Effect of High Molecular Weight Maltodextrin and Spray Drying Conditions for Developing an Encapsulated Noni Juice Powder

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***Abstract*—Researches have suggested that noni is a healthy drink due to the presence of wide range of bioactive components. Various review and research data proved that noni might protect the immune system and improve health benefits. Hence, our study focused on the development of spray dried noni powder, which can incorporate into the various food system. Noni juice was spray dried using 2% high or low molecular weight maltodextrin with whey protein as filler material at concentrations of 3 and 5% under different temperature and feed rate. The yield of spray dried noni was found to be more in high molecular weight maltodextrin with 7% whey protein at 120 ℃ with 20% feed rate. The color value of noni powder sprayed under high temperature and high concentration of whey protein showed higher brightness than the other conditions. The powder flowability falls under a passable and poor range of Carr index and Hausner ratio, due to the high hygroscopic nature of noni fruit juice. The SEM images of noni powder showed the spherical particle for both whey protein and the combination of whey protein with maltodextrin. The encapsulated noni powder showed the presence of total phenolic and antioxidant content due to the contribution of the functional group (bioactive component) present in the noni juice. The present study investigated the suitable conditions for encapsulating the noni powder without the loss of bioactive phenolic compound.**

***Index Terms*—noni, spray drying, phenol, antioxidant**

I. Introduction

Nowadays the trend of selecting the food products among the customers have slowly changed towards the healthy and natural based products, which attained more interest among the food scientist and researchers to develop healthy products. Hence, *Morinda citrifolia* L. (noni) has been in focus for its several health benefits. Various compounds such as alkaloids, sterols and nitric oxide present in leaves, root, and fruits possess nutraceutical properties [1]-[2]. More research has been carried out on noni fruits, to produce functional food; the fruit juice was also approved under the European Union's 1997 novel food regulation [3].

The noni juice was reported to possess high antioxidant and involved in DNA protection, blood lipid normalization, improving bone mobility, increase physical endurance and immune activity [4]. An important volatile compound, 3-methyl-2/3-butenyl ester was identified in the ripened and fermented noni juice that has promising antioxidant and antitumor activity [5]. Presence of scopoletin and epicatechin in noni juice enhance the energy production and regulation, which increase physical activity and diseases recovery [6]. *Morinda citrifolia* have a broad range of therapeutic effects such as antimicrobial, analgesic, anti-inflammatory, anti-cancer, antihelmintic, hypotensive and hypolipidemic activity [2], [7]. Noni is reportedly used to cure the central nervous system (CNS) disorders, and it also has the property to enhance memory impairment [8].

Presence of several bioactive compounds in noni such as acetyl derivatives, glycosides, organic acids, alcohols, ketones, and lactones exhibit potent antioxidant activity [9]. Due to the biochemical properties of noni, research has been actively carried out by food scientists and pharmacologist to dry the noni fruit and noni juice. Among the various drying methods, spray drying is a potential method to maintain the quality of the bioactive component during the drying process, especially for the conversion of juice into encapsulated powders [10]. In general, stickiness is an issue that occurs during the spray drying due to the low glass transition temperature of sugar molecules present in the juice products, which can be overcome through the carrier or filler material with high molecular weight [11]. Owing to the current commercialization trend of noni juice and its health benefits in preventing and treating various diseases, our study was formulated to develop an encapsulated noni juice by spray drying method. Our study also focused on masking the unpleasant flavor of noni due to the presence of more polyphenols in noni fruit, which is also responsible for the bitter taste of the juice.

II. Experimental Method

A. Materials

Noni Heaven Pvt. Ltd, from Pudukkottai, Tamil Nadu, India provided noni fruit juice. High (MD 4-7) and low molecular maltodextrin (MD 20), 2, 2'-diphenyl-1-

Manuscript received February 20, 2019; revised June 11, 2019.

picrylhydrazyl (DPPH), standard Gallic acid were purchased from Sigma chemicals, while sodium carbonate and methanol were obtained from Merck. Whey protein (80%) was procured from MuscleBlaze. All the chemicals used in this study were analytical grade.

B. Optimization of Spray Drying Condition

The juice was mixed with two different ratios of whey protein (WP) (5 and 7%) and with 2% high molecular weight maltodextrin (MD 4-7) or 2% low high molecular weight maltodextrin (MD 20) and spray dried under different temperature (100 and 120 ℃) and flow rate (20 and 25%) as per the experimental design conditions of full factorial layout. Initially, the respective concentration of whey protein and maltodextrin added in 100ml of noni juice, which was mixed and homogenized (IKA) for 15 mins at 15000rpm. Then the blended noni juice was subjected for drying using lab scale mini spray dryer (JISIL). Several spray dryings run as mentioned in the experimental design was carried out to estimate the effects of temperature, feed rate and concentration of whey protein on the yield efficiency and powder quality. The spray dried noni juice powder was collected and packed for further analysis. Different physicochemical properties were analyzed for noni powder, such as moisture, water activity, color value, tapped density, bulk density, particle size and shape, the presence of the functional group, total antioxidant and total phenol content.

C. Moisture Content

The moisture content of the spray dried noni powder under different conditions and with different concentration of carrier material was measured using the moisture analyzer (Mettler Toledo-HE53). The samples were analyzed in triplicates, and the values were recorded.

D. Water Activity

The water activity of the spray dried noni was measured using water activity meter (Aqua lab dew point water activity meter 4TE).

E. Color Measurement

The color value of spray dried noni powder was measured by direct readings on a color meter (Color flex EZ). The instrument were calibrated with both the white and black ceramic plate, and the readings were measure for the samples, where ‘L*’ indicate lightness, ‘a*’ indicates green to red and ‘b*’ indicates blue to yellow. Chroma and Hue angle were calculated with L*, a* and b*.

F. Powder Characteristic

The flowability of the encapsulated noni powder was estimated by terms of Carr index (CI) and Hausner ratio (HR), based on the bulk and tapped densities of the powder. The following formula was followed:

$$\mathrm{CI} = \frac{Tapped\ density - Bulk\ density}{Tapped\ density} \times 100$$

$$\mathrm{HR} = \frac{Tapped\ density}{Bulk\ density}$$

G. SEM and Particle size Analysis

The microstructures of spray dried noni powder were recorded using scanning electron microscopy (SEM) (TESCAN, VEGA, Cech Republic, EU). The samples were coated with a thin layer of gold and viewed in a microscope. The particle size was also measured using Zetasier Nano ZS (Malvern Instruments) at 25 ℃, and the results were analyzed using Zetasizer 7.01 software.

H. Functional Group Analysis

FTIR analysis was carried out to identify the functional groups present in the encapsulated noni powder FTIR spectroscopy (Sigma, Infinity). The FTIR spectrum was recorded for whey protein, maltodextrin, noni juice and dried noni powder to compare and identify the functional groups present in spray-dried noni powder.

I. Total Phenol Content

The presence of total phenol content in the spray dried noni power was determined by Folin-Ciocalteu reagent with slight modification as described by Yang *et al.*, (2007). About 10mg of the sample was dissolve in 10ml of distilled water, from this 100 µl of the sample was added to 100 µl of Folin-Ciocalteu reagent and 300 µl of sodium carbonate (20%). The reaction mixture was incubated at 40 ℃ for 30mins, and the absorbance value was measured at 765nm using multi-mode microplate reader (SpectraMax iD3, Molecular Devices). The total phenols were calculated based on the standard gallic acid (2-10 µg) and expressed as milligram per 100gm of noni spray dried powder.

J. Total Antioxidant Activity

The free radical scavenging activity of the spray dried noni powder was measured using 2, 2’-diphenyl-1-picrylhydrazyl (DPPH) assay as described by Blois (1958). About 10mg of spray dried powder dissolved in 10ml of distilled water, from this mixture, 100 µl used for the analysis. About 300 µl of DPPH solution (0.025g/l) was added with the 100 µl of a sample and incubated under for 20minutes. Absorbance values were measured at 515 nm using multi-mode microplate reader (SpectraMax iD3, Molecular Devices) and the percentage of radical scavenging was calculated.

K. Statistical Analysis

Full factorial experiment design was applied to study the individual and combined effects of three different factors, i.e. drying temperature, feed rate and concentration of whey protein. One-way analysis of variance (ANOVA) was performed to investigate the effects of temperature, feed rate, and whey protein concentration on the yield of encapsulated noni juice. P-value was used to analyse the significance between independent variables using STATISTICA 8.0 software (Statsoft, USA). Duncan test was performed for total phenol and antioxidant activity by SPPS software.

Response surface methodology was used for optimization of spray drying conditions.

III. Results and Discussion

A. Optimization of Spray Drying Conditions

The yield of encapsulated noni at a different temperature, feed rate and concertation of whey protein and maltodextrin was estimated based on 24 runs of full factorial design. Maximum yield was obtained in addition of 2% high molecular weight maltodextrin along with 7% whey protein under a temperature of 120 ℃ at 20% feed rate. From the ANOVA analysis it was found that yield of encapsulated noni powder increases significantly (P=0.0000) with increasing temperature as well as concentration of whey protein, interestingly it was observed that there was significant effect of feed flow rate and level of whey protein along with the high molecular weight maltodextrin (P=0.0000) (Table I).

The expanded model proposes linear and cross-product terms as follow:

$$Y=4.1+0.45X_1-0.15\,X_2+0.5\,X_3-0.5\,X_1X_2+0.15\,X_1X_3-0.2\,X_1\,X_2\,X_3$$

where X_1, X_2, and X_3 are the temperature, feed flow rate and concentration of whey protein respectively. This equation explains the effect of the variables on the response of yield (Y). All the three parameters showed the significant effect (P=0.0000) on the yield of encapsulated noni juice, which has statistically proven with multiple regression relationship. Furthermore, to evaluate the accuracy and fit of the model in this study, it was confirmed by plotting the predicted vs observed yield of the encapsulated noni juice, the results showed the value of 0.99 (r^2 value). Response surface methodology was used to predict the effect of independent variables on the yield of the noni powder. The graphical representation for the response (yield) was developed by the independent variables and their significance effect to the yield (Fig. 1) The 3-D surface plots also clearly indicating, that all the three factors play an important role in obtaining high yield for the final product.

B. Moisture and Water Activity

The moisture content of encapsulated noni juice with whey protein showed 8-11%, whereas in combination with high or low molecular weight maltodextrin it was estimated around 8-10% (Fig. 2). The water activity fall within the range of 0.4-0.6 (Fig. 3), due to the hygroscopic property of noni juice. No, any signification changes observed among the moisture content. Generally, the product with high MD 4-7 possess lowest moisture content, but in our study, there is no any significant changes found in addition of high molecular MD as well as low lower molecular MD due to the tendency of noni juice to absorb more moisture with high hygroscopic nature.

TABLE I. Effect of Spray Drying Conditions and Concentration of Carrier Material on the Yield of Noni Juice Powder

Optimization condition	Yield of encapsulated noni (gm/100ml) SS	Yield of encapsulated noni (gm/100ml) df	Yield of encapsulated noni (gm/100ml) MS	Yield of encapsulated noni (gm/100ml) F	Yield of encapsulated noni (gm/100ml) p
(1) Temperature	4.86	1	4.86	486	0
(2) Flow rate	0.54	1	0.54	54	0.000002
(3) Concentration (%)	6	1	6	600	0
1 by 2	6	1	6	600	0
1 by 3	0.54	1	0.54	54	0.000002
2 by 3	0.54	1	0.54	54	0.000002
1*2*3	0.96	1	0.96	96	0
Error	0.16	16	0.01		
Total SS	19.6	23			

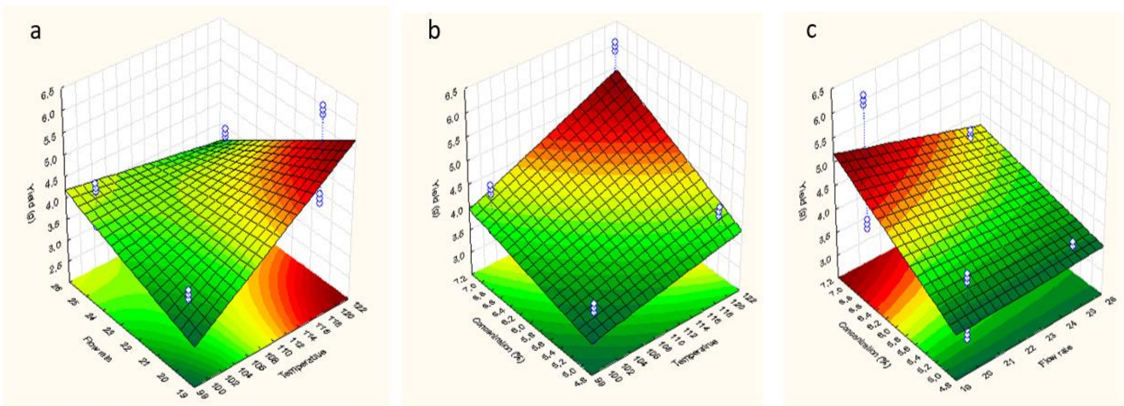

Figure 1. Effect of a) flow rate, b) temperature and c) feed flow rate on the yield of encapsulated noni juice

Low glass transition temperature, high hygroscopic and water solubility of juice products make them to absorbers the external moisture quickly and become too sticky. So, the ratio of carrier material is an important factor to increase the drying and yield efficiency [12]. The effect of MD 4-7 in accordance with the results obtained on the higher yield of encapsulated noni juice. About 25% carrier material was used for optimization of buckthorn spray dried juice.

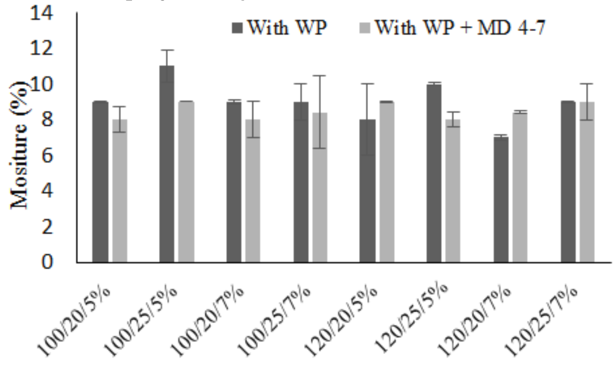

Figure 2. Moisture content of encapsulated noni

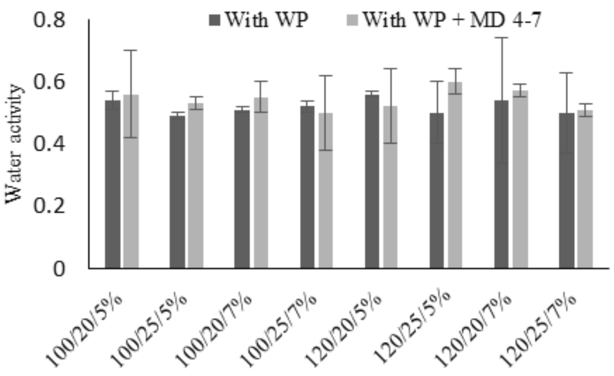

Figure 3. Water activity of encapsulated noni

C. *Color Measurement*

The noni juice encapsulated with whey protein and a combination of whey protein showed high lightness value at a higher temperature. Addition of maltodextrin showed the significance difference of L* value, where the value further increased as the temperature increases.

Whereas, the a* and b* value reduced significantly in the addition of maltodextrin treated group and by increasing the temperature, which showed a reduction in Chroma value with high Hue angle value. The color value measured have given in Table II and Fig. 4.

Addition of maltodextrin influence the color value of the spray dried product; pomegranate juice spray dried with 5-25% of maltodextrin showed color value from 45.54 to 74.46, where L* value increased and a* and b* value decreased [13], the similar trend was observed in our results. Similarly, Muaffar and Kumar [14], have also reported the change of color, due to the natural whitish color of maltodextrin and its effects in the drying of tamarind pulp powder. Our results are concurrence with Chen *et al.*, [15] where it was reported the low a* and b* value with high hue angle value. Watson *et al.*, (2016) [16] have reported that increasing temperature and increasing concentration of maltodextrin/cyclodextrin significantly affect the color values. Increasing the surface area during the spray drying may also cause rapid color change due to the oxidation process at a high temperature.

TABLE II. MOISTURE, WATER ACTIVITY AND COLOR VALUES OF ENCAPSULATED NONI

Optimization condition	L*	a*	b*
Only whey protein			
100/20/5% WP	56.57±0.03	11.46±0.02	27.215±0.07
100/25/5% WP	52.30±0.07	12.22±0.0	26.78±0.03
100/20/7% WP	60.42±0.0	11.36±0.27	26.85±0.22
100/25/7% WP	58.52±0.14	11.73±0.09	26.55±1.0
120/20/5% WP	54.23±0.07	11.54±0.07	25.75±0.17
120/25/5% WP	57.78±0.19	11.3±0.28	26.75±0.02
120/20/7% WP	65.34±0.03	9.72±0.38	25.65±1.19
120/25/7% WP	56.16±0.7	11.72±0.38	28.14±2.76
Combination with 2% MD 4-7			
100/20/5% WP	64.62±0.01	9.71±0.17	26.03±0.3
100/25/5% WP	61.03±0.04	9.97±0.12	26.03±0.3
100/20/7% WP	66±4.3	9.11±1.25	25.31±0.9
100/25/7% WP	62.92±0.02	10.4±0	25.31±0.9
120/20/5% WP	72.44±0.7	4.52±0.67	18.38±0.7
120/25/5% WP	71.04±1.3	4.035±0	18.37±0.07
120/20/7% WP	72.56±0.72	3.53±0.72	17.88±0.01
120/25/7% WP	70.49±1.9	4.13±0.08	18.37±0.71

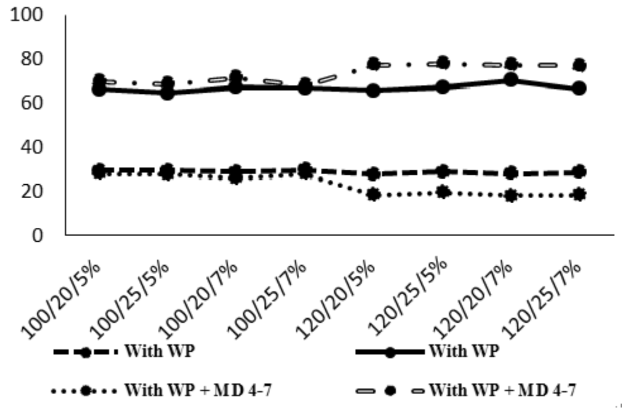

Figure 4. Chroma value and Hue angle of encapsulated noni

D. *Powder Characteristic*

Dry matter of powder is an essential factor in determining the shelf life of the product. Bulk and tapped density were estimated to calculate the Carr index and Hausner ratio for the encapsulated noni to evaluate the flowability. The Hausner values ranged from 1.2 to 1.38 for the whey protein encapsulated and 1.15 to 1.35, where the ratio was found to increase in the high concentration of feed rate at both 100 °C and 150 °C (Table III). The flowability of the powder has decreased due to the presence of moisture at high feed rate during spray drying and stickiness property of the noni juice.

The flowability has slightly increased with the addition of MD 4-7, but the results are not significantly different between the treatment groups. According to the Carr index value, the quality of powder falls between the rage of 11 to 22 for encapsulation of noni in WP, 12-26 for a combination of WP with MD. The powder quality increase as the temperature increases along with the incorporation of MD in noni juice, which increase the quality to a good and fair category of Carr index. Our results were associated with the results of Akhavan *et al.*, [17] due to the influence of MD and gelatin, whereas in sumac extract powder [18], incorporation of MD caused the better flowability and lower cohesiveness.

TABLE III. FLOWABILITY OF ENCAPSULATED NONI POWDER

Optimization conditions	WP		Combination of MD + WP	
	CI (%)	HR	CI (%)	HR
100/20/5% WP	14.28±0.02	1.16±0.5	17.36±1.2	1.9±0.5
100/25/5% WP	11.76±1.02	1.13±1.02	26.31±5.02	1.35±0.02
100/20/7% WP	21.73±2.07	1.27±0.02	13.33±1.01	1.15±0.1
100/25/7% WP	16.66±1.2	1.2±02	20.77±3.02	1.38±0.2
120/20/5% WP	20±2.02	1.25±0.02	15.36±1.01	1.13±0.0
120/25/5% WP	21.05±1.3	1.2±0.9	16.45±2.03	1.12±0.3
120/20/7% WP	22.77±3.02	1.38±0.1	12.15±2.02	1.13±0.1
120/25/7% WP	23.8±4.1	1.3±0.2	14.15±0.01	1.32±0.01

E. *SEM and Particle Size Analysis*

The maximum yield obtained treatment groups were subjected for the SEM and particle size analysis. Noni encapsulated only in WP (Fig. 5. a (7kx magnification) and b (10kx magnification) and in a combination of WP + MD 4-7 (Fig. 5. C (3kx magnification) and d (10kx magnification)) showed spherical shaped with a rough surface with 1.89 to 3.76 µm and 1.81 to 7.89 µm. The particles showed heterogeneous distribution due to the agglomeration of encapsulated powder, which reveals and confirmed the stickiness and high hygroscopic nature of noni juice. This can be overcome by incorporation of high ratio of high molecular maltodextrin. Shrinkage of particles was observed in both the samples treated at 120℃. The particle size analysis revealed the size ranging with 1µm for noni encapsulated whey protein and 8µm for a combination of MD with WP, the particle size is found to be bigger.

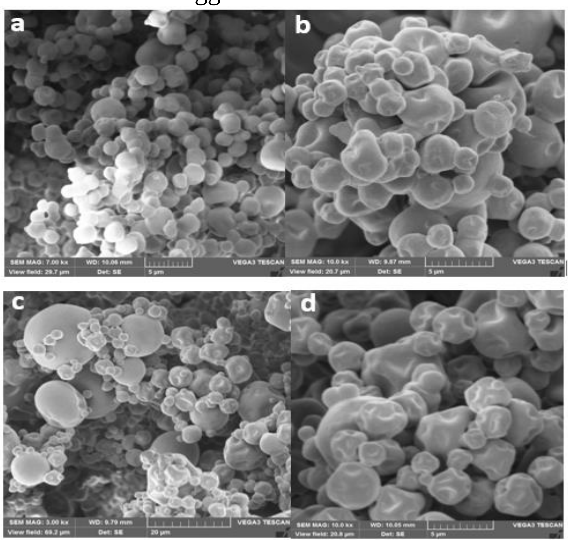

Figure 5. Microstructures of encapsulated noni

Evidently, the average particle size of 6 to 30µm was reported for the cactus mucilage encapsulated with maltodextrin. The distribution and size of the particles depend on the carrier material, temperature and feed rate [19]. Encapsulated powders of jamun showed some degree of shrinkage during the high temperature of the spray drying process [20], a similar trend was observed in the presented data.

F. *FTIR Analysis*

The FTIR is a crucial factor to detect the functional group present in samples. The FTIR spectrum (Fig. 6) of noni juice, encapsulated noni juice and carrier material WP and MD were analyzed and compared to evaluate the presence of functional groups in the encapsulated powder without degradation during the drying process. The IR spectrum of noni showed the characteristic peaks of phenols (3399 cm^{-1}), 1^0 amines (1627.21cm^{-1}), aromatics (1412.37 cm^{-1}) and aliphatic amines (1076.60cm^{-1}), these functional groups were also detected in the spectrum of encapsulated noni.

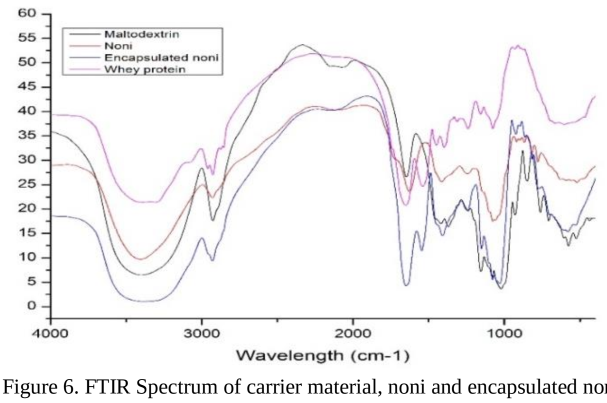

Figure 6. FTIR Spectrum of carrier material, noni and encapsulated noni.

This result confirms that all the functional groups were present in the encapsulated power without the loss during the drying process. The wavelength of encapsulated noni showed the quality similarities with the noni and carrier materials. The study on noni juice extract from noni powder [21] also demonstrated similar patterns, which corroborated with the presented data

G. Total Phenolic Content

The presence of total phenol was estimated in the encapsulated noni of WP with MD. All the encapsulated noni showed the presence of a phenolic compound; there is no any significant differences (p>0.05) observed between the factors of temperature, feed rate, and concentration. The phenolic content is found to more in the encapsulated noni powder dried under 100 ℃ at 25% feed rate (Fig. 7), which was followed by 7% of WP at 100 ℃. The phenolic content is found be less at a temperature of 120 ℃ comparatively.

A study on encapsulation of noni with carrageenan showed more total phenol content by increasing the wall material at a lower temperature. At high temperature the phenolic content decrease in the lower concertation of wall ratio. The results depict that increasing the concentration of wall material can protect the phenolic content even at higher temperature [9].

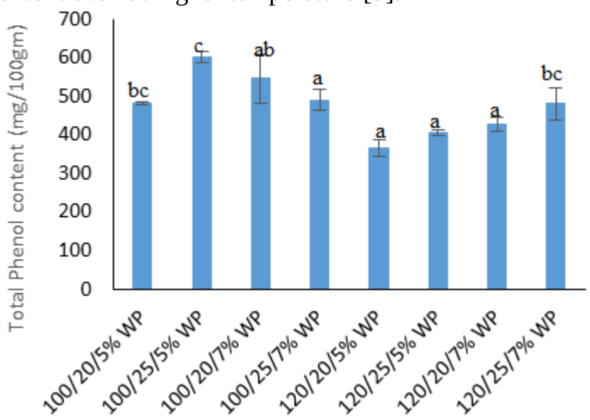

Figure 7. Total phenolic content of encapsulated noni

H. Total Antioxidant Content

The antioxidant activity of the encapsulated noni powders was evaluated by DPPH methods. The results are presented in Fig. 8, the values ranging from 16% to 25% for the 100 μg/100 μl concentration of encapsulated noni. The radical scavenging effect has reduced in the high temperature, and the activity is found to be more in the noni encapsulated in whey protein under 100 ℃ at 25% feed rate. No any significant difference (p>0.05) was observed for the activity among the various treatments.

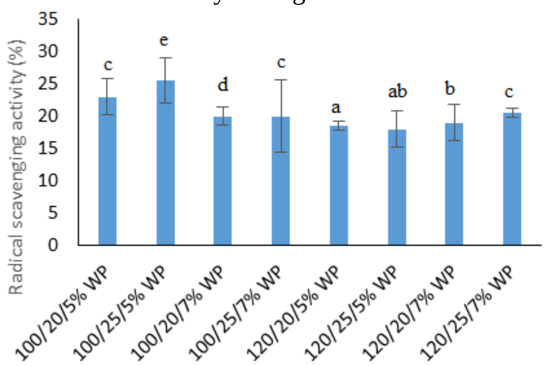

Figure 8. Total antioxidant content of encapsulated noni

When the temperature increase, there are possibilities to create structural changes, which result in the reduction of activity of phenolic component [22]. The incorporation of higher concentration of carrier material has protected the bioactive compounds from the temperature effect. The data validated that no any reduction in anti-oxidation effect among the experimental group.

IV. Conclusion

The encapsulation of noni powder was optimized with different combination of whey protein with high molecular weight maltodextrin (4-7) under different temperature, feed rate. The yield of powder has increased during the incorporation of MD (4-7), due to the high glass transition temperature. The results of statistical analysis determined the factors responsible for the yield of noni powder. The stickiness of the powder was controlled by the MD (4-7), but the flowability of the powder was fall in the fair range, which can be overcome by increasing the ratio of MD. The presence of total phenol and its antioxidant was estimated, which showed the significant activity, this was confirmed by the investigation of functional groups in the encapsulated noni powder by IR spectrum. Due to the encapsulation method through spray drying process, the raw and unpleasant flavor of noni have masked through the incorporation of whey protein and maltodextrin. This encapsulated noni powder can be used in various food system like milk shake and spread to attain the maximum health benefits of noni juice.

Acknowledgment

The authors wish to thank SERB, N-PDF scheme. This work was supported in part by a grant from Science and Engineering Research Board, Department of Science and Technology, Delhi (PDF/2017/001747).

References

[1] Bramorski, *et al.*, "Total polyphenol content and antioxidant activity of commercial Noni (*Morinda citrifolia* L.) juice and its components" *Brazilian Journal of Pharmaceutical Sciences*, vol. 46, no. 4, pp. 652-656, 2010.

[2] M. Y. Wang, *et al.*, "*Morinda citrifolia* (noni): A literature review and recent advances in noni research," *Acta Pharmacol. Sin.*, vol. 23, pp. 1127-1141, 2002.

[3] European Commission. Commission Decision of 5 June 2003 Authorising the Placing on the Market of "Noni Juice "(Juice of the Fruit of Morinda Citrifolia L.) as a Novel Food Ingredient under Regulation (EC) No 258/97 of the European Parliament and of the Council. Off. J. Eur. Union L 144 46, 12, 2003.

[4] B. J. West, *et al.*, "The potential health benefits of noni juice: A review of human intervention studies," *Foods*, vol. 7, no. 4, pp. 1-22, 2018.

[5] M. M. Wall, *et al.*, "Volatile changes in Hawaiian noni fruit, *Morinda citrifolia* L., during ripening and fermentation." *J. Sci. Food Agric*, vol. 98, no. 9, pp. 3391-3399, 2018.

[6] N. A. Shalan, N. M. Mustaoha, and S. Mohamed, "Morinda citrifolia leaf enhanced performance by improving angiogenesis, mitochondrial biogenesis, antioxidant, anti-inflammatory & stress responses," *Food Chem*, vol. 1, no. 212, pp. 443-52, 2016.

[7] A. Shoeb, *et al.*, "Effect of morinda citrifolia (Noni) fruit juice on high fat diet induced dyslipidemia in rats," *J. Clin. Diagn Res*, vol. 10, no. 4, pp. 6-10, 2016.

[8] S. D. Pachauri, *et al.*, "Protective effect of fruits of Morinda citrifolia L. on scopolamine induced memory impairment in mice: A behavioral, biochemical and cerebral blood flow study," *J. Ethanopharmacol*, vol. 6, pp. 34-41, 2012.

[9] D. Krishnaiah, *et al*., "Optimal operating conditions of spray dried noni fruit extract using carrageenan as adjuvant," *Journal of Applied Sciences*, vol. 9, no. 17, pp. 3062-3067, 2009.

[10] Garofulic, *et al*., "Optimization of sour cherry juice spray drying as affected by carrier material and temperature," *Food Technology Biotechnol*., vol. 54, no. 4, pp. 441-449, 2016.

[11] N. Phisut, "Spray drying technique of fruit juice powder: some factors influencing the properties of product," *Int. Food Res J*, vol 19, pp. 1297-306, 2012.

[12] Y. H. Roos and M. Karel, "Plasticizing effect of water on thermal behaviour and crytallization of amorphous food models," *J. Food Sci*., vol. 56, pp. 38-43, 1991.

[13] K. Muzaffar, *et al.*, "Determination of production efficiency, color, glass transition, and sticky point temperature of spray-dried pomegranate juice powder," *Cogent Food & Agriculture*, vol. 2, no. 1, pp. 1144444, 2016.

[14] K. Muzaffar and P. Kumar, "Effect of soya protein isolate as a complementary drying aid of maltodextrin on spray drying of tamarind pulp," *Drying Technology*, vol. 34, no. 1, pp. 142-148, 2016.

[15] B. H Chen, H. Y. Peng, and H. E. Chen, "Changes of carotenoids, color and vitamin A content during processing of carrot juice," *J. Agric. Food Chem.*, vol. 43, no. 7, pp. 1912–1918, 1995.

[16] M. A. Waston, J. M. Lea, and K. L. Betta-Garber, "Spray drying of pomegranate juice using maltodextrin/cyclodextrin blends as the wall material," *Food Sci. Nutr*., vol. 5, no. 3, pp. 820-826, 2017.

[17] M. S. Akhavan, S. M. Jafari, E. Assadpoor, and D. Dehnad, "Microencapsulation optimization of natural anthocyanins with maltodextrin, gum Arabic and gelatin," *Int. J. Biol. Macromol*, vol. 85, pp. 379-85, 2016.

[18] G. Caliskan and S. N. Dirim, "The effect of different drying processes and the amounts of maltodextrin addition on the powder properties of sumac extract powders," *Powder Technology*, vol. 289, pp. 308-314, 2016.

[19] M. C. Otalora, J. G. Carriazo, L. Itrurriaga, M. A. Nazareno, and C. Osoribo, "Micro encapsulation of betalains obtained from cactus fruit (*Opuntia ficus-indica*) by spray drying using cactus cladode mucilage and maltodextrin as encapsulating agents," *Food Chemistry*, vol. 187, pp. 147-181, 2015.

[20] S. Santhalakshmy, S. J. Don Bosco, S. Francis, and M. Sabeena, "Effect of inlet temperature on physicochemical properties of spray-dried jamun fruit juice powder," *Powder Technology*, vol. 274, pp. 37-43, 2015.

[21] Mahfoudh, *et al.*, "In vitro ex vivo assessment of Morinda citrifolia on drug metabolizing enzymes in spontaneously hypertensive rats," *Pharmaceutical Biology*, vol. 47, pp. 1108-1116, 2009.

[22] R. T Rigon and C. P. Z. Norena, "Microencapsulation by spray drying of bioactive compounds extracted from blackberry (*Rubus fructicosus*)," *Journal of Food Science and Technology*, vol. 53, no. 3, pp. 1515-1524, 2016.

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