Functional Properties of Spray-Dried White Dragon Fruit (*Hylocereus undatus*) Juice

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Abstract

A study was conducted to produce white dragon fruit (WDF) powder by optimizing the spray drying conditions using maltodextrin DE 10 (MD) as a carrier. The process was performed using a pilot plant spray drier by manipulating its inlet temperature (150-170°C), outlet temperature (75-85°C) and MD concentration (15-30%) as the independent variables while process yield, moisture content, water activity, hygroscopicity and bulk density were analysed as responses. The optimum conditions were obtained at an inlet temperature of 150°C, outlet temperature of 75°C and 18% of MD concentration. MD concentration had the most significant (p<0.05) effect on the powder properties. The WDF powder produced under optimum conditions was further investigated for its ability to support the growth of *Bifidobacterium longum* BB536 and *Lactobacilus casei* Shirota, and suppress the growth of *Salmonella choleraesuis* ATCC14028. Anaerobic growth of the bacteria at 37°C was determined every 6 h for 24 h in four MRS media containing glucose, MD, fructooligosaccharides (FOS) or WDF powder as the substrate. The results indicated that all the substrates significantly (p<0.05) increased the growth of the probiotic bacteria; *B. longum* BB536 and *L. casei* Shirota and WDF powder gave the highest bacterial count. The number of the pathogenic bacteria, *S. choleraesuis* ATCC 14028 did not differ significantly (p>0.05) from its initial count in media containing FOS and WDF powder while glucose and MD significantly (p<0.05) increased its numbers. These results indicated that WDF powder enhanced the growth of probiotic bacteria more than FOS and inhibited the growth of pathogen and as such can be considered as a functional food ingredient for the functional food industry.

INTRODUCTION

Fruit juices are well known for their contents of vitamins, minerals and antioxidants. Bates et al. (2001) suggested that juices of all types, in all forms have an important role in both food nourishment and enjoyment. However, fruit juices have short shelf life and proper storage is costly, and knowing that dried juice is easier in handling and has longer shelf life, numerous studies have been done on spray drying of fruit juices such as pomegranate juice (Yousefi et al., 2007), elderberry juice (Murugesan et al., 2011) and mango juice (Cano-Chauca et al., 2005).

Dragon fruit belongs to the *Hylocereus* sp., from the *Cactaceae* family which is native to Mexico, Central and South America (Le Belleca et al., 2006) and now has been planted widely in Asian countries (Hoa et al., 2006; Mizrahi et al., 1997). Wichienchot et al. (2009) reported that some oligosaccharides found in white and red flesh dragon fruits were capable of stimulating the growth of probiotics; lactobacilli and bifidobacteria in human stomach. This shows the potential of dragon fruit as a new prebiotic source for the functional food industry. Functional foods are defined as dietary components that may result in physiological effects on the consumer leading to justifiable health claims (Roberfroid, 1996). Red flesh dragon fruit powder has been produced by Amin (2009) as

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a natural colorant, but there was no report on the spray drying of white flesh dragon fruit and its characterization.

Spray drying is a process widely used to produce good quality fruit powder with low water activity and easy to transport and store (Tonon et al., 2008). The most commonly used materials for encapsulation are maltodextrins of different dextrose equivalents (DE) ranging from 3 to 20 to minimize the damage to the functional components such as vitamins, enzymes, pigments, flavours and antioxidants. Maltodextrin is water-soluble and is mostly added to reduce the stickiness during the spray-drying process as the addition of maltodextrin increases the glass transition temperature (Bhandari et al., 1997). Maltodextrin consists of short chains of D-glucose units connected with glycosidic bonds (1→4) (Righetto and Netto, 2005).

Knowing the potential of white dragon fruit as a prebiotic source and its short life, a study was conducted to determine the optimal spray drying conditions of WDF juice with maltodextrin 10 DE by evaluating the bulk density, hygroscopicity, water activity, moisture content and yield of the powder produced. The powder produced using the optimum conditions was then evaluated for its prebiotic activity using in vitro fermentation with pure cultures.

MATERIALS AND METHODS

Powder Production

White dragon fruits (*Hylocereus undatus*) were washed and peeled. Their juice was then extracted and the seeds were separated using a juice extractor machine (Santos, France). Maltodextrin DE 10 was then added to the juice and the mixture was homogenized for 10 min at 9500 rpm using a T25 basic lab homogenizer (IKA - WERKE, Germany). The spray drying was conducted using a pilot scale spray drier (Model Niro A/S, Gea, Germany) under the following operational conditions: air flow rate, 900 m^3/min; rotary atomizer type, 15000 rpm; peristaltic pump (Model BT300-2J); inlet temperature of 150 to 170°C, outlet temperature of 75 to 85°C, and MD concentration of 15 to 30%.

The WDF powder obtained by each treatment was analysed for the following: production yield according to Obon et al. (2009), moisture content by oven drying method (Kha et al., 2010), water activity using a water activity meter (AQUALAB Series 3 TE, USA), hygroscopicity according to Niro analysis method No.A-14-a, 2005 (modified according to Tonon et al. (2008) and bulk density according to Cai and Corke (2000).

Determination of the Functional Properties of White Dragon Fruit Powder

Commercial bacterial strains; *Lactobacilus casei* Shirota (isolated from Yakult, Japan), *Bifidobacterium longum* BB536 (Morinaga Milk Industry, Tokyo, Japan) and *Salmonella choleraesuis* ATCC14028 (American Type Culture Collection, VA, USA) were grown at 37°C in MRS broth supplemented with 0.05% L-cycstein hydrochloride. A series of in vitro experiments were conducted to evaluate the effect of WDF powder on the growth of the bacteria consisting of two probiotics and one pathogen. 1 ml of overnight culture of *B. longum* BB536, *L. casei* Shirota or *S. choleraesuis* was inoculated into 9 ml of MRS broth containing glucose (Glu), MD, WDF powder or FOS. The media were then incubated for 24 h in anaerobic jars containing Anaerocult® A. At every 6 h for 24 h, samples were taken for serial dilutions and colony counts.

Statistical Design and Analysis

The results were analysed by Response Surface Analysis using the Minitab 14 software. The experiments were based on a central composite design, two levels factorial; full factorial, with three independent variables, 20 runs (Table 1) analysed at $p<0.05$. Differences between bacterial numbers at 0, 6, 12, 18, 24 h of fermentation for each batch culture were checked for significant difference by paired t test, assuming equal variances and considering both sides of distribution. Differences were significant at $p<0.05$.

RESULTS AND DISCUSSION

The experimental responses are presented in Table 2. Estimated regression coefficients for each response with coefficient of determination (R^2) are shown in Table 3. Moisture content (MC) and water activity (a_w) were significantly influenced by all the variables with inlet (T_i) and outlet (T_o) temperatures showing the greatest influence. Water activity is different from MC as it measures the availability of free water, while MC represents the water composition in a food system. Water activity of the powders was <0.6, meaning that the powders produced were relatively stable microbiologically. Tonon et al. (2008) reported that at a higher T_i, the greater temperature gradient between the atomizer feed and the drying air led to a higher ability for water evaporation, causing a decrease in the MC and a_w of powders produced. Quek et al. (2007) also observed the same pattern when spray drying watermelon juice. Table 2 indicated that spray drying process yield is affected by T_i and MD concentration. Increasing T_i led to a higher yield due to the higher drying rate, and this was in agreement with that observed during spray drying of *Amaranthus* betacyanin pigments (Cai and Corke, 2000). Maltodextrin concentration also had a negative effect on powder yield which may be due to the higher solid content in the feed mixture causing more solids to paste on the chamber wall, thus lowering the yield (Cai and Corke, 2000).

The bulk density of powders increased with an increase in the T_i and T_o. Meanwhile, hygroscopicity (HYG) of the WDF powder produced was affected by all the variables. Higher MD concentration reduced the HYG. This was probably due to the fact that the carrier agent used was a material with low HYG, thus allowing MD to be an efficient carrier agent. Furthermore, HYG was also affected by T_i and T_o; the higher the T_i and T_o, the higher the HYG of the powders. This behaviour was related to the MC; the lower the MC of particles, the higher their HYG, which means the greater their capacity to adsorb ambient moisture (Tonon et al., 2008).

Functional Properties of White Dragon Fruit Powder

The recorded changes of three tested strains in MRS media containing MD, FOS, Glu and WDF powder are presented in Figures 1-3. With all the MRS media studied, WDF powder gave the highest number of prebiotic bacteria; *B. longum* BB536 and *L. casei* Shirota. Their populations significantly ($p<0.05$) reached maximum numbers from 6.04±0.26 to 8.56±0.10 $\log_{10}$ cfu/ml, and from 6.05±0.11 to 8.75±0.00 $\log_{10}$ cfu/ml, respectively. This finding was in agreement with that of Wichienchot et al. (2010), who reported that oligosaccharides of white flesh dragon fruit is capable of stimulating the growth of lactic acid bacteria; *L. delbrueckii* BCC 13296 and *B. bifidum* NCIMB 702715, respectively. Compared to the growth of the bacteria in the presence of FOS, there was no significant difference ($p>0.05$), but when compared to Glu and MD containing media, there were significant differences ($p<0.05$) in the bacterial growth. This result was consistent with that of Yeo and Leong (2010), who reported that supplementation of soymilk with FOS, MD and pectin increased the number of lactobacilli more than 7.00 $\log_{10}$ cfu/ml. The growth of *S. choleraesuis* ATCC 14028 in media containing WDF powder or FOS showed no significant difference ($p>0.05$) from its initial counts and this indicated that WDF powder as well as FOS were able to inhibit the growth of pathogenic bacteria. MRS media containing Glu and MD showed significant ($p<0.05$) increase in the growth of *S. choleraesuis* ATCC 14028 after 24 h fermentation.

CONCLUSIONS

The results of this study indicated that the optimum conditions for spray drying of WDF to obtain powder with good flow and physical properties were at 150°C inlet temperature, 75°C outlet temperature and 18% of MD concentration. The WDF powder produced using these conditions was able to enhance the growth of probiotic bacteria; *B. longum* BB536 and *L. casei* Shirota, better than the commercial prebiotic, FOS. In addition, the number of pathogenic bacteria, *S. choleraesuis* ATCC 14028 decreased in the media containing WDF powder. This illustrates the potential of WDF powder as a new functional food ingredient.

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Literature Cited

Amin, H. 2009. Development of dragon fruit (*Hylocereus polyrhizus*) powder as natural colorant. Master Thesis, Universiti Putra Malaysia.

Bates, R.P., Morris, J.R. and Crandall, P.G. 2001. Principles and practices of small- and medium-scale fruit juice processing. FAO Agricultural Services Bulletin 146.

Yousefi, S., Emam-Djomeh, Z. and Mousavi, S.M. 2010. Effect of carrier type and spray drying on the physicochemical properties of powdered and reconstituted pomegranate juice (*Punica Granatum* L.). J. Food Sci. and Technol. 48(6):677-684.

Hoa, T.T., Clark, C.J., Waddell, B.C. and Woolf, A.B. 2006. Postharvest quality of dragon fruit (*Hylocereus undatus*) following disinfecting hot air treatments. Postharvest Biol. Technol. 41:62-69.

Mizrahi, Y., Nerd, A. and Nobel, P.S. 1997. Cacti as crops. Hort. Rev. 18:291-320.

Cano-Chauca, M., Stringheta, P.C., Ramos, A.M. and Cal-Vidal, J. 2005. Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. Innovative Food Sci. and Emerging Technol. 6:420-428.

Murugesan, R. and Orsat, V. 2011. Spray drying of elderberry (*Sambucus nigra* L.) juice to maintain its phenolic content. Drying Technol. 29:1729-1740.

Roberforid, M.B. 1996. Functional effects of food components and the gastrointestinal system: chicory fructooligosaccharides. Nutr. Rev. 54:S38-S42.

Tonon, R.V., Brabet, C. and Hubinger, M.D. 2008. Influence of process conditions on the physicochemical properties of acai (*Euterpe oleraceae* Mart.) powder produced by spray drying. J. Food Eng. 88(3):411-418.

Righetto, A.M. and Netto, F.M. 2005. Effect of encapsulating materials on water sorption, glass transition and stability of juice from immature acerola. Intl. J. of Food Properties 8(2):337-346.

Bhandari, B.R., Datta, N. and Howes, T. 1997. Problems associated with spray drying of sugar rich foods. Drying Technology 15(2):671-684.

Wichienchot, S., Jatupornpipat, M. and Rastall, R.A. 2009. Oligosaccharides of pitaya (dragon fruit) flesh and their prebiotic properties. Food Chem. 120(3):850-857.

Le Belleca, F., Vaillant, F. and Embert, E. 2006. Pitahaya (*Hylocereus* spp.): a new fruit crop, a market with a future. Fruits 61:237-250.

Obón, J.M., Castellar, M.R., Alacid, M. and Fernández-López, J.A. 2009. Production of red-purple food colorant from *Opuntia stricta* fruit by spray drying and its application in food model system. J. Food Eng. 90:471-479.

Quek, S.Y., Chok, N.K. and Swedlund, P. 2007. The physicochemical properties of spray dried watermelon powders. Chem. Eng. Processing 46:386-392.

Kha, T.C., Nguyen, M.H. and Roach, P.D. 2010. Effect of spray drying conditions on the physicochemical and antioxidant properties of Gac (*Momordica cochinensis*) fruit aril powder. J. Food Eng. 98:385-392.

Cai, Y.Z. and Corke, H. 2000. Production and properties of spray-dried *Amaranthus* betacyanin pigments. J. Food Sci. 65:1248-125.

Yeo, S.K. and Leong, M.T. 2010. Effect of prebiotics on viability and growth characteristics of probiotics in soymilk. J. Sci. Food Agri. 90:267-275.

Tables

Table 1. Matrix of the central composite design (CCD).

Run	Block	T_i (°C)	T_o (°C)	MD (% w/w)
1	1	150	85	30.0
2	1	170	85	15.0
3	1	150	75	15.0
4	1	170	75	30.0
5	1	160	80	22.5
6	1	160	80	22.5
7	2	150	75	30.0
8	2	160	80	22.5
9	2	160	80	22.5
10	2	150	85	15.0
11	2	170	75	15.0
12	2	170	85	30.0
13	3	160	80	30.0
14	3	160	80	22.5
15	3	160	75	22.5
16	3	160	85	22.5
17	3	160	80	22.5
18	3	150	80	22.5
19	3	160	80	15.0
20	3	170	80	22.5

T_i = inlet temperature, T_o = outlet temperature, and MD = maltodextrin.

Table 2. Experimental data obtained for the response variables studied (Y_i) (mean ± standard deviation).

Run	Yield, Y_1 (%)	MC, Y_2 (%)	a_w, Y_3	HYG, Y_4 (g/100 g)	BD, Y_5 (kg/m^3)
1	51.16	3.12±0.29	0.23±0.00	15.11±0.10	600.3±0.00
2	75.95	3.88±0.03	0.24±0.00	21.44±0.23	642.2±0.01
3	79.19	5.14±0.00	0.30±0.00	13.36±0.83	615.3±0.00
4	50.90	4.44±0.06	0.29±0.00	14.06±0.07	599.3±0.00
5	70.73	3.37±0.03	0.25±0.00	17.33±0.18	600.5±0.00
6	69.29	2.69±0.07	0.26±0.01	17.11±0.05	600.5±0.00
7	58.81	4.00±0.07	0.26±0.00	15.02±0.06	587.4±0.00
8	69.90	2.89±0.07	0.22±0.00	16.37±0.09	620.2±0.01
9	69.44	2.49±0.13	0.23±0.00	16.35±0.08	622.4±0.02
10	76.04	4.01±0.03	0.25±0.00	14.560.050	652.3±0.00
11	78.84	4.11±0.03	0.25±0.00	14.73±0.12	645.4±0.01
12	56.33	2.90±0.03	0.17±0.01	17.56±0.02	642.3±0.01
13	31.60	3.96±0.19	0.28±0.01	15.98±0.12	605.4±0.00
14	67.30	3.07±0.01	0.28±0.00	16.36±0.51	600.5±0.00
15	54.53	4.23±0.15	0.32±0.00	14.85±0.17	600.2±0.01
16	58.93	3.29±0.02	0.28±0.01	15.98±0.03	607.2±0.00
17	67.53	3.65±0.22	0.30±0.00	16.07±0.86	602.6±0.00
18	74.74	3.04±0.06	0.25±0.00	18.36±0.55	577.3±0.02
19	70.81	4.14±0.06	0.30±0.00	17.42±0.07	625.3±0.02
20	66.70	3.26±0.15	0.27±0.01	19.36±0.05	600.4±0.02

MC= moisture content, a_w=water activity, HYG=hygroscopicity, and BD=bulk density.

Table 3. Regression equations and statistical parameters of the models for the physical properties of spray dried dragon fruit juice.

Equations	R^2
Yield , $Y_1 = 2049.60-25.48x_1+7.51x_3+0.08x_1^2-0.21x_3^2$	0.890
MC, $Y_2= 123.708-2.742x_2+0.017x_2^2+0.013x_3^2$	0.868
a_w, $Y_3 = 4.57215-0.10907x_2+0.00069x_2^2-0.00031x_2x_3$	0.875
HYG, $Y_4= 51.4982-5.8528x_1+9.8898x_2+1.7488x_3+0.0138x_1^2 -0.0825x_2^2+0.0223x_1x_2-0.0112x_1x_3$	0.891
BD, $Y_5 = -123.890-2.558x_3+0.033x_3^2+0.006x_1x_3$	0.840

MC=moisture content, a_w=water activity, HYG=hygroscopicity, BD=bulk density, x_1=inlet temperature, x_2=outlet temperature, and x_3=MD concentration.

Figures

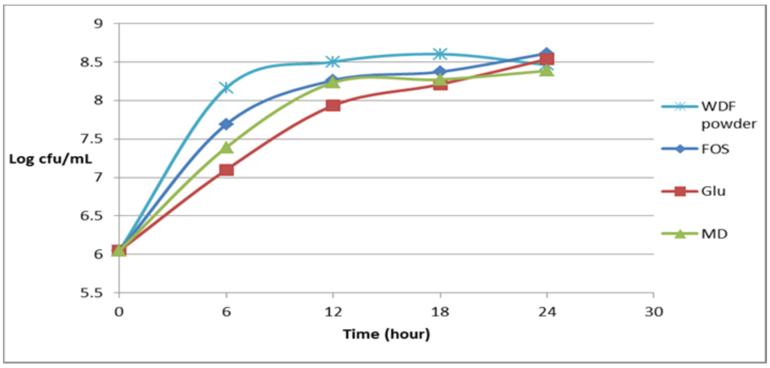

Fig. 1. Growth curve of *L. casei* Shirota in media containing four different substrates (Glu=glucose, FOS=fructooligosaccharide, MD=maltodextrin, and WDF=white dragon fruit) against time.

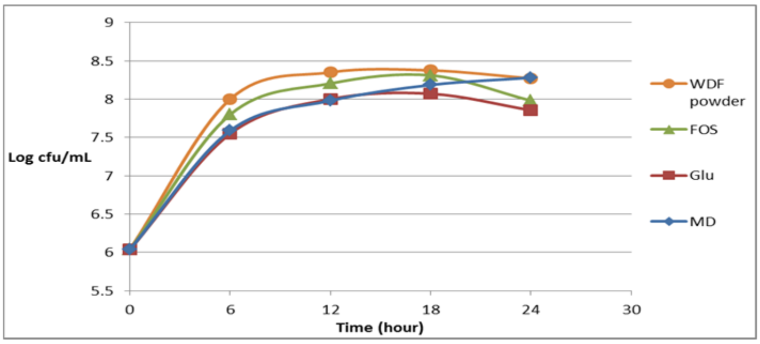

Fig. 2. Growth curve of *B.l ongum* BB536 in media containing four different substrates (Glu=glucose, FOS=fructooligosaccharide, MD=maltodextrin, and WDF=white dragon fruit) against time.

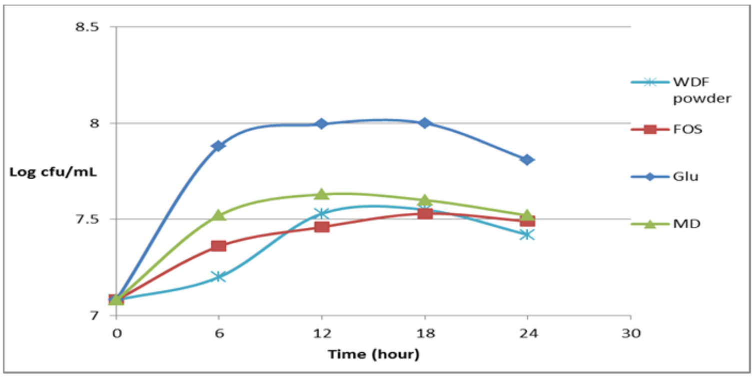

Fig. 3. Growth curve of *S. choleraesuis* ATCC 14028 in media containing four different substrates (Glu=glucose, FOS=fructooligosaccharide, MD=maltodextrin, and WDF=white dragon fruit) against time.