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Development of fortified banana pseudostem juice powder utilizing spray drying technology

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Abstract

Spray drying technology was optimized for the preparation of milk fortified banana pseudostem juice powder, overcoming the problems of browning and astringent taste. The taste and nutritional value of the powder was increased by blending it with milk, horse gram extract and cardamom powder. Spray drying parameters like inlet air temperatures of 185, 190 and 200° C, constant blower speed and feed speed of 1800 and 15 rpm were selected for the development of milk fortified banana pseudostem juice powder. Functional properties of final powder were analysed for assessing the quality characteristics. Moisture content, water activity, bulk density, colour characteristics and solubility of the powder were assessed by standard procedures. The treatment with 30% horse gram extract, 50% milk and 20% pseudostem juice exhibited appreciable quality enhancement during product analysis. During sensory analysis, the above treatment scored the best. Mineral profile analysis of standardised sample also revealed nutritive value of the trial product.

Keywords: Banana pseudostem juice, Fortification, Functional properties, Horse gram, Milk, Spray drying

Introduction

Spray drying is regarded as one of the most relevant application in food industry, because of its inherent capability to produce powders with minimum quantity of residual solvent and specific size during the entire drying process. Spray drying technique has been extensively used in the development of dried plant parts, plant extracts, by products, etc., both by pharmaceutical and food industries. It is the most widely recognized and monetarily feasible procedure to deliver microencapsulated nutraceuticals economically (Gharsallaoui et al., 2007). It offers protection of sensitive food components from nutritional loss.

In this context, the banana pseudostem, the huge biomass waste produced after the harvest of banana, was utilised for production of spray dried powder along with milk. Banana pseudostem, poses several medicinal properties like, dissolving renal calculi (Prashobh and Revikumar, 2011), assisting detoxification of the body and promoting haemoglobin and insulin production (Sampath et al., 2012). Because of its high content of phenolics and tannins, imparting an astringent flavour to the beverage, its consumption as juice is limited. Moreover, immediate browning reactions due to enzymatic activity is another hurdle in its commercialisation. Despite its medicinal value, attempts were not made to develop a viable product out of this underutilised plant by-product with superior quality and shelf life. This fuelled the interest for development of fortified product from banana pseudostem which might enhance its utility significantly. Present study on fortification of banana pseudostem envisages the inclusion of ingredients like horse gram and milk with cardamom flavour which will enhance the organoleptic properties and health benefits. Keeping

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in view the importance of pseudostem juice, milk and horse gram in health, food, and pharmaceutical application, a study was undertaken for the optimisation of spray drying process conditions for milk fortified banana pseudostem juice powder.

Materials and Methods

Sample preparation

Banana pseudostems (cv. *Palayankodan*) were sliced and dipped in 0.3% citric acid solution, followed by blanching at 100°C for one minute to arrest enzymatic activity (Saranya et al., 2016). Freshly prepared pseudostem juice squeezed out from the pre-treated pseudostem slices were blended with pressure cooked horse gram extract and pasteurised milk during feed preparation. Cardamom powder made from dried cardamom seeds were added in equal proportions to all the treatments. Various treatment combinations and the concentrations of ingredients in each treatment are given in Table 1.

Spray drying of fortified banana pseudostem juice

The different treatments were subjected to spray drying by atomizing them into the drying chamber using a two fluid nozzle at a pressure of 2 bar. Inlet temperature of 185, 190 and 200° C with constant feed and blower speed of 15 and 1800 rpm, respectively were selected as input parameters.

Table 1. Treatment combinations for milk fortified banana pseudostem juice powder

Combinations	Raw materials (%)
T1	P_{75}:HG_{10}:ML_{15}
T2	P_{65}:HG_{20}:ML_{15}
T3	P_{55}:HG_{30}:ML_{15}
T4	P_{65}:HG_{10}:ML_{25}
T5	P_{55}:HG_{20}:ML_{25}
T6	P_{45}:HG_{30}:ML_{25}
T7	P_{60}:HG_{10}:ML_{30}
T8	P_{50}:HG_{20}:ML_{30}
T9	P_{40}:HG_{30}:ML_{30}
T10	P_{40}:HG_{10}:ML_{50}
T11	P_{30}:HG_{20}:ML_{50}
T12	P_{20}:HG_{30}:ML_{50}

P=Pseudostem juice, HG=Horse gram extract, ML=milk, CP=Cardamom powder (2 pinch)

Microencapsulated spray dried product was collected from outlets and were immediately packed in LDPE pouches and stored at ambient conditions, for further analysis.

Quality parameters of spray dried powder

Physical properties such as moisture content (AOAC, 2005), water activity (Troller and Christian, 1978), bulk density (Caparino et al., 2012), colour characteristics using Hunter lab colour flex meter (Hunter Associates Laboratory, Reston, Virginia, USA), solubility (Chauca et al., 2005) and mineral profile analysis (Ponnambalam and Sellappan, 2014) of milk fortified banana pseudostem juice powders were assessed by standard procedures. Product yield of the pseudostem juice powder recovered after feeding was also estimated by taking the ratio of weight of sample collected to the juice fed to the drier (Fazaeli et al*.,* 2012; Arslan et al., 2015).

Sensory properties of the reconstituted drink prepared with water in the ratio of 1:10 was assessed for their sensory attributes like appearance, flavour, taste and overall acceptability by a 9-point Hedonic scale test.

Experimental design

Test of statistical significance was performed using the General factorial test in Design-Expert software. All experiments were conducted in triplicate. The analysis of variance (ANOVA) for each response was carried out during study.

Results and Discussion

Microencapsulated spray dried powder was developed from different combinations of banana pseudostem juice, horse gram extract and milk. The quality parameters of the products of each treatment were recorded as detailed below.

Moisture content

Moisture content of the products was found to be in the range of 3.64-4.5% w.b. (Fig. 1). It was

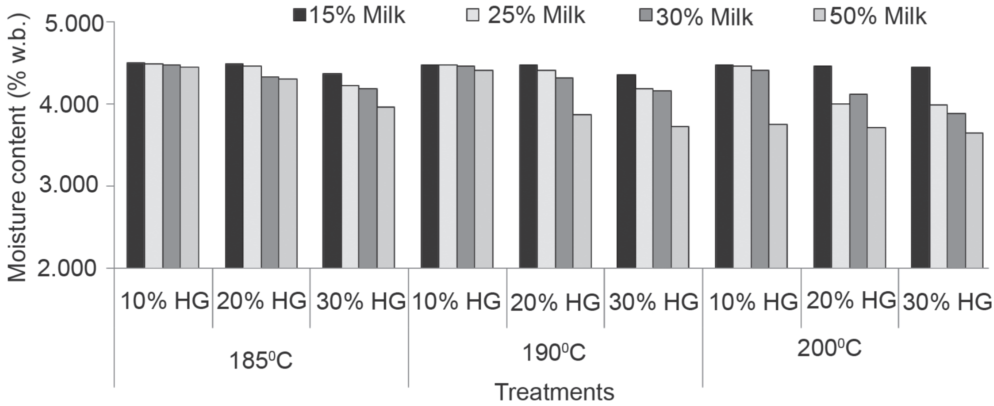

Figure 1. Moisture content of milk fortified banana pseudostem juice powder

observed that an increase in total solid content in feed as well as in inlet air temperature yielded a low moisture product. It can be elucidated that, as the total solid content in feed increased, the available water for evaporation gets decreased, while; the elevated inlet air temperature offered an appreciable driving force for moisture deduction (Goula and Adamopoulos, 2010). Statistical analysis indicated that various spray drying parameters and raw material concentration showed significant effect ($p<0.0001$) on moisture content. In the present study, feed with 30% horse gram extract and 50% milk exhibited the lowest moisture value of 3.64% at an inlet air temperature of 200° C.

Water activity

Water activity of fortified pseudostem juice powder showed a maximum value of 0.376 at 185° C and minimum of 0.221 at 200° C. Water activity exhibited a sudden drop with an increase in inlet air temperature and decrease in moisture content (Fig. 2). Though water activity of all the treatments differed significantly ($p<0.0001$), it was within the permissible limits (Stapelfeldt et al., 1997).

Bulk density

The bulk density of powdered samples varied from 309-431 kg m^{-3} (Table 2). Samples with 30% horse gram extract and 50% milk showed the highest bulk density values. The study revealed that the bulk density gets decreased under elevated process temperatures. The higher inlet air temperature resulted in enlarged particle formation due to rapid evaporation and layer development over feed droplets, which leads to low bulk density (Phisut,

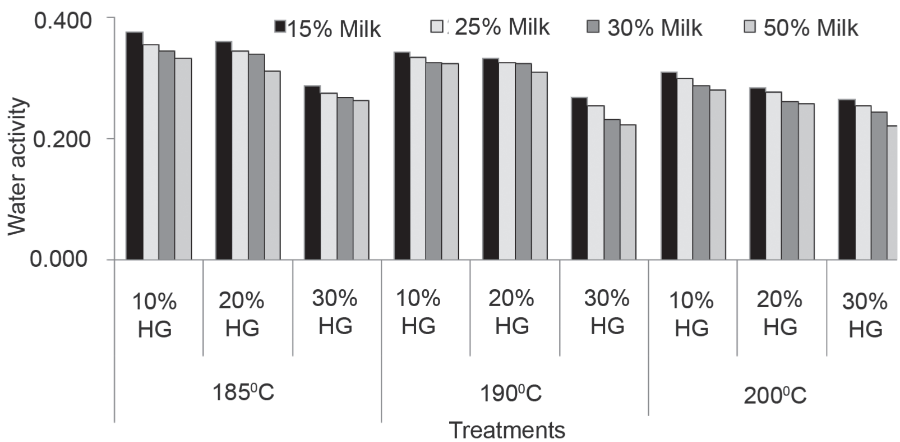

Figure 2. Water activity of milk fortified banana pseudostem juice powder

Table 2. Quality parameters of milk fortified banana pseudostem juice powder

Treat - ments	Inlet air temperature (°C)	Bulk density (kg m^{-1})	Solubility (%)	Product yield (%)
T1	185	345	93.000	55.750
	190	331	89.500	55.480
	200	309	53.000	10.630
T2	185	467	85.860	73.280
	190	456	78.940	73.280
	200	457	44.000	19.890
T3	185	512	82.730	75.320
	190	505	74.961	75.280
	200	477	49.400	33.490
T4	185	357	93.000	57.230
	190	332	89.000	60.720
	200	321	53.000	18.150
T5	185	399	85.740	76.860
	190	396	78.510	76.360
	200	369	44.000	23.850
T6	185	428	82.720	75.490
	190	425	74.670	77.230
	200	412	47.540	46.620
T7	185	365	90.120	66.370
	190	342	88.770	69.080
	200	325	51.200	19.870
T8	185	403	85.700	77.340
	190	398	78.010	74.230
	200	385	45.000	25.760
T9	185	426	82.300	76.860
	190	423	72.610	78.380
	200	415	44.560	46.820
T10	185	365	90.010	71.690
	190	344	88.520	71.590
	200	331	47.000	21.300
T11	185	406	85.000	77.330
	190	403	75.750	72.820
	200	385	45.600	29.750
T12	185	431	82.060	78.730
	190	427	70.000	79.250
	200	421	43.800	47.050

2012). An increase in feed concentration also led to an increase in bulk density values, which could be due to the resultant decrease in particle volume (Chegini and Ghobadian, 2007).

Solubility

Solubility is a key parameter to be evaluated for assuring the quality of final powder. The solubility value of fortified pseudostem juice powder was found to be in the range of 43.80- 93% and varied significantly ($p<0.0001$). Among various treatments solubility value was low for the one with high feed concentration (30% horse gram and 50% milk) (Table 2). The reduced solubility observed at high temperature could be due to denaturation of protein and the formation of a rigid surface film above the powder particles (Chegini and Taheri, 2014). The formed film act as barrier to water and therefore a larger fraction of powder remained as insoluble solids.

Product yield

Product yield was one of the important parameters for the product optimisation (Fazaeli et al., 2012; Arslan et al., 2015). Product yield of fortified pseudostem juice found to be in the range of 10.63 to 79.25% (Table 2). It was found that product yield was affected significantly by wall material concentration and inlet air temperature. The higher the inlet air temperature, the lower was the product yield (Dolinsky et al., 2000).

Colour characteristics

Colour characteristics including L*, a* and b* were recorded for different treatments (Table 3). The L* value of milk fortified banana pseudostem juice powder decreased at elevated temperature due to product oxidation (Bento et al., 2008) whereas a* and b* values of powder increased with inlet air temperature as a result of Maillard reaction. The maximum a* value of 10.63 was found in the treatment T1, whereas minimum value of 4.94 was recorded in T12. In this study, colour values of fortified pseudostem juice powder were significantly affected by feed concentration as well as inlet air temperature ($p<0.0001$).

Optimisation of process parameters

Optimisation of process variables especially inlet air temperature and raw material concentration were performed using the General composite design. Feed pump rpm and blower speed were already fixed based on preliminary trials. Statistical models were employed to determine numerical optimisation to fix the optimal process parameters for developing fortified banana pseudostem juice powders. In the

Table 3. Colour characteristics of milk fortified banana pseudostem juice powder

Treat-ments	Inlet air temperature (°C)	L* value	a* value	b* value
T1	185	85.460	7.510	19.440
	190	84.540	7.540	20.510
	200	67.000	10.630	24.710
T2	185	87.540	7.220	19.370
	190	85.460	7.260	20.370
	200	77.800	9.650	21.550
T3	185	88.600	7.090	18.280
	190	84.990	7.090	20.100
	200	80.350	8.840	20.480
T4	185	86.460	7.300	19.430
	190	84.650	6.860	20.500
	200	74.000	9.980	21.650
T5	185	87.890	7.200	18.300
	190	85.870	7.140	20.350
	200	85.870	7.140	20.540
T6	185	88.980	6.160	18.190
	190	85.870	7.130	18.910
	200	81.200	8.440	19.450
T7	185	86.850	6.830	17.960
	190	84.760	6.470	18.490
	200	76.000	9.760	21.640
T8	185	88.010	7.010	16.320
	190	85.680	6.950	17.330
	200	80.430	8.610	19.530
T9	185	89.990	5.240	17.140
	190	86.560	5.710	18.220
	200	81.200	8.150	19.440
T10	185	87.430	5.430	16.400
	190	85.440	6.350	18.450
	200	77.100	8.960	20.620
T11	185	88.240	5.170	15.780
	190	86.900	6.300	17.220
	200	81.070	8.550	19.440
T12	185	90.030	4.940	15.190
	190	88.000	5.500	18.820
	200	81.490	8.150	18.820

*All parameters were significant at 1%level of probability

present investigation, the independent variables were kept within the range and dependent variables were chosen as maximum and minimum. The experimental sample had the optimum process conditions of inlet air temperature (Table 4) and raw material concentration. Treatment T12 (30% horse gram extract and 50% milk + 20% pseudostem juice) was optimised as the best sample according to the qualitative and statistical analysis.

Table 4. Optimised spray drying parameters for milk fortified banana pseudostem juice powder

Process parameters	Optimised Conditions
Speed of the atomizer (rpm)	1800
Inlet air temperature (°C)	185
Outlet temperature (°C)	74-92
Feed flow rate (rpm)	15

Mineral profile analysis

Mineral profile analysis of the optimised product done by absorption spectro-photometry revealed the presence of minerals like potassium (1.18%), calcium (2.88%) and magnesium (0.31%).

Comparing the mineral analysis data obtained in this study for fortified banana pseudostem juice powder with that of fresh banana pseudostem sap, Feriotti and Igutti, (2008) showed that the powder had a higher mineral content than fresh pulp. Thus fortifying the pseudostem juice with horse gram extracts and milk significantly enhanced the nutritive value of final powder.

Sensory analysis

Sensory analysis is an important parameter for consumer acceptability. The products were analysed by 12 semi – trained sensory panellists. The optimised pseudostem juice powders developed at different temperatures were reconstituted with normal water in 1:10 ratio. The fresh pseudostem juice with freshly prepared horse gram extract and pasteurized milk with sugar was taken as control. The results of the sensory evaluation of product are given in Fig. 3.

Comparing with control, which scored best score of 8, treatment T12 (185° C) maintained similar sensory quality. Apart from this, T12 (185° C) exhibited appreciable product stability during three month storage. Thus T12 (a treatment combination of 20% banana pseudostem juice and 30% horse gram extract with 50% milk with an inlet air temperature of 185° C) was optimised as the best treatment.

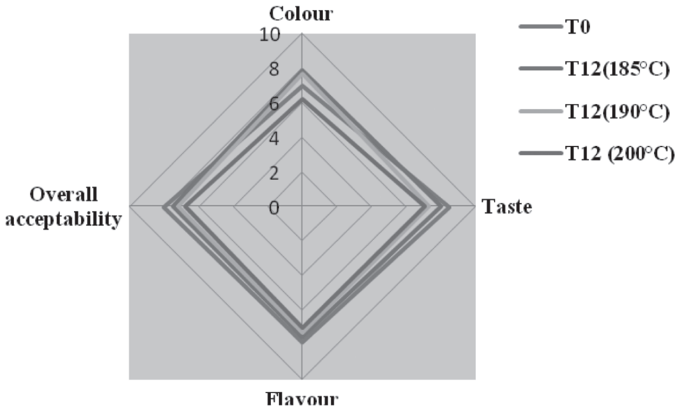

Figure 3. Sensory score obtained for milk fortified banana pseudostem juice powder

Present study revealed that development of banana pseudostem juice incorporating with milk and horse gram extract would remarkably transform the underutilised banana pseudostem waste into a healthy product. The inlet temperature and feed concentration influenced the quality attributes of the prepared powder. It was recommended that the inlet air temperature of 185° C, and a feed concentration of 20% banana pseudostem juice, 30% horse gram extract with 50% milk was the best combination for the development of fortified banana pseudostem juice powder.

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