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Encapsulation of jackfruit extracts by spray, freeze drying and utilization of encapsulates for enrichment of mango RTS beverage

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Abstract
The effect of dextrose equivalence (DE) of maltodextrin (MD), carrier to extract ratio on spray and freeze dried encapsulates of ethanolic waste extract of varikka (firm flesh type) Jackfruit were investigated. The total phenolic content (TPC), total flavonoid content (TFC), total antioxidant activity (DPPH scavenging activity), ascorbic acid content (AAC) and recovery of encapsulates were recorded for freeze and spray encapsulates. Freeze-drying with 20 DE MD at 1:20 carrier to extract ratio resulted in the encapsulate with highest retention of TPC (126.78 mg GAE 100 g^{-1}), TFC (11.62 mg QE 100 g^{-1}), AAC (28.65 mg 100 g^{-1}), antioxidant activity (1.95 mg mL^{-1}) and recovery of encapsulates (95.29%) respectively. Lowest moisture content of 2.22 per cent was recorded in the freeze encapsulate prepared using 10 DE MD at 1:10 carrier to extract ratio. Based on the physicochemical properties of encapsulates, two superior encapsulates (each one from freeze and spray encapsulates) were selected and utilized for preparation of fortified Mango RTS beverage. Maximum quantity of encapsulate to be dissolved in RTS was set as 50 mg of encapsulate per 100 mL (based on preliminary studies). Mango RTS beverage enriched with 50 mg 100 mL^{-1} of freeze encapsulate produced antioxidant rich and organolepticaly acceptable beverage compared to commercial mango RTS beverage available in the market.

Keywords: jackfruit, encapsulate, maltodextrin, dextrose equivalence, carrier, RTS

Introduction
The consumption of bioactive plant products is gaining significance all over the world. Jackfruit contains many classes of compounds *viz*., carotenoids, flavonoids, volatile acids, sterols and tannins, the concentration of these varies with the variety (Arung, *et al*., 2007) [1]. Quite a number of works have demonstrated the occurrence of different bioactive compounds in both jackfruit pulp and wastes and fruit wastes are proved rich sources compared to pulp. Several studies conducted have validated jackfruit's pharmacological properties *viz.*, antioxidant, anti-inflammatory, and antibacterial, anti-cariogenic, anti-cancerous and wound healing and other properties. About 60% of Jackfruit is inedible and unutilized (Subburamu *et al.*, 1992) [2]. These fruit wastes create problem to the processing industries and suitable methods can be used to convert these wastes into value-added products. By-product recovery from fruit wastes can not only improve the overall economics of processing units but also reduce the problem of environmental pollution considerably. Recovery of bioactive compounds is one of the avenues for utilization of the waste generated from processing industries.

The commercial utilization of phytochemical extracts in their crude form generally exhibit some formulation problems *viz*., lack of long-term stability, making these natural compounds sensitive to light and heat. Many of these molecules possess a very astringent and bitter taste, which limits their use directly in food and must be masked before their incorporation in foodstuffs. Among the existing stabilization methods, encapsulation is an efficient means and the microencapsulated products are widely used in the food, pharmaceutical and cosmetic industries. Different techniques are used for the encapsulation of bioactive compounds, spray-drying is widely used in the food industry due to its rapidity and low cost (Ray *et al*., 2016) [3]. Spray-chilling, freeze-drying, melt extrusion and melt injection are also some of the techniques employed for encapsulation. However, spray-drying conditions for the encapsulation of polyphenols must be optimized in order to avoid accelerated degradation. Freeze-drying is an alternative technique, which can be utilized for the encapsulating bioactive compounds that are sensitive to high temperature.

Compared with spray-drying, freeze-drying suffers from comparative disadvantages including significantly higher processing times and higher unit cost.

Maltodextrins are D-glucose polymers, commonly used for the encapsulation of polyphenols due to their high solubility, low viscosity, and good gel formation properties (Chronakis *et al*., 1998 and Mahdavi *et al*., 2016) [4, 5]. It is commonly available with DE values of 4, 10, 15, 20, 25, 30 and 42 with average molecular weight decreasing as DE increases. Higher DE maltodextrins form a more dense more oxygen impermeable matrix providing longer shelf life. The aim of this study was to encapsulate ethanolic extract of Jackfruit (varikka-firm flesh type) waste (except pulp, seed and green horny portion) by two encapsulation techniques (spray-drying and freeze-drying), using two levels of maltodextrin with three levels of carrier to extract ratio.

Materials and Method

Jackfruit type varikka (affirm fleshed type) collected from the Instructional Farm, Vellayani at optimum maturity stage and utilized for the experiment. Fruits were allowed to ripe and cut opened at optimum ripening stage after removing the green horny/spiny portion of the fruit. Excluding bulbs and seeds, all other portions of the fruits *viz*., rind, rachis, rag, core seed coat and were cut into small pieces of 1.0-2.0 cm and utilized for the experiment were dried using freeze dryer at -45 to -50^{o} C at pressure up to 0.05 mbar. The samples were dried until it reached a moisture content of 12-15 percentage. The dried samples were pulverized and made into fine powder by sieving through 70-mesh size sieve.

Extraction of pulverized dried samples was carried out using 60 per cent ethanol at 1:50 solid to solvent ratio and the extraction was carried out at room temperature for 6 hours in a mechanical shaker (end to end) at 100 rpm, followed by centrifugation at 5000 rpm for 10 min. The supernatants were collected and the residues were re-extracted twice under similar conditions. The supernatants thus collected were combined, filtered and concentrated in vacuum evaporator at 20 rpm and utilized for encapsulation (Zhang *et al*., 2017) [6].

Maltodextrin of two dextrose equivalence (10 and 20) were homogenized with the extracts at 1:10, 1:15 and 1:20 carrier to extract ratio using magnetic stirrer at 1500 rpm for 20-25 minutes. The homogenized mixture was spray dried in SprayMate (JISML Pvt. Ltd. Mumbai) laboratory scale spray drier at inlet and outlet temperature 180° C and 80^{o} C respectively. Freeze encapsulates were obtained by drying the homogenized extracts prepared by freeze drying in a laboratory scale freeze drier (CoolSafe, SCANVAC, *mas tek* Instruments Co., Banglore) at condenser temperature of -45 to -49^{o}C and pressure up to 0.05mbar. Freeze drying was continued until the encapsulates reached a constant weight. Microencapsulates thus obtained after drying were ground in a mortar and pestle and analyzed for physicochemical properties.

Analysis of encapsulates for physicochemical properties

Total Flavonoid Content (TFC)

The TFC of the encapsultes was determined according to the method narrated by Zhishen *et al*., (1999) [7]. 0.5 g of encapsulates were dissolved in water, volume adjusted to 10.0 mL and the mixture was vortexed and filtered. 0.5 mL of encapsulate mixture was mixed with 1.0 mL distilled water and 0.15 mL of 5% (*w*/*v*) $NaNO_2$ and incubated at ambient temperature for 6 min. Then, 0.15 mL of 10% (*w*/*v*) $AlCl_3$ was added and the mixture was left at room temperature for 6 min. Subsequently, 2 mL of 4% (*w*/*v*) NaOH and 0.7 mL of H_2O were added and the solution was left at room temperature for 15 min before the absorbance was measured at 510 nm. The total flavonoid content calculated in mg QE 100 g^{-1} by using a standard curve (R^2 = 0.9928) which was built by dissolving quercetin in methanol.

Total Phenolic Content (TPC)

The TPC of the encapsulates was determined as described by Skerget *et al*., (2005) [8] with suitable modifications. 2.5 mL of 10% (*v*/*v*) Folin–Ciocalteu reagent was mixed with a 0.5 mL sample, followed by the addition of 2 mL of 7.5% (*w*/*v*) Na_2CO_3. The mixture was incubated for 1 hour at ambient temperature and the absorbance was recorded at 760 nm. The total phenolic content was calculated using a standard curve (R^2 = 0.9960) which was built by dissolving gallic acid in water at different concentrations (0, 10, 20, 30, 40, and 50 µg mL^{-1}) and expressed as mg of gallic acid equivalents per 100 gram (mg GAE 100g^{-1})

Total Antioxidant (DPPH) activity

Different concentrations of the encapsulates were prepared (0.5 mg/mL to 5.0 mg/mL) and allowed to react with 3 ml of DPPH solution. The reaction mixture was shaken vigorously and left to stand at room temperature for 30 min in the dark. The absorbance of the mixture was measured using *UV-vis* spectrophotometer at 517 nm. A control sample without the encapsulate was also analyzed and the results were expressed as radical scavenging activity (% RSA).

Ascorbic Acid Content

Ascorbic acid content of the extracts was analysed as per the procedure laid out by (AOAC, 2000) [9] and expressed as mg/100g.

Encapsulation Productivity (EP)

The EP for TPC, TFC and antioxidant capacity (FRAP) was determined using the following equations (Tao *et al*., 2017) [10].

$$EP_{TPC} = \frac{TPCc}{TPC_{all}} \times 100 \quad EP_{TFC} = \frac{TFCc}{TFC_{all}} \times 100 \quad EP_{AAC} = \frac{AACc}{AAC_{all}} x100$$

Moisture content (%)

The moisture content of the freeze and encapsulates was determined as per the procedure described by Paini *et al*. (2015) [11]. Encapsulates were dried at 105 ◦C in an oven until it reached a constant weight. The moisture content was calculated based on the weight loss between before and after drying.

Recovery of encapsulate

Recovery percentage of encapsulation was calculated for both spray and freeze drying using the formula.

$$\text{Recovery (\%)} = \frac{(M_1X(100\text{-}X))}{M_2XV} \times 100$$

Where

M_1 - the weight of the encapsulated powder (g)

X- moisture content of the encapsulated powder (%)

M_2- the dry matter in 1 mL feed (g)

V - the input volume feed (mL).

Preparation of enriched RTS beverage with encapsulates

Based on the encapsulation studies, following encapsulates were selected for enrichment of Mango RTS beverage.

1. Freeze encapsulate- prepared using 20 DE MD at 1:20 carrier to extract ratio
2. Spray dried encapsulate- prepared using 20 dextrose matodextrin at 1:20 extract to carrier ratio by spray drying at inlet and out let temperature of 180 and 80 ºC respectively.

Preliminary trial to fix concentration of encapsulate

A preliminary study was conducted to know the quantity of encapsulates to be dissolved in mango RTS. Mango RTS prepared following FSSAI standards. The encapsulates were dissolved in varied concentration (10-100 mg mL^{-1}) and sensory evaluation was conducted on nine point hedonic scale. Based on sensory evaluation scores for taste, it was decided to dissolve 50 mg of encapsulate per 100 mL of mango RTS beverage.

Mango RTS were prepared with following specifications and analyzed for physico-chemical properties.

1. Mango RTS + 50 mg spray dried encapsulate per 100 mL
2. Mango RTS+ 50mg freeze dried encapsulate per 100 mL
3. Commercial fortified beverage
4. Control (without addition)

Analysis of mango RTS beverage for biochemical parameters

Total soluble solids (° Brix)

TSS of the prepared RTS beverage was measured using hand refractometer.

Total Sugars (g $100g^{-1}$)

The total sugar content of the prepared mango RTS beverage was analyzed and expressed as per cent sugar (Ranganna, 1986) [12].

Acidity (%)

Acidity of the mango RTS beverages was determined by titration method. Volume of 10.0 mL of RTS beverage was made up to 50.0 mL with distilled water. A known volume of the beverage (10 mL) was titrated against 0.01N NaOH using phenolphthalein as indicator. Acidity was calculated as percentage of citric acid equivalents using citric acid standard curve (Ranganna, 1986) [12].

Polyphenol content (mg GAE 100 mL^{-1})

The total phenolic content of the mango RTS beverage was analyzed according to the Folin-Ciocalteu method which is based on colorimetric oxidation/reduction reaction of phenols (Singleton *et al*., 1999) [13] using gallic acid as standard and expressed as mg GAE 100 mL^{-1}.

Antioxidant activity (DPPH) scavenging activity

Antioxidant activity of the extracts was assessed by 2,2-diphenyl-1-picrylhydrazyl (DPPH) as per the procedure given by Kang and Saltveit. (2002) [14] with suitable modifications.

Sensory analysis

Sensory analysis carried out by semi-trained panel of experts, based on nine point hedonic sale.

Statistical analysis

Statistical analysis of the results was done with the OPSTAT (Online Agriculture Data Analysis Tool created by O.P. Sheoran, Computer Programmer at CCS HAU, Hisar, India) at a level of $p<0.05$. To calculate the IC_{50} value, dose-response data (concentrations x_1, x_2, ...,x_n and inhibition y_1, y_2, ...,y_n) was used ; x values were plotted against y, fit to a straight line (linear regression), the equation Y = MX-C was obtained from the graph, Y was substituted with 50 (50= MX-C) and X values were obtained.

Results and Discussion

Polyphenol Content and Antioxidant Capacity of the encapsulates

The TPC, TFC, TAC and antioxidant activity (DPPH scavenging activity) values of the ethanolic (60 per cent) Jackfruit waste extract before and after encapsulation is presented in Table 1. The Jackfruit extracts before encapsulation had higher TPC, TFC AAC and antioxidant (DPPH scavenging activity) values (156.10 mg GAE 100 g^{-1}; 15.66 mg QE 100 g^{-1} 43.45 mg $mL^{-1}$and 0.83 mg mL^{-1} respectively) compared to the encapsulates produced either by spray or freeze-drying. In the process of freeze encapsulation, polyphenol degradation might have occurred due to freezing and dehydration stresses generated during the encapsulation process, as well as the grinding after lyophilization (Abdelwahed *et al*., 2006) [15]. During the grinding of the lyophilized material, the surface area exposed to oxygen increased, leading to the oxidation of the phenolic compounds and antioxidants. In case of spray-drying, the lower polyphenol and antioxidant capacity values could be attributed to the polyphenol degradation/conversion due to the high inlet temperatures generated during the process (Jia *et al.*, 2016) [16].

The TPC, TFC, TAC and DPPH scavenging activity were found to significantly influenced by encapsulation method, levels of dextrose equivalence of maltodextrin and carrier to extract ratio. The TPC, TFC and AAC values for the encapsulates obtained by freeze-drying ranged from 112.35 to 126.78 mg GAE g^{-1}; 10.05 to and 11.62 mg QE g^{-1} and from 24.01 to 28.65 mg 100 g^{-1}, respectively. Highest DPPH scavenging activity with lowest IC_{50} value 1.95 mg mL^{-1} was also recorded in the same treatment. The values obtained by spray-drying for TPC and TFC and ranged from 95.22 to 115.47 mg GAE g^{-1}; 8.63 to 10.49 mg QE g^{-1} (TFC) respectively. Ballesteros *et al*., (2017) [17] in a study conducted on encapsulation of extract from spent copy found that freeze-drying using maltodextrin as coating agent was a more efficient technique than spray-drying for the encapsulation of phenolic compounds extracted from spent coffee grounds.

Significantly highest TPC (126.78 mg GAE 100 g^{-1}), TFC (11.62 mg QE 100 g^{-1}), TAC (28.65 mg 100 g^{-1}) values, were recorded for the extracts encapsulated from freeze drying with 20 DE MD (C_2) at 1:20 carrier to extract ratio. The increased carrier concentration resulted in increased encapsulation productivity of TPC, TFC and TAC significantly for both the levels of dextrose equivalence of MD. In a similar study on ethanolic Pomegranate Peel Extract (PPE) encapsulated using MD (DE=16.5–19.5) as carrier material mixed in a weight ratio (weight/weight) at 1:5, 1:10 and 1:15, higher retention of anthocyanin and total phenolic contents was noticed with increased carrier material from 5 to 15 per cent. The increased TPC, TFC and TAC found in both freeze and spray

encapsulates in our study at higher carrier to extract ratio of 1:20 compared to 1:10 is in agreement the study on pomegranate peel encapsulation. The increased amounts of the TPC, TFC and TAC in the freeze microcapsule by increasing the concentration of wall materials from 10 to 20 per cent might be due to interference of maltodextrin and increased stability of compounds under higher concentration of carrier material. In general, the higher amount of maltodexxtrin retained higher TPC and total anthocyanin content than the lower amount of MD, showing the ability of MD to bind of anthocyanin with the phenolic compounds.

EP is the ratio (%) between the TPC, TFC, and antioxidant capacity of the extracts used as a core material before encapsulation and the TPC, TFC, and antioxidant capacity of the encapsulates obtained after encapsulation either by spray or freeze-drying (Tao *et al*., 2017) [10]. The results of the encapsulation productivity are presented in Table 1. The highest EP_{TPC}, EP_{TFC}, and EP_{AAC} values were recorded for extracts freeze encapsulated using MD of 20 DE at 1:20 carrier to extract ratio. These results are in agreement with Ballesteros *et al*., (2017) [17], who found that freeze-drying was more efficient for the encapsulation of phenolic compounds extracted from ground coffee using maltodextrin as a coating agent. The efficiency of coating agents to encapsulate polyphenols is associated to their solubility in dispersion, structure, and capacity to form films. The enhancement of encapsulation productivity with the increased carrier to extract ratio and DE of MD is due to the interaction of the protein with the maltodextrin and the formation of complexes with interfacial and amphiphilic properties (Tao *et al*., 2017) [10]. These results suggest that the encapsulation productivity of jackfruit ethanolic extracts rich in bioactive compounds (particularly polyphenols and flavonoids) is affected by both the coating agent and the encapsulation technique. Freeze-drying was found to be a more efficient method than spray-drying for the retention of polyphenols and antioxidants.

The moisture content of the microparticles produced by freeze-drying varied from 2.22 to 4.15 per cent whereas for spray encapsulates it was 3.05 to 4.33 per cent. Significantly lowest moisture content was recorded in the encapsulates from the extract encapsulated with 10 DE MD at 1:10 carrier to extract ratio. These results are in accordance with Ramírez *et al*. (2015) [18] and Papoutsis *et al*. (2018) [19] who reported lower moisture content in the microparticles produced by freeze-drying compared to those produced by spray-drying.

Analysis of mango RTS beverage enriched with selected freeze and spray encapsulates

Qualitative analysis of the prepared beverages were conducted to assess the possibility and extent of fortification with the encapsulates. The results of the qualitative parameters as influenced by quantity of encapsulates used for enrichment of the mango RTS beverage are presented below.

Physico-chemical properties of the prepared RTS beverages viz., Total soluble solids, total sugars (%), acidity (%), total phenolic content (TPC) and antioxidant activity (DPPH) were significantly affected by the enrichment process (Table 2).

Highest TSS and sugar content of 15.28 and 13.19 g 100 mL^{-1} were recorded in T_1 (Mango RTS+50 mg 100 mL^{-1} freeze encapsulate) which was found to be on par with T_2 (Mango RTS+50 mg 100 mL^{-1} spray encapsulate) T_4 (Commercial fortified beverage) (13.05 g 100 mL^{-1}). Slight increase in the TSS and total sugar content of the RTS beverage compared to control may be due to added encapsulates. Increase in TSS and total sugar content of mango RTS beverage enriched with whey protein was noticed by Sakhale *et al*. (2012) [20] in RTS beverage enriched with mango RTS beverage

The highest TPC of 41.05 mg GAE 100 mL^{-1} was recorded in T_1 (Mango RTS+50 mg 100 mL^{-1} freeze encapsulate) which was found to be on par with T_2 (Mango RTS +50 mg spray encapsulate 100 mL^{-1}) (40.90 mg GAE 100 mL^{-1}). Significantly highest scavenging activity with 78.07 per cent inhibition was noticed in RTS beverage enriched with 50 mg 100 mL^{-1} freeze encapsulate (T_1), followed by T_2 (Mango RTS+50 mg 100 mL^{-1} freeze encapsulate) (74.25%). Increased antioxidant activity observed may be attributed to the higher phenolic content observed in the enriched RTS beverages.

Mango RTS beverage enriched with encapsulates differed significantly for acidity content. The highest acidity of 0.31 per cent was recorded in T_1 (Mango RTS+50 mg 100 mL^{-1} freeze encapsulate) which was on par with T_2 (Mango RTS+50 mg 100 mL^{-1}).

Scores for organoleptic properties of RTS beverage enriched with encapsulates is presented in Table 3. Organoleptic parameters viz., color and appearance, consistency, flavor, taste and overall acceptability of RTS beverage enriched freeze and spray encapsulates were not significantly affected by the concentration of encapsulate added to the beverage. This indicates added encapsulates did not influence the sensory properties of the enriched beverages and there sensory properties were not altered by the added encapsulates.

Table 1: Total Phenolic Content (TPC) (mg GAE 100 g^{-1}), Total Flavonoid Content (TFC) (mg QE 100 g^{-1})Ascorbic acid content (mg 100 g^{-1}) and Antioxidant activity (DPPH) (IC_{50} values-mg mL^{-1}), Encapsulation Productivity (EP%) for TPC, TFC,AAC moisture content and recovery (%)for the freeze and sprayencapsulates

Method	Maltodextrin (C)	Carrier to extract ratio (Cr)	TPC	TFC	AAC	DPPH	EP_{TPC}	EP_{TFC}	EP_{AAC}	Moisture content (%)	Recovery of encapsulate
Freeze drying	C_1	Cr_1	112.35	10.05	24.01	2.53	71.97	64.15	55.27	2.22	87.94
		Cr_2	118.81	10.78	27.50	2.19	76.11	68.86	63.31	3.39	91.72
		Cr_3	121.93	11.19	28.81	2.13	78.11	71.45	66.31	3.79	94.53
	C_2	Cr_1	117.58	10.03	24.25	2.34	75.32	64.03	55.83	3.12	89.67
		Cr_2	122.23	11.21	27.70	2.20	78.30	71.58	63.76	3.91	92.74
		Cr_3	126.78	11.62	28.65	1.95	81.22	74.18	65.96	4.15	95.29
Spray Drying	C_1	Cr_1	95.22	8.63	19.61	2.57	61.00	55.12	45.16	3.55	79.77
		Cr_2	104.80	9.45	22.65	2.46	67.14	60.32	52.14	3.05	77.55
		Cr_3	112.65	10.05	23.18	2.18	72.16	64.15	53.37	3.42	73.95
	Cr_2	Cr_1	97.46	8.86	20.86	2.46	62.43	56.61	48.03	4.33	82.89
		Cr_2	106.74	9.85	24.43	2.29	68.38	62.92	56.23	3.91	80.73
		Cr_3	115.47	10.49	25.50	2.22	73.97	67.00	58.71	3.89	74.99

Extract	156.10	15.66	43.45	0.83					
CD (0.05)	0.92	0.25	0.56	0.08	0.59	1.66	1.79	0.06	0.62

Table 2: Effect of encapsulate concentration on quality parameters of mango RTS enriched with spray and freeze encapsulates

Treatments	Color and appearance	Consistency (mouth feel)	Flavor	Taste	Overall acceptability
T_1- Mango RTS+50 mg 100 mL^{-1}spray encapsulate	8.63	8.44	8.50	8.38	8.25
T_2- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	8.63	8.38	8.50	8.25	8.25
T_3- Control	8.25	8.38	8.25	8.63	8.50
T_4-Commercial fortified beverage	8.38	8.50	8.63	8.38	8.63
C.D. (0.05)	NS	NS	NS	NS	NS
SE±(m)	0.13	0.17	0.18	0.17	0.12

Table 3: Organoleptic evaluation of mango RTS beverage enriched with spray and freeze encapsulates

Treatments	Total soluble solids (° Brix)	Sugars g 100 mL^{-1}	Acidity (%)	Total phenolic content (mg 100 mL^{-1})	Antioxidant activity (%)
T_1- Mango RTS+50 mg 100 mL^{-1}spray encapsulate	15.25	13.10	0.30	40.90	73.21
T_2- Mango RTS+50 mg 100 mL^{-1} freeze encapsulate	15.28	13.19	0.31	41.05	76.29
T_3- Control	14.96	12.13	0.27	38.23	55.19
T_4-Commercial fortified beverage	15.20	13.05	0.27	38.48	63.17
C.D. (0.05)	0.08	0.35	0.02	0.54	0.86
SE±(m)	0.024	0.11	0.007	0.17	0.28

Conclusion

Extracts from inedible parts from firm flesh jackfruit containing polyphenol content and antioxidant capacity, could be utilized by the beverage industry for enrichment of RTS beverage by spray and freeze encapsulation. For prolonging storage life, preserving beneficial properties, and removing some undesirable odors, the bioactive compounds contained in ethanolic extract from inedible jackfruit parts has to be encapsulated. In case of encapsulation by spray drying DE of MD, carrier to extract ratio and temperature of spray drying and in case of encapsulation by freeze drying DE of MD and carrier to extract ratio were found to significantly affected the encapsulates for TPC, TFC, ascorbic acid, and antioxidant activity (DPPH). Encapsulation by freeze drying of extracts with MD of 20 DE and encapsulated at 1:20 carrier to extract ratio found to be the most efficient for the production of powders with the highest TPC, TFC, and antioxidant capacity (DPPH). Sensory evaluation of mango RTS beverages enriched with spray or freeze encapsulate revealed that color and appearance, consistency, taste, flavor and overall acceptability scores were not influenced by quantity of spray dried encapsulate used for enrichment. The RTS beverages enriched with both the encapsulates were similar to commercial fortified beverage with respect to sensory parameters and no negative effect of encapsulation was noticed on the sensory properties of the beverage. These spray and freeze encapsulates could be utilized for fortifying mango RTS beverage @ 50 mg 100 ml^{-1} without affecting the sensory parameters with an enhanced antioxidant activity compared to commercial fortified mango RTS beverage.

References

1. Arung ET, Shimizu K, Kondo R. Structure–activity relationship of prenyl-substituted polyphenols from Artocarpus heterophyllus as inhibitors of melanin biosynthesis in cultured melanoma cells. Chemistry and Biodiversity. 2007;4(9):2166-2171.
2. Subburamu K, Singaravelu M, Nazar A, Irulappan I. A study on the utilization of jack fruit waste. Bioresource Technology. 1992;40(1):85-86.
3. Ray S, Raychaudhuri U, Chakraborty R. An overview of encapsulation of active compounds used in food products by drying technology. Food Bioscience. 2016;13:76-83.
4. Chronakis IS. On the Molecular Characteristics, Compositional Properties, and Structural-Functional Mechanisms of Maltodextrins: A Review. Crit. Rev. Food Sci. Nutr. 1998;38:599-637.
5. Mahdavi SA, Jafari SM, Assadpoor E, Dehnad D. Microencapsulation optimization of natural anthocyanins with maltodextrin, gum Arabic and gelatin. International journal of biological macromolecules. 2016;85:379-385.
6. Zhang L, Tu ZC, Xie X, Wang H, Wang H, Wang ZX *et al*. Jackfruit (*Artocarpus heterophyllus* Lam.) peel: A better source of antioxidants and a-glucosidase inhibitors than pulp, flake and seed, and phytochemical profile by HPLC-QTOF-MS/MS. Food Chemistry. 2017;234:303-313.
7. Zhishen J, Mengcheng T, Jianming W. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chemistry. 1999;64:555-559.
8. Skerget M, Kotnik P, Hadolin M, Hras AR, Simoni M, Knez Z. Phenols, proanthocyanidins, flavones and flavonols in some plant materials and their antioxidant activities. Food Chemistry. 2005;89:191-198.
9. AOAC. Official methods of analysis. 17th ed. Association of Official Analytical Chemists, Gaithersburg, MD, 2000.
10. Tao Y, Wang P, Wang J, Wu Y, Han Y, Zhou J. Combining various wall materials for encapsulation of blueberry anthocyanin extracts: Optimization by artificial neural network and genetic algorithm and a comprehensive analysis of anthocyanin powder properties. Powder Technol. 2017;311:77-87.
11. Paini M, Aliakbarian B, Casazza AA, Lagazzo A, Botter R, Perego P. Microencapsulation of phenolic compounds from olive pomace using spray drying: A study of operative parameters. LWT Food Science Technolnology. 2015;62:177-186.
12. Ranganna S. Hand book of analysis and quality control for fruit and vegetable products. Tata Mc-Graw-Hill Publ. Co. Ltd., New Delhi, 1986.
13. Singleton VL, Orthofer R, Lamuela-ranventos RM. Analysis of total phenols other oxidation substrates and

antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol. 1999;299:152-178.
14. Kang HM, Saltveit ME. Antioxidant capacity of lettuce leaf tissue increases after wounding. Journal of Agricultural and Food Chemistry 2002;50(26):7536-7541.
15. Abdelwahed W, Degobert G, Stainmesse S, Fessi H. Freeze-drying of nanoparticles: formulation, process and storage considerations. Advanced drug delivery reviews. 2006;58(15):1688-1713.
16. Jia Z, Dumont MJ, Orsat V. Encapsulation of phenolic compounds present in plants using protein matrices. Food Biosci. 2016;15:87-104.
17. Ballesteros LF, Ramirez MJ, Orrego CE, Teixeira JA, Mussatto SI. Encapsulation of antioxidant phenolic compounds extracted from spent coffee grounds by freeze-drying and spray-drying using different coating materials. Food Chem. 2017;237:623-631.
18. Ramírez MJ, Giraldo GI, Orrego CE. Modeling and stability of polyphenol in spray-dried and freeze-dried fruit encapsulates. Powder Technol. 2015;277:89-96.
19. Papoutsis K, Golding JB, Vuong Q, Pristijono P, Stathopoulos CE, Scarlett CJ *et al*. Encapsulation of citrus by-product extracts by spray-drying and freeze-drying using combinations of maltodextrin with soybean protein and ι-Carrageenan. Foods. 2018;7(7):115.
20. Sakhale BK, Pawar VN, Ranveer RC. Studies on the development and storage of whey based RTS beverage from mango cv. Kesar. Journal of Food Processing and Technology, 2012, 3(3).