kanpairo et al., 2012). The a_w of sweet toddy powder was in the range of 0.28±0.00 and 0.35±0.02 during the one year storage period (Table 1). Therefore, the results reveal that spray dried sweet toddy was microbiologically stable over the storage period of one year.

Table 1. Physical parameters of spray-dried sweet toddy on storage

Time(months)	Moisture (%)±SD	Water activity(a_w)±SD
0	1.64±0.12	0.28±0.00
1	1.77±0.14	0.29±0.00
2	1.97±0.10	0.29±0.01
3	2.04±0.11	0.30±0.01
4	2.08±0.13	0.31±0.00
5	2.13±0.12	0.32±0.01
6	2.15±0.09	0.35±0.02
7	2.21±0.08	0.36±0.01
8	2.35±0.14	0.35±0.01
9	2.38±0.12	0.36±0.01
10	2.42±0.10	0.35±0.02
11	2.46±0.09	0.33±0.01
12	2.55±0.10	0.35±0.02

4. CONCLUSIONS

More than 55 % of amorphous unfermented coconut sap (sweet toddy) powder was produced with 20 % maltodextrin (DE 10) and the powder could be stored in triple laminated aluminium pouches for more than a year under ambient conditions (30±2^{o}C). The amounts of sucrose, glucose and fructose were 32.7±0.02%, 22.4±0.01%, 11.0±0.01%, respectively, in the powder composition.

5. ACKNOWLEDGEMENT

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