Optimization of Spray Drying Parameters for Carrot Juice Powder by using Central Composite Design (CCD)

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Abstract

The optimal characterization of carrot juice powder was designed in a central composite design model to analyze different spray dryer parameters such as inlet airflow temperature (155℃– 175℃), the addition of maltodextrin for acquiring proper encapsulation (5% - 15%), and feed rate (400 ml/h – 600 ml/h). The experimental results were ($P < 0.05$) fitted in quadratic polynomial order to analyze the various responses as powder yield (%), hygroscopicity (g/100g), total anthocyanin content (%), and RSA value (%). Powder yield increased with an increase in inlet air temperature, but anthocyanin content and color retention decreased. Gradual decreases in hygroscopicity were seen by increasing in the maltodextrin addition rate. Maltodextrin addition and feed rate have shown non – significant model ($P > 0.05$) factors on other responses except RSA. The optimal condition we found to be at inlet airflow temperature (165○C), maltodextrin addition (15%), and feed flow rate (500 ml/h).

Keywords: carrot juice powder, maltodextrin, spray dryer, anthocyanin content, and radical scavenging activity.

1. Introduction

Color is an important significant factor for deciding the quality or screening many fruits and vegetables to customers. Crude pigments are valuable input coloring agent in vegetables as referred as anthocyanin content in carrot. Higher the content of pigment makes the product fresh appearance (S Murali et al, 2014). As anthocyanin exhibit the highest potential of anti-inflammatory and reduce proliferation of tumor cells and its activity. Small and highly colored fruits basically good source of anthocyanin and one of the main source of anthocyanin in India is from Carrot having biological name (*Daucaus Carota*). These are actively present in the fruits, vegetables also I berries that provides the colors like orange, red and blue. The active method for the preservation of the fruits and vegetables are mainly by using conventional methods. This may leads to the loss in quality and functionality/degradability of the pigment (B. K. Tiwari et al, 2009). As the stability of the anthocyanin is different at different levels of water activity of the sample and also relay on the conditions such as temperature and oxygen content. (Bindu and pradyuman, 2016). Spray drying process, one of the most applicant proposed to produce good quality with minimum water activity that can lead to easy transportation with less effort e (Abadio et al., 2004;

Cano-Chauca, 2005; Quek, 2007). Due to its sensitivity towards the high temperature, this process is challengeable. To outward this effect, a compound named maltodextrin also called as drying carriers with higher molecular weight is added along with sucrose content solutions to avoid stickiness to the chamber in spray dryer. The addition rate of maltodextrin is purely categorized with dextrose equivalent (DE). A lower the DE means the minimum addition ratio of maltodextrin to the sample that retains better encapsulation (Krishnan et al., 2005; Adhikari et al., 2009). Spray drying is well known application in all food industries to convert the liquid into the powder without causing losses in the nutritional factors. Contribution of the color along with some special characters such as water binding property of final product and also applicative in snacks and ice – cream and some of the diet drinks (Mohamad et all, 2012).

Response surface methodology is mainly used to standardize or optimize the various conditions with optimal design. In this work we were used the polynomial model type with quadratic process order. RSM includes the di-variant type of variables as independent and dependent variables were the dependent variables are majorly effected by independent variables and also said to be experimental values. Shavaki et all, 2012 mentioned that response surface methodology can be applied to find best conditions of various fruits and vegetables such as pomegranate arils (ramanji et all 2020).

As carrot is a seasonal product the availability compared to other fruits and vegetables. Due to its nutritional availability of the carrot, application of spray dryer to convert into powder will make the product available throughout the year and also increase the shelf life of the carrot. A simple lab model of spray dryer is used by varying the temperature, inlet air flow and feed flow (Mohamad et all, 2012).

2. Materials and Methods

Sample Preparation

Primary raw material (Carrot), were purchased from OOTY carrot cultivation region. Preliminary washing of carrots were done and the carrot slices are made with average diameter of 1 – 2 mm in order to increase the efficiency of the juice extractor. The extracted pulp is filtered with clean muslin cloth for 3 to 4 times to avoid heavy particles that cause blockage in feed inlet pipe. The extracted juice is stabilized by blanching process (60° C) for 5 minutes of time. This process smoothens the juice for proper binding with carrier agent. The sample is weighed and yield is calculated for total amount of raw material taken.

$$\frac{weig\ htoffinaljuiceobtained}{totalamountofrawmaterials} = Yield(\%)\text{----------} \quad \text{(i)}$$

Quantified amount of the sample is mixed with various proportions of maltodextrin with having dextrose equivalent number of 7. The osmometric DE determination is one of the rapid and environmentally friendly. This is also inexpensive method and easy to operate with user friendly method (Y. Rong et all, 2009)..

Spray Dryer

The medium scale of lab model level spray dryer is used in drying process of carrot juice sample. Independent variables of spray dryer such as inlet air temperature ($^\circ$C) and feed flow (ml/hour), sample mixed with maltodextrin is given as feed to the spray dryer with the

temperature range of 155°C to 175°C. Microencapsulation will provide the sample to inhibit the water gain to the sample by reducing the sample contact to the environment.

Response Surface Methodology

Quadratic process order with polynomial model type is used for the modeling optimization of independent variable. Correlation between each independent variable towards the dependent variable is analyzed with significant error of 0.5 and $P< 0.05$. The estimated P value indicates whether the estimated model is significant or not-significant. The file version of 13.0.1.0 with randomized sub type containing 17 runs in quadratic design model.

Table 1: Independent factors present for the sample in spray drying process.

Factor	Name	Units	Minimum	Maximum	Mean	Std. Dev.
A	IAT	Degree Celsius	155.00	175.00	164.71	7.60
B	MD addition Rate	%	5.00	15.00	10.00	3.95
C	FF Rate	ml/h	400.00	600.00	500.00	79.06

IAT: internal air temperature, MD: maltodextrin, FF rate: feed flow rate

Table 2: Dependent factors that are formed from experimenting with installed factors in spray dryer.

Response	Name	Units	Observations	Minimum	Maximum	Mean	Std. Dev.	Ratio
R1	Powder Yield	%	17.00	40.26	53.89	45.88	4.05	1.34
R2	Hygroscopicity	g/100g	17.00	13.21	21.67	15.53	2.08	1.64
R3	Color value	Value	17.00	21.45	34.65	28.16	3.88	1.62
R4	total anthocyanin content	%	17.00	38.91	49.31	43.99	2.76	1.27
R5	RSA	%	17.00	55.45	66.85	61.18	3.14	1.21

Std. Dev: Standard deviation.

Table 1, 2 are independent and dependent factors respectively with minimum and maximum value of 17 runs, mean value and std deviation. The total observation extracted from the RSM are 17. Each observation is experimented through the spray dryer and response factors are noted for each observation. Each response is analyzed through the ANOVA model and sequential model sum of squares are observed weather the result is suggested or not. The R^2 value for for each response through quadratic model is ranged from 0.6 to 0.88 means 88% of variation formed in output variable. Effective fit for the model was seen in yield variable compared to other variables as shown 0.88.

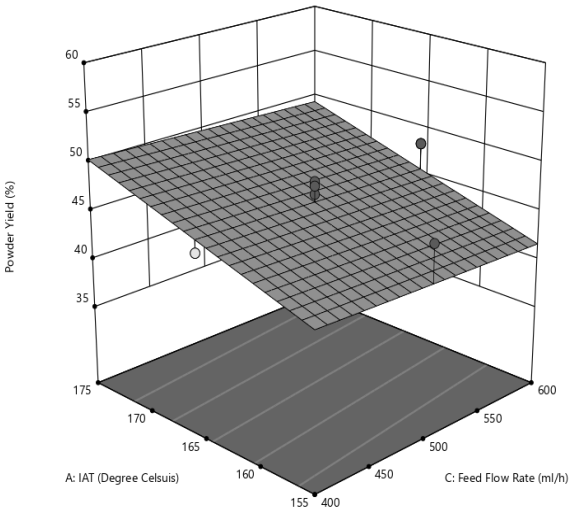
Anthocyanin content

Anthocyanin content and radical scavenging ability by ABTS as represented in (shivaraj hariram nile et all, 2015). Each value is converted into percentage value and noted for statistical analysis process. Point prediction is considered for optimized condition to produce the carrot juice powder.

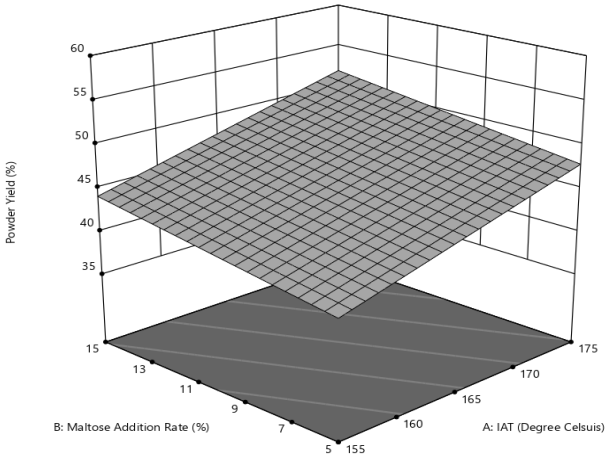
Table 3: Optimized independent variables and dependent variables

Run	A:IAT	B:MD Addition Rate	C:Feed Flow Rate	Powder Yield	Hygroscopicity	Colour value	total anthocyanin content	RSA
1	155	10	500	46.1	13.84	34.65	45.31	64.3
2	175	5	400	50.03	15.3	21.45	40.4	55.45
3	165	10	400	45.15	15.45	32.6	41.35	63.4
4	155	5	500	40.3	14.15	30.26	45.25	62.91
5	165	10	600	48.29	13.25	25.21	44.29	60.06
6	155	15	400	42.4	16.23	31.21	46.12	64.01
7	175	5	600	43.95	11.5	26.12	43.02	58.91
8	165	10	500	46.8	15.6	26.01	42.91	60.05
9	170	5	600	43.67	12.87	26.11	43.21	58.12
10	165	10	500	48.12	15.05	26.72	44.21	60.01
11	175	15	600	53.73	17.51	24.21	42.25	58.53
12	165	15	500	43.25	15.12	33.45	49.03	66.57
13	165	10	500	43.21	13.29	25.93	43.15	59.93
14	155	5	400	40.26	11.56	30.21	46.51	62.42
15	155	15	600	43.23	15.51	33.53	49.31	66.85
16	165	10	500	47.65	13.25	26.28	38.91	60.26
17	175	15	400	53.89	17.76	24.71	42.62	58.23

Each optimized observations given by RSM software is analyzed and response factors are noted in the response factors. Each factor is analyzed with correlating each independent variables, significance in each response is seen through the P value.



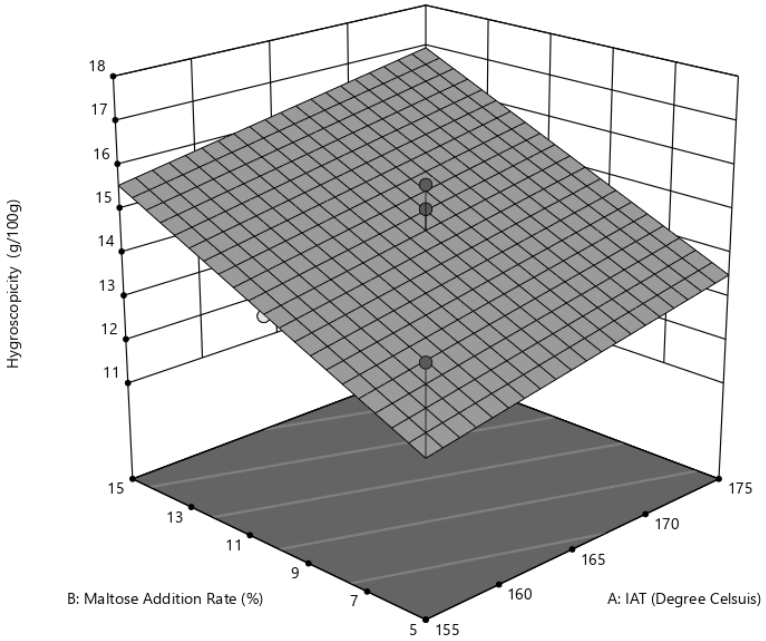
Graph 1



graph 2

Graph 1: correlation between yield and MD addition rate, IAT, Graph2: correlation between powder yield and IAT and FF rate

As you see in the graph the correlation or relation between the internal air temperature and powder yield is more significant with P value of 0.0008. As the internal air temperature increases the powder yield constantly increasing, same with maltodextrin addition rate with P value of 0.0338. The feed flow rate is considered as non - significant towards the powder yield by having the P value greater than 0.1.



Graph 3: Correlation between the hygroscopicity and internal air temperature, MD addition rate.

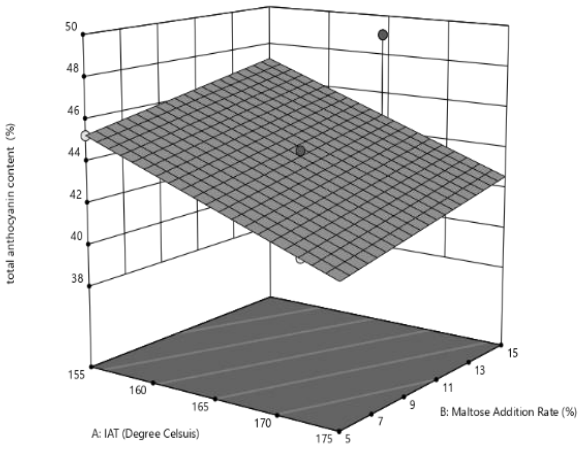
The hygroscopicity towards the powdered products are more significant factor in which the moisture absorbance is estimated. The hygroscopicity is mainly significant towards the maltodextrin with P value of 0.0004 and non-significant with other two factors in the model. This is because as the as the maltodextrin concentration increases the encapsulation of powder will occur efficiently by reducing the relation between environment moisture. The final equation in terms of the actual factors is expressed below

$$3.15 + 0.068 * IAT + 0.341870 * MD\ addition - 0.00691 * FF\ rate = \text{Hygroscopicity}$$

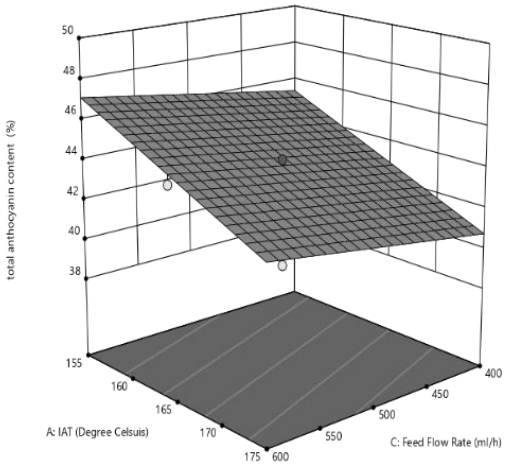
The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor

Table 4: Predicted and experimental values at optimum conditions

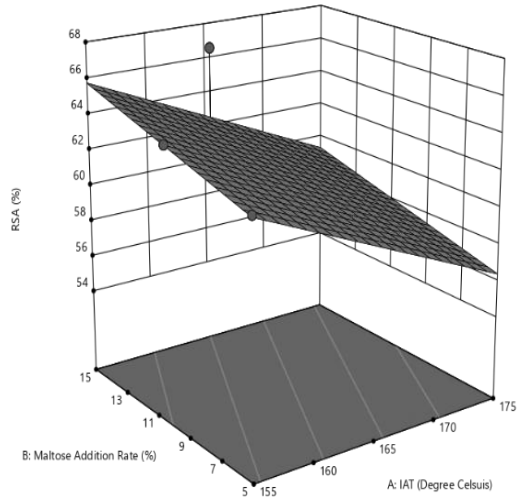
Run 12 Response	**Predicted Mean**	**Predicted Median**	**Observed**	**Std Dev**
Powder Yield	48.0209	48.0209	43.25	2.6933
Hygroscopicity	16.2731	16.2731	15.12	1.14538
Color value	29.1446	29.1446	33.45	2.58683
Carotene retention	44.9011	44.9011	49.03	2.13465
RSA	62.561	62.561	66.57	1.72938



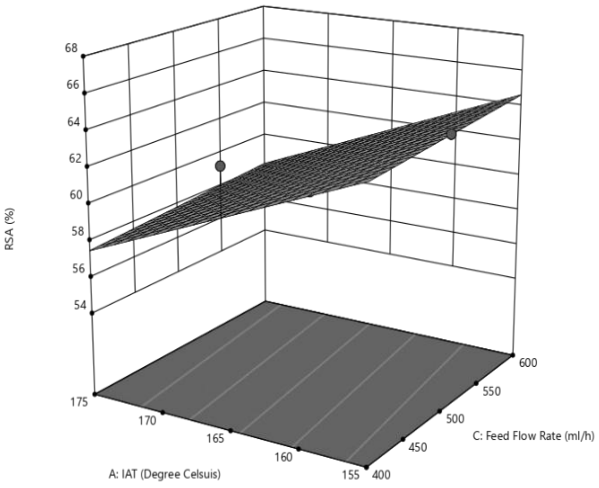
Graph 6



Graph 7



Graph 8



Graph 7

Graph 4, 5: Color value vs. IAT and MD addition; Graph 6, 7: anthocyanin content vs. IAT, MD addition rate and FF rate; Graph 8, 9: RSA vs. MD addition rate, IAT and feed flow rate.

Correlation between the IAT and the MD addition rate is more significant but not significant with the F rate. As IAT increases the color degree decreases, due to the degradation in the pigments in the carrot juice. Same scenario happened with gradual rise in the maltodextrin where it is directly proportional to addition rate, this may due to increase in the MD rate will protect or reduce the IAT effect towards the pigment molecule. Final equation in terms of actual factors Is expressed below for color value.

$$89.40 - 0.387731 * IAT + 0.2204 * MD\ addition + 0.000816 * FF\ rate = \text{Color Value}$$

Equation in terms of actual factors can be used to make perfect prediction about the response for given levels of each other. The levels should be specified in the original units for each factor. It cannot be used to determine the relative impact of each factor.

Anthocyanin content is likely significant with IAT with the P value of 0.0063 as inversely proportional to each other i.e. as decrease if IAT increases more retention of anthocyanin content. This occurs due to the sensitivity towards the temperature as higher temperature

degrades the anthocyanin which cause the loss of the pigment and this function effects the color value by decreasing its value.

$$75.92 - 0.231 * IAT + 0.195 * MD\ addition - 0.00855 * FF\ rate = \text{Anthocyanin Content}$$

The spectrophotometer analysis for RSA is analyzed and resulted with more significant towards the IAT and MD addition rate with P value of 0.0001 and 0.0182 respectively. Increasing with temperature reduces the RSA value, but increasing the MD addition rate will gradually increases the RSA by resulting the lower degradation rate. The Model F value of 13.25 implies the model is significant with 0.03% chance of that an F-value could occur due to noise.

$$109.03 - 0.3199 * IAT + 0.295 * MD\ addition - 0.00375 * FF\ rate = \text{RSA}$$

3. Conclusion

Extraction of carrot juice from the local variant purchased from the farmers of ooty id done and mixed with various proportions of MD addition having the DE value of 7. The prepared sample is incurred in the drying process with using spray dryer to prepare the carrot juice powder. The 5 factors are observed with 17 runs and statistically analyzed with response surface methodology in central composite design (CCD). Each response factors are analyzed in quadratic polynomial model type and significance of each model is determined by P-value. The effect of maltodextrin rate and IAT is more in color value, anthocyanin retention and RSA value. Powder yield is mostly signified in FF rate and IAT but not in MD addition rate. Model obtained is acceptable and study state that the retention of anthocyanin (%) is improved in carrot juice powder.

References

[1] Arnous A., Makris D.P., Kefalas P., 2002. Correlation of pigment and flavanol content with antioxidant properties in selected aged regional wines from Greece. J. Food Compos. Analy., 15, 655-665.

[2] Burns J., Gardner P.T., Oneil J., Crawford S., Morecroft I., Mcphail D.B., Lister C., Matthews D., Maclean M.R., Lean M.E., Duthie G.G., Crozier A., 2000. Relationship among antioxidant activity vasodialtion capacity and phenolic content of red wines. J. Agric. Food Chem., 48, 220-230.

[3] Chiou A., Karathanos V.T., Mylona A., Salta F.N., Preventi F., Andrikopoulos N.K., 2007. Currants Vitis vinifera L, content of simple phenolics and antioxidant activity. Food Chem., 102, 516- 522.

[4] Bazaria, B., & Kumar, P. (2016). Optimization of spray drying parameters for beetroot juice powder using response surface methodology (RSM). Journal of the Saudi Society of Agricultural Sciences, 17(4), 408–415.

[5] Murali, S., Kar, A., Mohapatra, D., & Kalia, P. (2015). Encapsulation of black carrot juice using spray and freeze drying. Food Science and Technology International, 21(8), 604–612.

[6] Abadio, F. D. B., Domingues, A., Borges, S. V., & Oliveira, V. (2004). Physical properties of powdered pineapple (Ananas comosus) juice—effect of malt dextrin concentration and atomization speed. Journal of Food Engineering, 64(3), 285–287.

[7] Rong, Y., Sillick, M., & Gregson, C. (2009). Determination of Dextrose Equivalent Value and Number Average Molecular Weight of Maltodextrin by Osmometry. Journal of Food Science, 74(1), C33–C40.

[8] Bowen-Forbes, C. S., Zhang, Y., & Nair, M. G. (2010). Anthocyanin content, antioxidant, anti-inflammatory and anticancer properties of blackberry and raspberry fruits. Journal of Food Composition and Analysis, 23(6), 554–560.

[9] Tiwari, B. K., O'Donnell, C. P., & Cullen, P. J. (2009). Effect of non-thermal processing technologies on the anthocyanin content of fruit juices. Trends in Food Science and Technology, 20(3–4), 137–145.

[10] Tonon, R. V., Brabet, C., & Hubinger, M. D. (2008). Influence of process conditions on the physicochemical properties of açai (Euterpe oleraceae Mart.) powder produced by spray drying. Journal of Food Engineering, 88(3), 411–418.