BEST: International Journal of Humanities, Arts, Medicine and Sciences (BEST: IJHAMS)
ISSN (P): 2348-0521, ISSN (E): 2454-4728
Vol. 5, Issue 12, Dec 2017, 53-58

COMPARITIVE STUDY ON OPTIMIZATION OF SPRAY DRYING PARAMETERS, FOR BEETROOT JUICE POWDER USING BOX-BEHENKEN DESIGN AND CENTRAL COMPOSITE METHOD

LITTY MARY ABRAHAM[1], ANJALI KRISHNA T. U[2] & S. ELIZABETH AMUDHINI STEPHEN[3]

[1,2]Department of Food Processing and Engineering, Karunya Institute of technology and Sciences, Coimbatore, Tamil Nadu, India

[3]Department of Mathematics, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India

ABSTRACT

Comparison on the optimization of beetroot juice powder were done using Box-Behnken design and central composite method, to optimize the spray drying parameters of inlet air temperature (160-180), maltodextrin addition rate (5-15%), and feed flow rate (400-600 ml/h). The experimental results were done for ($p<0.05$), fitted in the second order polynomial model, to describe and predict the responses, in terms of the powder yield, redness value and beta lain retention.

Studies done with box-benken design showed the responses as redness value and betalain retention increased with an increase in maltodextrin concentration, and the optimum conditions were found as inlet air temperature:160 deg, feed flow rate:400ml/h, maltodextrin concentration:15%. Optimization, done with central composite method showed an increase in powder yield alone, with corresponding decrease in redness value, betalain retention and the optimizing conditions were inlet air temperature:170 deg, maltodextrin concentration:10% and feed flow rate:500ml/h. Redness value, along with powder yield plays an important factor, in the optimization of spray drying parameters, hence box behnken design is the most desirable operation.

KEYWORDS: Spray Drying, Beet Root Juice, Optimization & Redness Value

INTRODUCTION

Nowadays, there is an increasing interest among consumers, to buy food based on their quality evaluation and colour is the primary screener. The application of colours to food includes giving colour to colourless foods and retaining the original colour of the food, after any unit operations. (Shishir et al., 2016). Algae, fungi, lichens, or bacteria's are the sources of natural colour, in the form of pigments. Anthocyanin and betalains are the two pigments used to provide red colour in food industry. Betalains, are derived from beetroot, which are water-soluble nitrogenous pigments. The betalains are widely used in dairy products such as ice creams, yogurt, dry soft drink, confectionaries, soups, and bacon products. Betalains are pH stable compounds in the range of 3-7. (Jackman and smith 1996). Betalains are mainly composed of red-violet betacyanin and yellow-orange betaxanthin, containing betalamic acid as the bioactive unit. On varying the levels of water activity, temperatures, exposure to oxygen, and light, the stability of betalains changes. The red beet, Amaranthus, Hylocereuspolyrhizus (red pitaya) are the natural sources of betalains. Spray drying is a method of dryinga solution, suspension or slurry, in order to produce a powder with good quality, low water activity and easier transport and storage. Powder produced by spray drying without carriers may have low quality and stability and is undesirable in food industries (Gokhale and Lele, 2011). Maintaining a high content of betalains in dried spray juice powder is a challenge. High molecular weight drying carriers (maltodextrin) are added with sugar-containing juices, to avoid the stickiness of wall chamber and among the dried particles.

Nemzer et al (2001), compared the betalainic and nutritional profiles of pigments present in beetroot dried and extracted by freeze, air and spray drying. Bind et al (2016), found the optimization parameters of spray drier, for betroot juice powder, using box-behenken design. Tee et al.(2012), studied the optimization of spray drying parameters of piper betle l. leaves extract, coated with maltodextrin using box behenken design. The optimum operation conditions for the highest hydroxyl chavinol content with lowest moisture content and particle size were found out.

MATERIALS AND METHODS

Powder Yield

Powder yield after drying was evaluated in percentage, as total solids collected to the total solids provided in the feed suspension.

Colour

The powder colour was determined using Chroma meter.

Betalain Retention

A spectro photometric method is used, for the quantification of betalains using UV-VIS spectrophotometer.

Experimental Design

The Box-Behnken design is a better prediction operation, in the centre of the factor space Design-Expert 9.0, Stat-Ease, Inc.). The 3-factor-3-level Box-Behnken design Montrogomery, 2008; Box and Behnken, 1960) at the centre point, with five replicates was used for spray drying of beetroot juice powder, taking 3 independent variables: inlet air temperature (160, 170 and 180 deg), feed flow rate (400, 500 and 600 ml/h) and MD concentration (5%, 10% and 15%) to make the predictive models for different responses. The responses were analysed by using second order polynomial (SOP) model:

$$Y_k = \beta_{k0} + \sum_{i=1}^{n} \beta_{ki} x_i + \sum_{i=1}^{n} \beta_{kii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{kij} x_i x_j$$

Where, Yk =response variable; Y1 =powder yield (%); Y2 =hygroscopicity (g/100 g); Y3 = redness value; Y4 = betalain retention (%) and Y5 =RSA (%); xi represent the coded independent variables (x1 = temperature of inlet air, x2 = concentration of maltodextrin concentration and x3 = feed flow rate), the value of the fitted response at the centre point of the design, i.e., point (0, 0, 0).

The central composite design is one of the most commonly used response surface design experiment. It is used mostly for solving sequential experiments. The factors levels are coded as +1 and -1.

Table 1: Experimental Design for Spray Drying Test using Central Composite Method

Central Composite Design

Each numeric factor is set to 5 levels: plus and minus alpha (axial points), plus and minus 1 (
every combination of the categorical factor levels.

Numeric factors: 3 (2 to 50) Horizontal
Categoric factors: 0 (0 to 10) Vertical

	Name	Units	Low	High	-alpha	+alpha
A [Numeric]	inlet air temera	deg c	160	180	153.182	186.818
B [Numeric]	malto dextrin a	%	5	15	1.59104	18.409
C [Numeric]	feed flow rate	ml/h	400	600	331.821	668.179

RESULTS AND DISCUSSIONS

The experimental results of percentage of powder yield, redness, value betalin retention of the powders are shown in Table 2.

Table 2: The Percentage for Powder Yield, Redness Value and Betalin Retention were Obtained for different Runs

C:\Users\Litty Mary Abraham\Desktop\MATHS WORK.dxpx - Design-Expert 10.0.

Options Design Tools Help Tips

Std	Block	Run	Space Type	Factor 1 A:inlet air te... deg C	Factor 2 B:maltodextri... %	Factor 3 C:feed flow ... ml/h	Response 1 Powder yield %	Response 2 Hygroscopicity g/100g	Response 3 Redness value	Response 4 Betalin retent... %
4	Day 1	1	Factorial	180	15	400	54.31	19.23	24.67	63.16
9	Day 1	2	Center	170	10	500	48.03	16.56	27.92	65.78
10	Day 1	3	Center	170	10	500	48.03	16.56	27.92	65.78
7	Day 1	4	Factorial	160	15	600	42.43	15.04	33.21	69.49
5	Day 1	5	Factorial	160	5	600	41.31	14.71	31.78	67.96
1	Day 1	6	Factorial	160	5	400	41.31	14.71	31.78	67.96
2	Day 1	7	Factorial	180	5	400	51.54	20.68	22.56	61.34
11	Day 1	8	Center	170	10	500	48.03	16.56	27.92	65.78
6	Day 1	9	Factorial	180	5	600	53.34	19.67	24.21	62.84
3	Day 1	10	Factorial	160	15	400	44.73	14.86	34.67	70.46
8	Day 1	11	Factorial	180	15	600	47.82	16.45	27.03	65.82
12	Day 1	12	Center	170	10	500	48.03	16.56	27.92	65.78
19	Day 2	13	Center	170	10	500	48.03	16.56	27.92	65.78
15	Day 2	14	Axial	170	1.59104	500	40.34	15.32	24.21	62.23
20	Day 2	15	Center	170	10	500	48.03	16.56	27.92	65.78
18	Day 2	16	Axial	170	10	668.179	40.25	14.36	22.64	61.54
16	Day 2	17	Axial	170	18.409	500	42.31	14.71	27.32	62.23
13	Day 2	18	Axial	153.182	10	500	40.34	15.53	22.56	62.84
14	Day 2	19	Axial	186.818	10	500	48.65	16.56	34.78	61.35
17	Day 2	20	Axial	170	10	331.821	41.32	15.32	22.56	61.32

The linear model for all the responses in terms of coded factors are shown in equation below:

Equations

- $\mathbf{Y_1}$=+47.38+3.75A+0.37B-0.64C-0.91AB-0.30AC-1.32BC-0.083A²-1.20B²-1.39C²
- $\mathbf{Y_2}$=+27.52-0.91A+1.06B+0.20C+0.076AB+0.68AC-0.094BC+0.98A²-0.052B²-1.17C²
- $\mathbf{Y_3}$=+64.45-1.85A+0.65B+0.26C
- $\mathbf{Y_1}$=POWDER YIELD
- $\mathbf{Y_2}$=REDNESS YIELD
- $\mathbf{Y_3}$=BETALIN RETENTION
- **A**-inlet air temperature
- **B**-malto dextrin addition rate
- **C**-feed flow rate

Table3: Design Summary

File Version	10.0.5.0											
Design Wizar	Optimization > Factorial / RSM > HTC											
Study Type	Response Surface		Subtype	Randomized								
Design Type	Central Composite		Runs	20								
Design Mode	Quadratic		Blocks	2	Build Time (r	125.00						

Factor	Name	Units	Type	Subtype	Minimum	Maximum	Coded	Values	Mean	Std. Dev.
A	inlet air temper	deg C	Numeric	Continuous	153.182	186.818	-1.000=160	1.000=180	170	8.4781
B	maltodextrin ac	%	Numeric	Continuous	1.59104	18.409	-1.000=5	1.000=15	10	4.23905
C	feed flow rate	ml/h	Numeric	Continuous	331.821	668.179	-1.000=400	1.000=600	500	84.781

Response	Name	Units	Obs	Analysis	Minimum	Maximum	Mean	Std. Dev.	Ratio	Trans	Model
R1	Powder yield	%	20	Polynomial	40.25	54.31	45.909	4.46931	1.34932	None	Quadratic
R2	Hygroscopicity	g/100g	20	Polynomial	14.36	20.68	16.3255	1.73405	1.44011	None	Linear
R3	Redness value		20	Polynomial	22.56	34.78	27.575	3.98243	1.54167	None	Quadratic
R4	Betalin retentio	%	20	Polynomial	61.32	70.46	64.761	2.81883	1.14905	None	Linear

Powder Yield

The higher yield with higher maltodextrin concentration was not due to the addition of total solids in the form of carriers (maltodextrin), but due to the reduction in stickiness by the encapsulation of maltodextrin (Fazaeli et al., 2012). The feed flow rate has a negative effect on the powder yield, because of the slow heat and mass transfer rate, by using the BBD. But, in case of model designed with central composite method, the powder yield increased on increasing the feed flow rate and maltodextrin concentration.

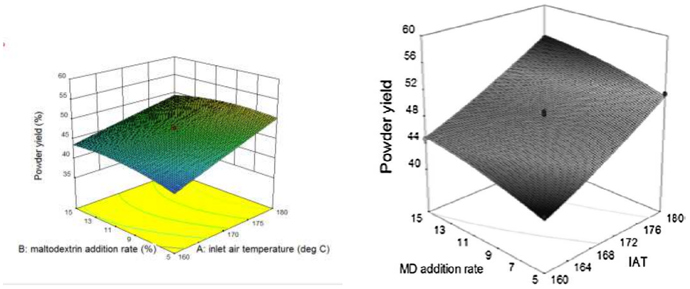

Figure 1: Central Composite Design Box Behenken Design

Redness Value

Redness in beetroot is the major factor, which indicates the best quality of powder after drying. The retention of redness was higher at initial drying temperatures, but there was a steep decrease in the plot, for redness value at higher initial air temperature, due to the degradation of the pigment at higher temperature using the Box-behenken design. But, in case of central composite design, there was a decrease in redness value, with increase in inlet air temperature and maltodextrin concentration.

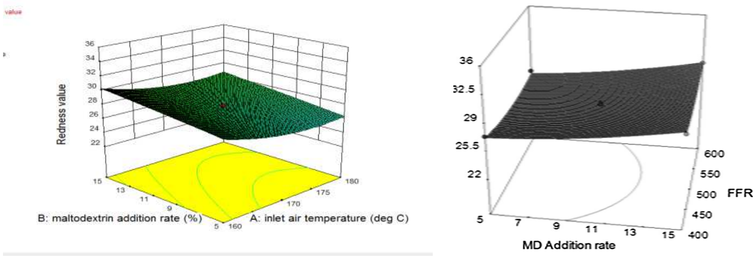

Figure 2: Central Composite Design Box-Behenken Design

Betalain Retention

Betalains have several biological activities, antioxidant, anti-inflammatory, hepato-protective, and antitumor properties along with a red colour. Inlet air temperature and maltodextrin addition rate had a significant effect, on the retention of betalain pigment. The highest pigment retention (70.46%) was found in powders with 15% maltodextrin, MD acted as a carrier to prevent damage to pigments at higher temperature, in box-behenken design. But, in the central composite design, betalain retention showed a significant decrease with increase in inlet air temperature and maltodextrin concentration, on comparing it with BBD.

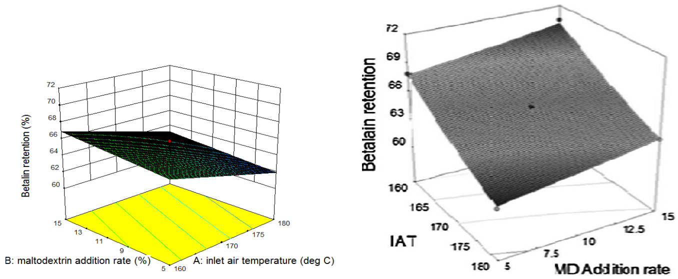

Figure 3: Central Composite Design Box-Behenken Design

OPTIMIZATION OF PROCESS PARAMETERS AND VERIFICATION OF THE MODEL

Individual responses such as. Powder yield, redness value, betalain retention were compared using Design expert software (box-behenken design and central composite design). For solving the problem constraints were set in the form of

Minimum and maximum range values for all independent variables (Table 1).

Table 4: Confirmation Report

Confirmation Report

Two-sided Confidence = 95% n = 1

Factor	Name	Level	Low Level	High Level	Std. Dev.	Coding
A	inlet air temper	170.00	160.00	180.00	0.000	Actual
B	maltodextrin ac	10.00	5.00	15.00	0.000	Actual
C	feed flow rate	500.00	400.00	600.00	0.000	Actual

Response	Predicted Mean	Predicted Median1	Observed	Std Dev	n	SE Pred	95% PI low	Data Mean	95% PI high
Powder yield	47.3758	47.3758	-	2.26671	1	2.45	41.83		52.92
lygroscopicity	16.2071	16.2071	-	1.19738	1	1.23	13.59		18.82
ledness value	27.5218	27.5218	-	4.82339	1	5.22	15.72		39.32
etalin retention	64.4481	64.4481	-	1.84005	1	1.89	60.43		68.47

CONCLUSIONS

Different runs for the box-behenken design and central composite design were used, to study the parameters of beetroot juice powder, at various levels of inlet air temperature, of maltodextrin addition rate. The response optimization showed the optimizing conditions, for maximizing redness value, betalin retention and powder yield. Comparative study showed that, the box-behenken design is the more reliable design model with optimizing conditions that could be applied in real time problems.

REFERENCES

1. Tee L. H., Luqmanchuah, Pin k. Y.,2014. Optimiztion of spray drying process parameters of piper betlel. Leaves extract coated with maltodextrin. J. of chemical and pharmaceutical research 4(3):1833-1841.

2. Bindubazaria, p adyuman kumar 2016. Optimization of spray drying parameters for beetroot juice powder using response surface methodology. J. Saudi society of agricultural sciences 148106.

3. Fazaei M., AshtariA. k., Omid M., 2011. Effect of spray drying conditions and feed composition on the physical properties of black mulberry juice powder. Food bioprod. Process. 90. 667-675.

4. Gokhale S. V., Lele, S. S., 2011. Dehydration of red beet root by hot air drying process optimization and mathematical modelling. Food sci. biotechnol.20 (4), 995-964.

5. Lee, S. C., Kim j. H. jeong, S. M., k Kim 2003, Effect of far infrared radiation on the antioxidant activity of rice hulls. Food chem 51, 4400-4403.

6. Nemzer, B., Pictrzkowski, Stalica., wybraine.,2011 Betanic and nutritional profiles of pigment –enriched red beetroot dried extract. Food chem.127, 42-53