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Optimize the process for spray drying of aloe vera (*Aloe barbadensis*) gel

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SUMMARY : Aloe vera drying process experimental design was developed by considering the factors such as inlet drying air temperature, feed rate and maltodextrin per cent with their levels; (153.18-186.82°C), (19.32-22.68 ml/min) and (11.59-28.41 %), respectively. The objectives of present research work was to select the range of operational parameters for spray drying of Aloe vera gel in such a way that by minimizing the changes in moisture content, bulk density and maximizing the yield, overall acceptability of powder, the quality can be improved during drying process. A mathematical model was developed that determines optimum operating conditions by optimizing the above parameters. The response surface method (RSM) with a criteria based on acceptable moisture reduction and quality. Comparison between the experimental and calculated results showed that the mathematical model could predict fairly well. The optimal parameters claimed for the model of optimization to dry the Aloe vera gel with the good characteristics in powder yield, moisture content, bulk density, solubility and overall acceptability were found to be 14.42 per cent, 6.46 per cent, 0.67 g/ml and 7.28, respectively.

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Aloe vera (*Aloe barbadensis* Miller) is a perennial plant of Liliacea. Its name is most likely derived from the Arabic word *Alloeh* meaning shining bitter substance. Aloe vera is a spicy cactus-like, xerophytic plant. It is not a cactus but a member of lily family. It has now been designated as its own family, known as Aloeaceae. The plant has many common names and is often referred to as Aloe vera, burn plant, first aid plant or medicine plant or silent healer.

Aloe vera is known as Ghee-kanwar or Ghi-kuvar in Hindi and has been in use since ages as folk medicine. It grows wildly in Maharashtra, Tamil Nadu states, whereas, Andhra Pradesh, Gujarat and Rajasthan states are known for its cultivation. Major areas of Aloe vera production are Alwar in Rajasthan, Satnapali in Andhra Pradesh, Rapipla in Gujarat and dry areas of Maharashtra and Tamil Nadu. The annual consumption of Aloe vera extract by the Indian pharmaceuticals companies is 200 tones which is met from the wild sources from the states of Maharashtra and Tamil Nadu.

The resulting dried product may be around 598, presented in different forms such as powders, granules or agglomerates, depending upon the physical and chemical properties of the feed and dryer design and operation (Andrade and Flores, 2004). Each foodstuff has powder requirements to be met during manufacture (Master, 1991). The advantages of spray drying as a continuous and economic process allowing the production of good quality powders is established. (Pérez and Farías,1995) From this point of view, the present study was carried out with following objective.

– Standardize the processing conditions for quality Aloe vera gel powder and study the effect of inlet temperature and maltodextrin concentration on yield, moisture content, bulk density and overall acceptability of Aloe vera gel powder at feed flow rate 21 ml/min.

EXPERIMENTAL METHODS

Standardization of process for the preparation of Aloe vera gel powder was done by spray dried in a LSD 48 mini spray dryer (JISL), as per the methods outlined by Banga and Singh (1994), The inlet temperatures, Flow rate were maintained 160-180°C and 20–22 ml/min, respectively with maltodextrin of 15-25 per cent. This

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methodology allows the modeling of second order term and the interaction terms as indicated equation- 1 *(Al-Kahtani and Hassan, 1990).*

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum \beta_{ij} x_i^2 + \sum\sum_{i<j} \beta_{ij} x_i x_j + \in \quad (1)$$

The term "*y*" is the measured response variable, and the optimization it was analyzed by multiple regression employment of response surface methodology (RSM). The RSM analysis was made through pure error method to fit the equation (1) in the statistical program (Box *et al.*,1978). The parameters of the mathematical model were estimated and used to predict the curve generated by the model and the variance analyses Table (ANOVA).

Aloe vera
↓
Scooping of pulp manually

↓ **Peel (skin)**
Blending for homogenization
↓
Weighing
↓
Adding of binding agent maltodextrin
↓
Staining through muslin cloth and addition of distilled water to adjust TSS
↓
Spray drying
(Through laboratory scale mini spray dryer at varying inlet temperature, feed rate and maltodextrin per cent)
↓
Collection of powder
↓
Packaging and storage

Flow sheet 1 : Standardize the process for the preparation of Aloe vera gel powder

Table A : The level of different process variables and responses in coded form for spray drying of Aloe vera gel powder

Independent variables	Units	levels					
		Coded	- 2	-1	0	1	+ 2
Feed flow rate	ml/hr	x_1	-1.68	20	21	22	+0.68
Maltodextrin concentration	%	x_2	-3.41	10	15	25	+3.41
Inlet air temperature	°C	x_3	-6.82	160	170	180	+6.82
Response variables						Symbols	
Yield	g/lit					Y_1	
Moisture content	%					Y_2	
Bulk density	g/ml					Y_3	
Solublity	Sec					Y_4	
Overall acceptability	1-9					Y_5	

Table B : Optimization of the process for formulation of Aloe vera gel powder

Run	Coded levels		
Sr. No.	X_1	x_2	x_3
1	0	-2	0
2	+1	-1	-1
3	-1	-1	-1
4	0	+2	0
5	0	0	0
6	-2	0	0
7	-1	+1	+1
8	+1	-1	+1
9	+2	0	0
10	0	0	-2
11	-1	-1	+1
12	+1	+1	-1
13	0	0	0
14	-1	+1	-1
15	0	0	0
16	0	0	0
17	0	0	+2
18	0	0	0
19	+1	+1	+1
20	0	0	0

EXPERIMENTAL FINDINGS AND ANALYSIS

The model obtained from regression analysis for lateral expansion in terms of coded levels of the variables was developed as follows:

Yield (Y_1) :

Y_1= +439.68989 -3.2762* X_1+5.09918* X_2 -18.58398* X_3 +7.85000E-003* X_1* X_2 +0.14575*X_1*X_3-0.30250*X_2*X_3.

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% Moisture content (Y_2) :

Y_2= +2.49667 -3.89417E-003* X_1-8.72034E-003* X_2 +0.22832* X_3

Bulk density (Y_3) :

Y_3=+52.53390-0.35781*X_1+0.11504*X_2-2.18586*X_3-7.15000E-004*X_1*X_2+8.07500E-003*X_1*X_3-1.30000E-003*X_2*X_3+5.99331E-004*X_1^2+8.84115E-004*$X_2^2$0.020335*X_3^2.

Solubility (Y_4) :

Y_4=+50.15009+0.58378*X_1-0.15111*X_2+1.30136*X_3

Overall acceptability (Y_5) :

Y_5 = -73.18762+0.79563 * X_1-3.29687* X_2+4.33297* X_3+4.02500E-003*X_1*2+3.12500E-003*X_1*X_3+0.10775* X_2* X_3-2.69728E-003* X_1^2+8.65631E-003* X_2^2-0.17073* X_3^2.

The Aloe vera gel powder can be successfully prepared by deciding an adequate combination of inlet temperature and feed rate. The most effective parameters during spray drying of Aloe vera gel were maltodextrin concentration as binding agent. The preliminary trials show that the Aloe vera gel powder with desirable quality can be obtained in the range of 160 to 180°C of inlet air temperature, 20 to 21 ml/min of feed flow rate, 15-25 per cent concentration of maltodextrin. Response surface methodology (RSM) is a useful technique for studying the effect of several process variables and optimization of process variables on the basis of various quality parameters of Aloe vera gel powder.

For the determination of optimal level of three variables *viz.,* inlet air temperature, feed flow rate and maltodextrin concentration response surface approach was applied by using a set of experimental design having three independent variables at five levels each. The low and high levels of inlet air temperature, feed flow rate and

Table 1 : Central composite rotatable design with experimental values of response variables

Run	Independent variables			Dependent variables				
Sr. No.	Inlet temp. (°C)	Maltodextrin (%)	Feed flow (ml/min)	Yield (%) (g/lit)	M. C. (%) (w.b.)	Bulk density (g/ml)	Solublity (Sec)	Overall acceptablity (1-9)
CODE	x_1	x_2	x_3	Y_1	Y_2	Y_3	Y_4	Y_5
1.	0	-2	0	15.32	6.1	0.592	169	8.02
2.	+1	-1	-1	9.76	6	0.769	175	8.12
3.	-1	-1	-1	15.23	6.8	0.687	174	8.01
4.	0	+2	0	15.31	6.4	0.737	170	8.01
5.	0	0	0	12.46	6.8	0.519	175	6.97
6.	-2	0	0	15.32	6.2	0.814	164	5.98
7.	-1	+1	+1	13.41	6.4	0.519	175	6.97
8.	+1	-1	+1	17.44	6.9	0.806	184	6.3
9.	+2	0	0	11.81	6.3	0.729	190	7.3
10.	0	0	-2	15.24	6	0.547	158	6.92
11.	-1	-1	+1	14.58	6.5	0.589	165	6.64
12.	+1	+1	-1	16.21	6	0.582	180	7.1
13.	0	0	0	9.7	6.6	0.501	190	7.1
14.	-1	+1	-1	17.61	6.3	0.831	160	6.76
15.	0	0	0	12.21	6.8	0.637	169	7.43
16.	0	0	0	15.12	6.5	0.667	190	7.96
17.	0	0	+2	15.24	7.2	0.772	165	6.92
18.	0	0	0	15.34	6.7	0.611	180	7.98
19.	+1	+1	+1	15.34	6.4	0.781	171	8.01
20.	0	0	0	15.8	6.2	0.644	170	7.2

Table 2 : Model Statistics and ANOVA for the selected responses

	Response				
Term	Yield (%)	M. C. (%)	Bulk density (g/ml)	Solublity (Sec)	Overall acceptablity (1-9)
Model	2FI	Linear	Quadratic	Linear	Quadratic
F Value	1.98	2.95	1.50	2.12	4.35
P>F	0.1421	0.0642	0.2682	0.1381	0.0156
Mean	14.42	6.46	0.67	173.70	7.28
Standard Deviation	1.92	0.29	0.097	8.84	0.40
R Squared	0.4775	0.3562	0.5743	0.2842	0.7965
Adj. R Squared	0.2363	0.2355	0.1911	0.1500	0.6133

maltodextrin concentration were selected as 150 to 170°C, 200 to 300 ml/hr, 10 to 20 per cent, respectively. Twenty experiments were augmented with six replications at the center points to evaluate the error.

Performance of the process was evaluated analyzing the responses, which were yield (%), moisture content, bulk density, solubility and overall acceptability. The optimization of process was aimed at finding the optimum levels of independent variables *viz.,* inlet air temperature, Feed flow rate and maltodextrin concentration that would give maximum possible per cent yield, solubility and overall acceptability while minimum possible moisture content, bulk density.

The maltodextrin level at 20 per cent had maximum positive effect followed by inlet air temperature 170°C and feed flow rate 21 ml/min which indicates that as feed flow and lowering inlet air temperature increses ,process yield also increses (14.38) in Fig. 1.

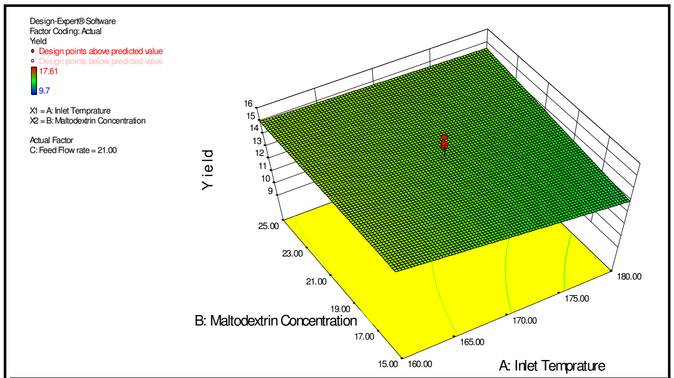

Fig. 1 : Response surface showing the maltodextrin and inlet temperature at feed flow 21 ml/min on yield in powder of Aloe vera

The air inlet temperature (170°C) incresed with the decrease in moisture content. An increase in feed flow rate (22 ml/min) led to increase in moisture content of the final product.There was decrease in moisture content with

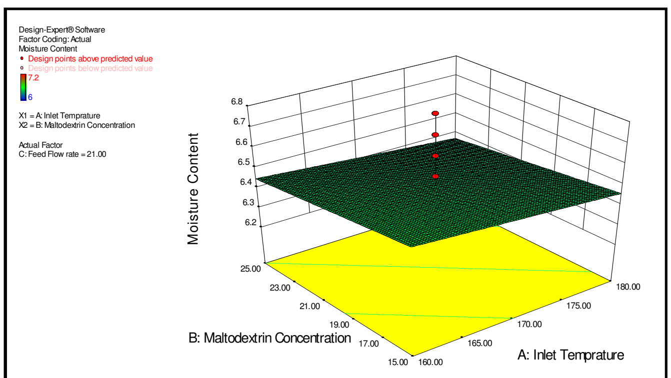

Fig. 2 : Response surface showing the maltodextrin and inlet temperature at feed flow 21 ml/min on moisture content in powder of Aloe vera

increase (6.41) in inlet air temperature and maltodextrin (20%) concentration while there was increase in moisture content of Aloe vera gel powder with increase in feed flow rate. The feed flow rate negatively affected powders moisture content. Higher flow rates imply in a shorter contact time between the feed and the drying air, making the heat transfer less efficient and resulting in lower water evaporation. It is also observed that the powders moisture content increased with increasing feed pump flow rate and with decreasing inlet air temperature, and the effect of temperature was greater than the effect of pump flow rate.

The positive effect of inlet air temperature on bulk density was governed by moisture content (Fig. 3). Increase in inlet temperature (170°C) caused a reduction in bulk density(0.41), as evaporation rates are faster and products dry to a more porous structure of Aloe vera gel powder, inlet air temperature and maltodextrin at 20 per cent concentration and feed flow rate, it was observed that bulk density of Aloe vera gel powder increased (0.67) with increase inlet air temperature and maltodextrin concentration while it showed insignificant effect of feed flow rate.

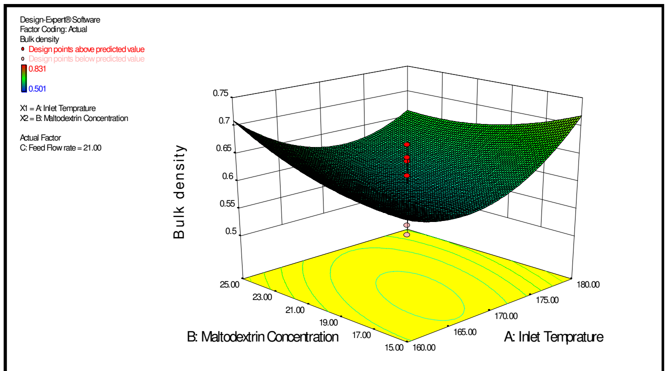

Fig. 3 : Response surface showing the maltodextrin and inlet temperature at feed flow 21 ml/min on bulk density in powder of Aloe vera

Increase in inlet air temperature (170°C) and maltodextrin percentage, there was increase in solubility of spray dried Aloe vera gel powder. The solubility is a function of effective moisture content of the finished powder coupled with low moisture content responsible for fast dissolution. An increase in feed flow rate resulted in a decrease in solubility time associated with increased moisture content of the powder. Solubility time of the powder increased with an increase in inlet temperature. This may be due to the effect of inlet temperature on residual moisture content (Fig. 4). Lower the moisture content higher is the solubility of the powder. Increase in inlet temperature during drying process results in increased

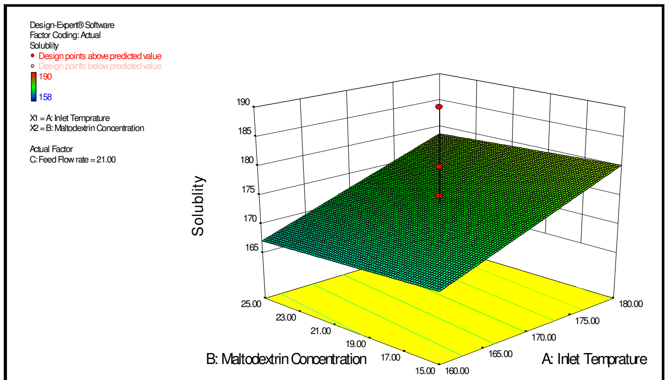

Fig. 4 : Response surface showing the maltodextrin and inlet temperature at feed flow 21 ml/min on solubility in powder of Aloe vera

particle size subsequently helps in reducing the time to dissolve.

The Maltodextrin concentration was the variable that most affected powders overall acceptability by the judges followed by Feed flow rate and Inlet air temperature (Fig. 5). This denotes that overall acceptability of Aloe vera gel powder decreased with increase in maltodextrin concentration. This might be due to degradation of colour and flavour of powder with increase in maltodextrin concentration, interaction effect of 'Inlet air temperature and feed flow rate' and 'inlet air temperature and maltodextrin percentage which showed the significant result. The equation of the model fitted for overall acceptability the actual form of process variables after eliminating the non-significant co efficient. Further, with increase in maltodextrin concentration powder becomes more sweet which hamper its natural taste.

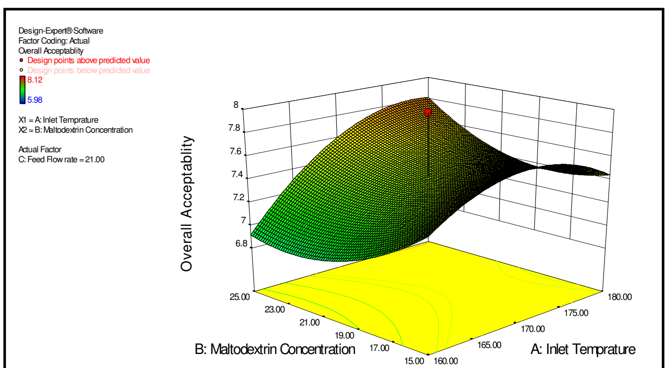

Fig. 5 : Response surface showing the maltodextrin and inlet temperature at feed flow 21 ml/min on overall acceptability in powder of Aloe vera

Conclusion:

The experimental evaluation by spray drying results obtained for acceptable quality of Aloe vera gel powder with the inlet temperature, feed flow rate and per cent maltodextrin for their conservation, the spray drying should be managed according to the following operation range: Temperature 153.18 - 186.82°C, flow of feeding 19.32 - 22.68 ml/min and maltodextrin 11.59 - 28.41 per cent. This characteristic solves the problem of stickiness in the drying chamber. The good operational characteristics were obtained by means of the method of response surface (RSM). Overall acceptability of the powder (7.39) which is having good yield of 14.42 per cent the relative moisture content, bulk density and solubility in the powder were 6.46 per cent, 0.67 g/ml and 173.70 sec, respectively. Further studies are needed to establish the changes that are likely to modify and or alter the original compounds due to the spray drying process of Aloe vera gel which will help the industrialist to draw definite conclusions.

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