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Optimization of Coating Process Parameters by Design of Experiment (DOE)

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Abstract: The purpose of this research work was to study the suitability of natural colours in film coating of ayurvedic tablets on laboratory scale with side-vented perforated pan-coating apparatus. The film coating of tablet is an essential unit operation to impart the elegance and appearance along with the tablet protection against the environmental conditions. Results of preliminary trials indicate that inlet air temperature, atomizing air pressure; spray rate affected a lot the characteristics of film coating. Critical coating parameters like atomizing air pressure(x_1), spray rate (x_2) and inlet air temperature(x_3) were optimized by using 2^3 full factorial designs, Design Expert version software(DOE). Factorial design was employed to study the effect of independent variables atomizing air pressure, spray rate and Inlet air temperature on dependant variables like Surface Roughness, Coating Process Efficiency (R_1) and Coating Uniformity (R_2). The best batch exhibited spray rate of coating solution 10 gm/min, inlet air temperature 50°C, atomizing air pressure 2.0 Kg. /cm^2 for CUR-coated and for Ac-CUR coated the spray rate of coating solution 8 gm/min, inlet air temperature 30°C, atomizing air pressure 1.0 Kg./cm^2 . Thus, the coating process parameter optimization was done to set the coating parameters for coating of any strength of tablet batch.
Keywords: Factorial design, inlet air temperature, atomizing air pressure, Optimization, Coating process efficiency, Coating Uniformity.
Abbr.: TGA- Triphala gugglu ayurvedic, CU –Coating Uniformity, CPE-Coating process efficiency CUR- Curcumin, Ac-CUR- Acetylated curcumin.

Introduction

The application of coatings to pharmaceutical solids offers many benefits namely, improving aesthetic qualities of dosage forms, masking unpleasant odour or taste, easy ingestion, improving product stability and modifying release characteristics of the drug [1,2]. By applying the film coating, the tablets become strong enough to withstand the handling / transportation stress and also become less sensitive to the atmospheric variations like exposure to oxygen, light etc [3] Film coating is multivariate process with many different factors such as coating equipment process conditions, composition of the core tablets and coating solutions which affect the pharmaceuticals quality of final product [4, 5, 6]. The coloring stage is one of the most critical parts of the operation. It gives the tablets its color and in some cases it's finished its size. Here success measured in terms of the elegance of the final color coated tablets. Before the 1950s, traditional color coating for solid dosage forms was usually performed using soluble dyes as the prime colorant. This system produces the most elegant tablet. However, many difficulties arise usually related to the dye being soluble, color migration other colouring of tablets and many smoothing coats are needed before any color can be applied. Care must be taken to ensure that the tablets do not become over colored [7,8]. Late in the 1950s, the pigment sugar-coating process was developed. Now a days film coating is in use. Some coating process parameters such as coating equipment, process conditions, composition of the core tablet and coating liquid affect the final product quality of coated tablets. So it is necessary to optimize the coating process [9,10]. Inlet air temperature and atomizing air pressure greatly affects the surface property of coated tablets. The spray rate is an important parameter which affects the moisture content of the formed film and subsequently, the quality and uniformity of the film. The inlet air temperature affects the drying efficiency (i.e. water evaporation) of the coating pan and the uniformity of coating [11]. Thus in the present work optimization of the coating process parameters by 2^3 full factorial design has been carried out by using natural colorants extracted from *Curcuma longa* in film coating of TGA tablets. The previous work of Goel et al shows that the tablets coated with turmeric extract, turmeric dye, and curcumin are realy unstable at environmental condition as well as in stability chamber [12,13]. The acetylation of the curcumin was carried out to increase its stability and also used in the coating of tablets. The combined effect of these parameters were studied by Design of Experiment (DOE).

The methodology of Design of Experiment (DOE) ensures that all factors and their interactions are systematically investigated, thus, information obtained from a DOE analysis is much more reliable and complete than results from one factor at a time experiments that ignore interactions and may lead to misleading conclusions [14]. DOE has been used to improve the understanding of the relationship between product and process parameters and the desired performance characteristics such as in the coating process. The identification of critical process variables for coating actives on to tablets was performed via statistically designed experiments[15].

Material and Method

The instacoat powder (ready mix coating powder, Ideal cure Pvt. Ltd. Delhi), was obtained as free sample from Divya Yog Pharmacy, Haridwar. Natural colors were extracted from *Curcuma longa L* in lab scale. TGA uncoated tablets were also obtained as free sample from Divya Yog Pharmacy, Hardwar. The coatings were applied on laboratory scale in a Pan Coating Apparatus (Harrison Pharma Pvt Ltd.). A high Shear Mixer (Remi Equipments Pvt. Ltd) was used to make the coating solution. All chemicals used were of analytical grade and double distilled water was used throughout the analysis.

Preparation of coating solution:

Required quantity (3% weight gain) of instacoat powder (10 gm) was added in water and IPA (60: 40). The mixture was taken into solution suitable vessel with high shear mixer at a speed of 250-300 rpm for 20-30 min. The use of alcohol/water solvents also allowed for relatively fast coating [16]. Stir the above mixture to form a vortex without entrapment of air in to the liquid. Now add 2.0-2.5% colorant extracted with continuous stirring till all colorant get mixed properly. Then this solution was filtered through 100 mesh sieve and used for coating.

Coating Process:

Tablet coating was performed in a conventional coating pan, with one spray gun. The coating pan was previously cleaned using alcohol 95%. A batch size of 1/2 kg of triphala guggle core tablets was selected for coating. The core tablets were loaded into the coating pan. Tablet cores were pre-heated to about 40°C utilizing a dryer and air compressor. Warm air was introduced into the coating pan (up to 35–40°C) during the entire coating process. All process parameter were adjusted before coating. First 3.2% of TiO_2 is used for base coating of tablets, and then the spray gun was filled with colour coating solution and operated at a proper flow rate. The tablets were blow dried for 20-25minutes in the coating pan. The core tablets gained around 3% weight. After coating of tablets these were evaluated for their organoleptic and physico-chemical parameters**.** Many factors such as coating equipment, coating liquid, and coating process parameters affect the pharmaceutical quality of final coating [17].

Optimization of Coating Process Parameters:

In film coating of TGA tablets the optimization of spray rate (gm/min), inlet air temperature (^{O}C), atomizing air pressure (bar), rotating speed of pan (rpm) and distance from tablet bed to spray gun, were carried out as follows-

(1) **Optimization of inlet air temperature**:

Coating was performed at different inlet air temperature 30, 40,50,60,70^{0}C at constant spray rate (12ml/min), atomizing air pressure (2 kg/cm^2), and pan speed (8 rpm) and, distance of nozzle from tablet bed (12 cm). The inlet air temperature was optimized for weight gain, CPE, % LOD & surface roughness.

(2) Optimization of spray rate:

To study the effect of spray rate of coating solution, coating was performed at different spray rate of 4,8,10,12,16 ml/ min at constant inlet air temperature (50^0C), atomizing air pressure (2kg/cm^2), pan speed (8 rpm), distance of nozzle from tablet bed (12 cm). The spray rate was optimized for weight gain, CPE, % LOD & surface roughness. Where inlet air temperature (50^0C) was previously optimized.

(3) Optimization of atomizing air pressure:

To set the atomizing air pressure coating was performed at different atomizing air pressure 1.0, 1.5, 2.0, 2.5, 3.0kg/cm^2 at constant spray rate of (10ml/min), inlet air temperature (50^0C), pan speed (8 rpm), and distance of nozzle from tablet bed (12 cm). The atomizing air pressure was optimized for weight gain, CPE, % LOD & surface roughness. where spray rate of 10 ml/min and inlet air temperature (50^0C).

(4) Optimization of rotating speed of pan:

To optimize the rotating speed of pan, coating was performed at different rotating speed of pan like 5, 10,15,20 at constant spray rate (10ml/min), atomizing air pressure (2 bar), inlet air temperature (50^0C) and distance of nozzle from tablet bed (12 cm). The rotating speed of pan was optimized for weight gain, CPE, % LOD & surface roughness where, inlet air temperature of 50^0C, at spray rate of 10 ml/min, atomizing air pressure of 2 bars.

(5) Optimization of distance between nozzle and tablet bed:

The distance between tablet bed and spray gun(nozzle) of 8, 12, 16,20cm at constant spray rate (10ml/min), atomizing air pressure (2 bar), inlet air temperature (50^0c), rotating speed of pan (10cm) was varied to optimized the distance between nozzle and tablet bed for weight gain, CPE, % LOD & surface roughness. where spray rate of 10 ml/min, atomizing air pressure (2 bar) inlet air temperature (50^0C) and rotating speed of pan (10 cm) were optimized as above [18].

Optimization by Factorial Design:

Analysis of variance of coefficients of regression equation was carried out using **Design expert software-7.0.0.1**. On the basis of the preliminary trials a 2^3 full factorial design was employed to study the effect of independent variables; inlet air temperature (X_1), spray rate (X_2) and speed of pan rotation (X_3) on responses such as % weight gain (Standard Deviation) and Coating process efficiency (CPE) as dependent variables. A statistical model incorporating interactive and polynomial terms was used to evaluate the responses,

$$Y=b_0+b_1X_1+b_2X_2+b_3X_3+ b_{12}X_1X_2+ b_{13}X_1X_3+ b_{23}X_2X_3$$

where,
Y is the dependent variable,
b_0 is the arithmetic mean response of the 8 runs, and
b_i is the estimated coefficient for the factor X_i.

Results and Discussion:

The TGA tablets were film coated with Instacoat readymix coating material with colorant extracted from *Curcuma longa L*, in the suitable ratio of water and Isopropyl alcohol (60:40). The film formed with this formulation is free from major defects like cracking, orange peel, picking with good gloss and very slight chipping and spilliting occasionally [19,20]. Uniformity in tablet weight gain and thickness of the film coat data obtained from film measurements are supportive for elegant film formation. This preliminary study infers that many factors significantly influence the quality of film coats. The results of some coating process parameters are as follows.

Optimization of Inlet air temperature:

From the results shown in **Table-01**. It is clear that temperature plays an important role in coating of ayurvedic tablets. Sticking and picking seen in the coating at 30^0C inlet air temperature because solvent was not evaporated from tablet surface totally and tablets stuck to each other and also at the walls of pan, while when inlet air temperature was 70^{0}C, the nozzle blocks because at high temperature coating solution get dried very quickly. At 40^{0}C and 60^{0}C inlet air temperature, CPE and surface roughness of coating was decreased because at 60^{0}C more particles were dried in the air and at 40^{0}c particles pass from tablet to pan. Thus it can be concluded that the inlet air temperature has an important role during coating and has to be optimized. From the data it was observed that 50^{0}C temperature was optimum because it shows good coating process efficiency as well as surface roughness. Hence it can be concluded that 50^{0}C inlet air temperature is optimum and has been kept constant in optimization of other parameters [21, 22,23].

Table-01. Optimization of Inlet air temperature

Batch No.	Inlet air temperature (^{0}C)	CU(mg)	CPE%	Surface roughness	% LOD	Problem during coating
1.	30	3.25	82.05	-	4.63	Stiking& picking
2.	40	2.98	87.37	-	3.29	**O.K**
3.	50	3.19	94.67	+	2.49	**O.K**
4.	60	2.56	87.92	-	1.99	White spot
5.	70	3.01	86.11	-	1.81	Nozzel block

Table-02. Optimization of spray rate

Batch No.	Spray rate (ml/min)	C.U(mg)	CPE (%)	Surface roughness	% LOD	Problems during coating
1.	4	3.21	79.89	-	2.19	Rough surface
2.	8	3.14	89.48	+	**2.64**	O.K
3.	10	3.19	90.036	+	**2.83**	O.K
4.	12	3.13	83.16	-	**3.27**	White spot
5.	16	3.21	76.13	-	**4.52**	Sticking &picking

Optimization of spray rate:

For optimization of spray rate of coating solution, it was varied from 4 -20 ml/min. It is clear from the data presented in **Table-02** when spray rate was 16 and 20 ml/ min, sticking and picking were seen on coated tablets, because at higher spray rate the moisture of the tablet surface increased due to smaller proportional magnitude of drying. The drying of coating solution was prolonged and subsequently the surface was rougher. At low spray rate 4-8 ml/min coating process efficiency was lower because the particles were dried between the paths before reaching the tablet bed, which also results into the rougher surface. Data also show when spray rate was increased the % LOD was increased. At 10 ml/min spray rate the CPE, surface roughness and other parameter values were appropriate. Hence it can be concluded that 10 ml/min was used for coating the tablets [24,25].

Optimization of atomizing air pressure:

Table-03. Optimization of Atomizing air pressure

Batch No.	Atomizing air pressure (Bar)	CU (mg)	CPE%	Surface roughness	% LOD	Problems during coating
1.	1.0	3.51	78.24	-	4.64	Sticking &picking
2.	1.5	3.29	84.89	-	3.94	O.K
3.	2.0	3.00	90.03	+	2.90	O.K
4.	2.5	3.12	70.75	-	2.43	O.K
5.	3.0	3.33	64.07	-	1.92	Cracks Dust formation

From the data presented in **Table-03** it was noted that at higher atomizing air pressure 3.0 bar small droplets of coating solution were formed and particles were dried before reaching to the tablet bed which causes excess dust in the pan and make the surface rough and low coating process efficiency. At low atomizing air pressure 1.0 bar big droplets of coating material were formed, allowing water to penetrate into the tablet core causing sticking and picking and low coating process efficiency. Maximum coating efficiency, surface roughness and minimum % LOD was observed at 2 bar pressure. Hence, it was concluded that 2 bar atomizing air pressure was optimum and kept constant in optimization of other parameters [26-27].

Optimization of rotating speed of pan:

Table-04. Optimization of Pan speed

Sample No.	Pan speed (rpm)	Wt. gain (mg)	CPE (%)	Surface roughness	LOD (%)	Problems during coating
1	5	3.65	75.44	-	2.17	White spot
2	10	3.05	89.37	+	2.90	O.K
3	15	2.98	87.65	-	3.32	O.K
4	20	3.61	81.92	-	3.59	Sticking

Rotating speed of pan mainly affects the coating uniformity of tablets. As shown in **Table-04**, it was observed that with the increase of the pan speed, coating uniformity was increased, which meant that standard deviation decreased (variation in tablet weight decreased). Higher rotating speed of the pan improves the mixing of the tablets and distribution of the coating solution onto the tablet bed. This results in reduced thickness variation and improves the uniformity of the coating. But at very high rotating speed of pan friability problems were seen because of excessive attrition and breakage. Thus, it was concluded that 10 rpm pan speed is optimum and was utilized for further studies [28-29].

Optimization of distance between tablet bed and spray gun:

Table-05. Optimization of distance from Nozzel (spray gun) to bed temperature

Batch No.	Pan speed (rpm)	CU(mg)	CPE (%)	Surface roughness	% LOD	Problem during coating
1.	8	3.78	81.75	-	5.68	Sticking
2.	12	3.27	80.75	+	4.23	O.K
3.	16	2.40	87.54	+	3.21	O.K
4.	20	2.15	84.89	+	5.36	Rough
5,	22	2.05	79.50	-	5.98	Spot formation

Results presented in **Table 05** show that at low distance of 8.0cm between tablet bed and spray gun, the sticking and picking was observed on tablet surface because more solution was sprayed at tablet. On the other hand at high distance (20 & 22 cm) unsatisfactory coating was observed because solution gets evaporated before reaching tablet surface. Thus both high and low distance between tablet bed & spray gun affects CPE & weight gain. Good CPE, weight gain and surface were obtained at a distance of 16cm which was chosen as optimum [30]. Thus spray rate (10 ml/min), atomization air pressure (2.0 kg/cm^2), distance of nozzle from tablet bed (16cm), inlet air temperature (50^{0}C) and pan speed (10 RPM) were found optimum. The values are presented in **Table- 06**, used with CUR, and Ac- CUR tablet coating.

Table-06, Final Process parameter for Coated tablet		
S.N	**Process parameter**	**Specification**
1.	Equipment	Harrison Pharma coating pan
2.	Substrate	500 gm TGA tablets
3.	Solvent	Water/IPA (60:40)
4.	No. of spray gun	01
5.	Pan speed	10rpm
6.	Inlet air temperature	50^0c
7.	Exhaust air temperate	40^0c
8.	Bed temperature	35-40^0c
9.	Spray rate	10ml/min
10.	Distance between spray gun and Tablet bed	15 cm.
11.	Atomizing air pressure	2.0 bar

Optimization of atomizing air pressure, Inlet air temperature and spray rate by using 2^3 factorial design:

The tablets were coated in side vented perforated pan coater. Process parameters were kept as specified in table. On the basis of preliminary trials, a 2^3 full factorial design was employed to study the combined effect of independent variables [inlet air temperature (X_1), atomizing air pressure(X_2), and spray rate(X_3)] on dependent variables % weight gain (S.D) and coating process efficiency (CPE) of the film coating of TGA using curcumin, acetylated curcumin to give yellow color to tablet coatings.

Independent variables:

Inlet air temperature (X_1), Atomizing air pressure (X_2), Spray rate(X_3)

Dependant variables:

Weight gain(S.D) and coating process efficiency (CPE).

Three levels:

(-1,0,+1) Coating parameters showed in Table and Trial bathches with evaluation with shown in table.

(1)2^3 level full factorial analysis of TGA-CUR tablets:

Effect analysis of dependent variables:

Figure 1.01 shows that the factor X_2 (atomizing air pressure) and X_3 (Spray rate) are significantly controlling the % weight gain (SD), which is represented by point B and point C respectively in half-normal probability plot and also **Figure 1.02** shows that the factor X_3 (spray rate) and X_1 X_3 shows significant effect on the coating process efficiency (CPE) which is represented by point C and AC, respectively in half-normal probability plot. Surface roughness plot and contour plot (**Figure 1.03 and1.04)** depicts that the decrease in spray rate and increase in atomizing air pressure results in decrease in weight gain, In case of decreases in inlet air temperature (^{0}C) and a spray rate at constant atomizing air pressure favours the CPE. (**Figure 1.05 and 1.06**).

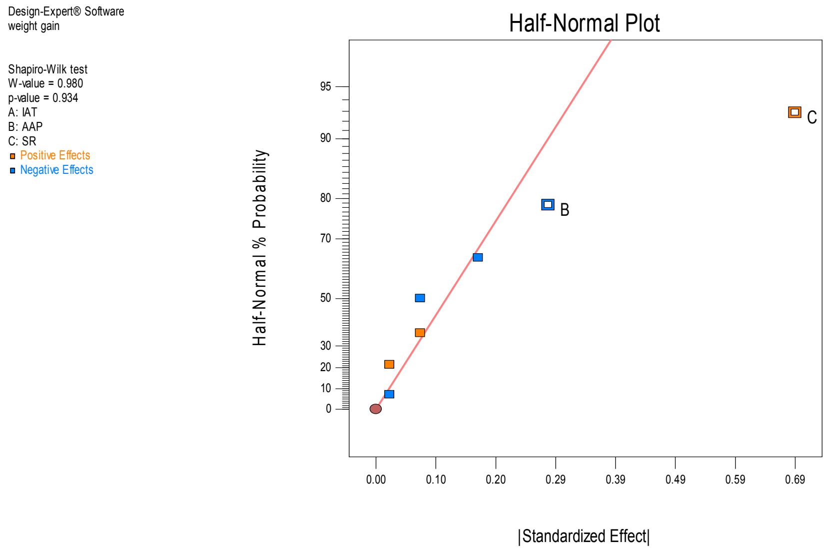

Figure-1.01, Half normal plot of Weight gain (mg) of TGA tablets coated with Curcumin

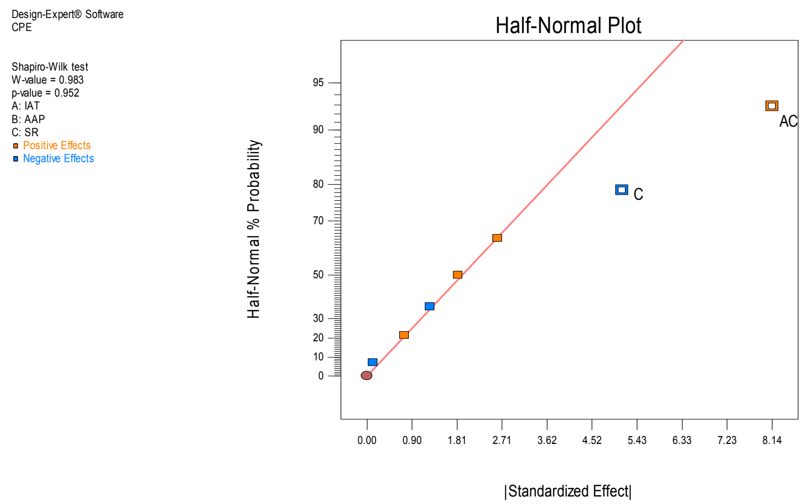

Figure-1.02, Half normal plot of Coating process efficiency (%) of TGA tablets coated with Curcumin

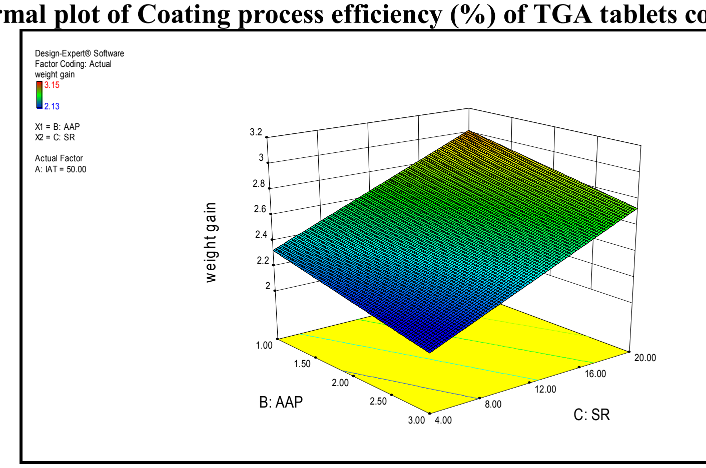

Figure-1.03, Response surface plot of Weight gain (mg) of of TGA tablets coated with Curcumin

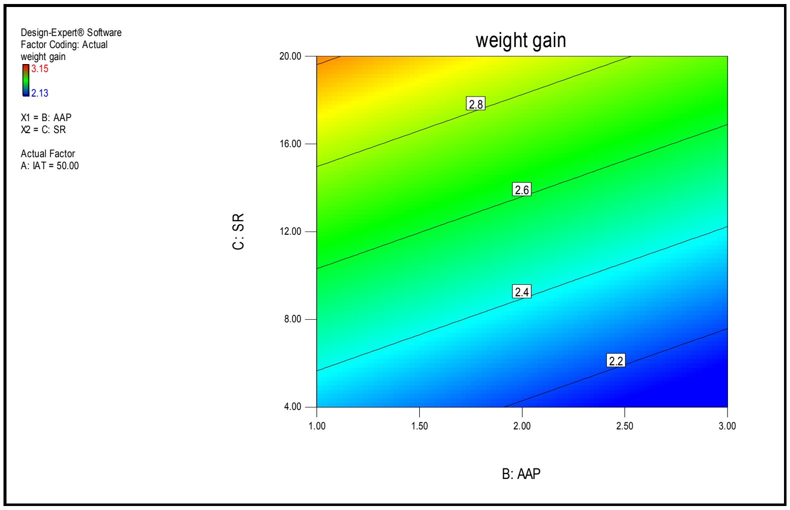

Figure-1.04, Contour plot of Weight gain (mg) of TGA tablets coated with of Curcumin

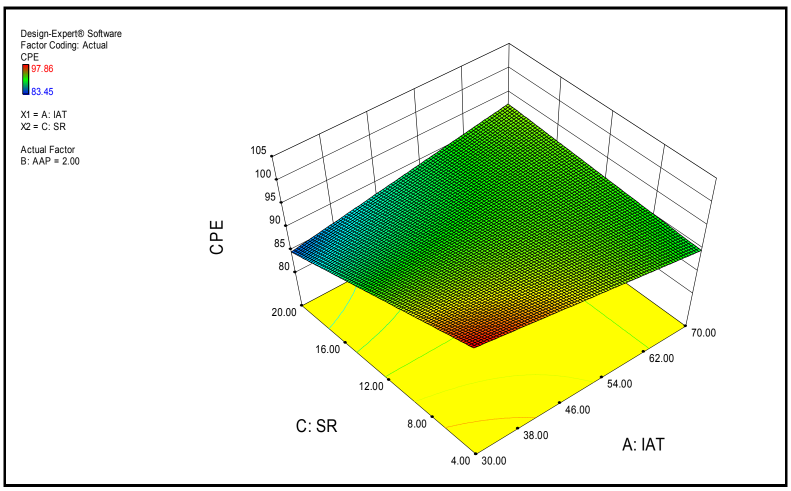

Figure-1. 05, Response surface plot of Coating process efficiency (%) of of TGA tablets coated with Curcumin

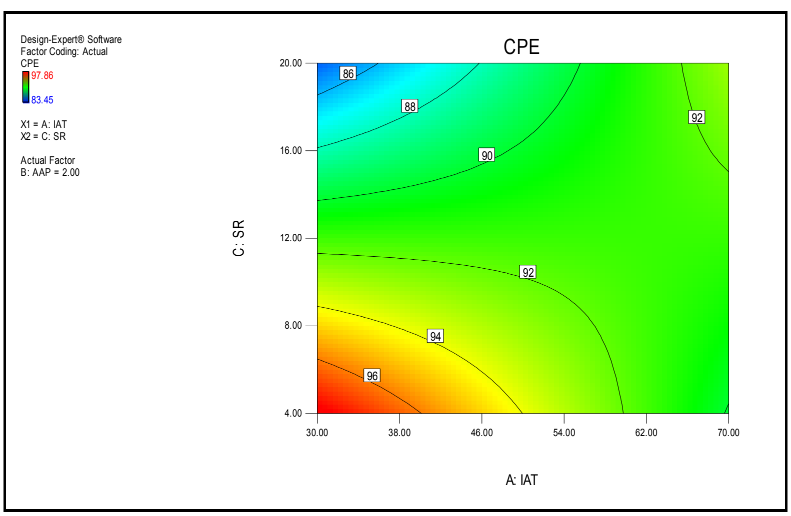

Figure-1.06, Contour plot of Coating process efficiency (%) of of TGA tablets coated with Curcumin

Model assessment for % weight gain:

Table – 7.01					
Annova analysis of weight gain of TGA tablets coated with Curcumin					
Source	**SS**	**df**	**MS**	**F-value**	**p-value Prob>F**
Model	1.10	2	0.55	34.89	0.0012
Residual	0.079	5	0.016		
Cor Total	1.18	7			

The coating uniformity for coated tablet varied from 2.13 to 3.15 **Table- 07.** The polynomial equation can be used to draw conclusions considering the magnitude of coefficient and the mathematical sign it carries as positive or negative. The fit summary was applied to data, in that Response surface single factorial model had been analyzed with the correlation coefficient (R^2=0.9331) and *p*-value with 0.0012($p<0.05$) in **table 7.01**. So, Model polynomial equation in coded terms,

Weight gain (SD) = + 2.53 – 0.14*X_2 + 0.34 *X_3.. (1)

Results of the equation indicate that the effect of X_2 (Atomizing air pressure) is more significant than X_1 (Inlet air temperature) and X_3 (spray rate). In the above equation, the negative coefficient of factor X_2 shows that as its value increases the response weight gain(SD) get decreases, which is required.

Model assessment for coating process efficiency :

Table- 07, 2^3 full factorial design layout for Curcumin					
Sample No.	**Variable level in coded form**			**Weight gain (mg)**	**Coating process efficiency** (%)
	X_1	**X_2**	**X_3**	**R1**	**R2**
1	-1	-1	-1	2.34	95.63
2	-1	1	-1	2.13	97.86
3	-1	-1	1	3.05	83.45
4	-1	1	1	2.65	83.52
5	1	-1	-1	2.15	93.21
6	1	1	-1	2.13	89.25
7	1	-1	1	3.15	93.65
8	1	1	1	2.65	94.84

Translation of coded level in actual values

Levels of variables	**X_1 Inlet air temperature(^{O}C)**	**X_2 Atomizing air pressure(kg/cm^2)**	**X_3 Spray Rate (ml/min)**
Low (-1)	**30**	**1**	**4**
High(1)	**70**	**3**	**20**

Table – 7.02					
ANOVAs analysis of Coating process efficiency of TGA tablets coated with Curcumin					
Source	**SS**	**Df**	**MS**	**F-value**	**p-value Prob>F**
Model	184.92	2	92.46	18.65	0.0048
Residual	24.79	5	4.96		
Total	209.71	7			

Coating process efficiency(CPE) = + 91.43 - 2.56 * X_3 + 4.07 * X_1* X_3 ....(2)

2^3 level full factorial analysis of TGA-Ac.CUR tablets:

Coating process efficiency (CPE) is a measure of the actual amount of coating applied to the tablets relative to the theoretical quantity of coating applied. It can therefore be another indicator of over wetting or over drying. The coating process efficiency of coated tablets varied from 83.45 to 97.86% as show in **Table-07** which shows that with correlation coefficient (R^2 = 0.8818). Results of the equation indicate that the effect of X_3 (spray rate) has significant effect than X_2 (atomizing air pressure). Moreover, spray rate had a negative effect on coating process efficiency (i.e. spray rate increased, the coating process efficiency decreased. This might be due to at high spray rate water got in excess for a results sticking and picking observed and finally CPE decreases. The linear model generated for coating process efficiency was found to be significant with a *p*-value of 0.0172 ($p<0.05$) from **table 7.02.**

Effect analysis of dependent variables:

Figure -2.01 shows that the factor X_2 (Atomizing air pressure) and X_1X_3 is significantly controlling the % weight gain (SD), which is represented by point B in half-normal probability plot. In the same way the factor X_1 (Inlet air temperature) and X_2 (Atomizing air pressure) shows significant effect on the coating process efficiency (CPE) which is represented by point A, B and AC in half-normal probability plot **Figure 2.02.** Response surface plot and contour plot depicts that the increase in inlet air temperature & spray rate results in increase of weight gain (SD) at constant atomizing air pressure as shown in **Figure 2.03 and 2.04**, whereas (**Figure2.05 and 2.06**) show that decrease in inlet air temperature (°C) & spray rate favours increase in coating process efficiency at constant atomizing air pressure.

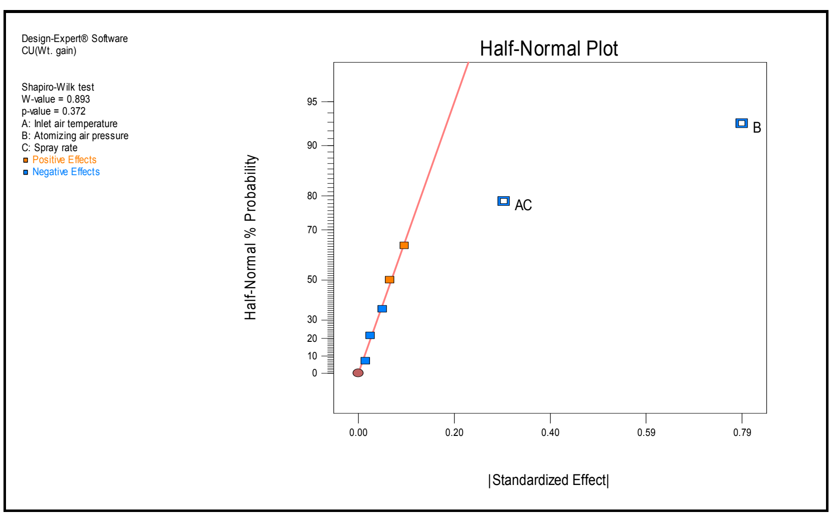

Figure-2.01, Half normal plot weight gain (mg) of of TGA tablets coated with Acetylated Curcumin

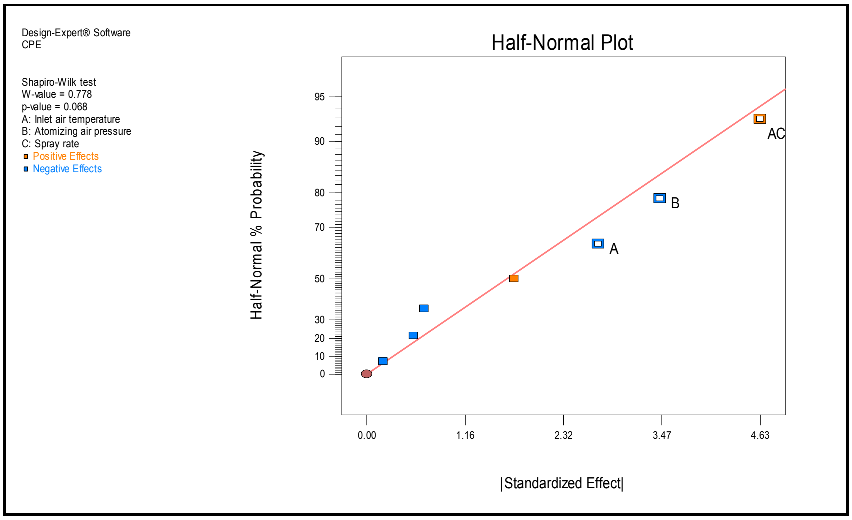

Figure-2.02, Half normal plot of coating process efficiency (%) of of TGA tablets coated with Acetylated Curcum

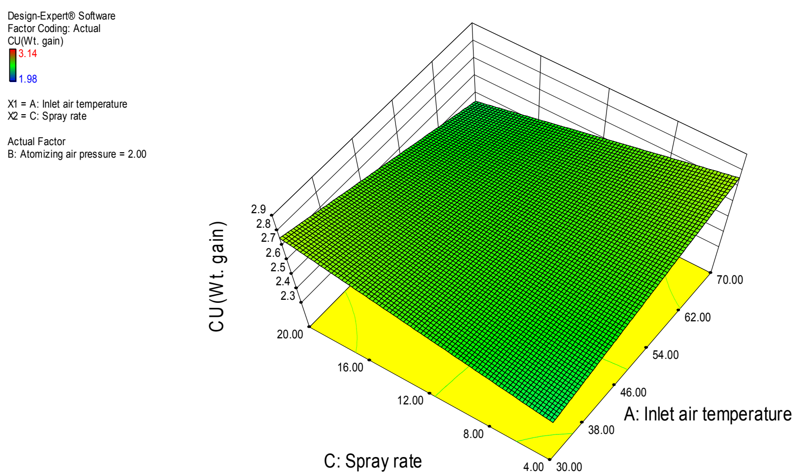

Figure-2.03 Response surface plot of weight gain(mg) of of TGA tablets coated with Acetylated Curcumin

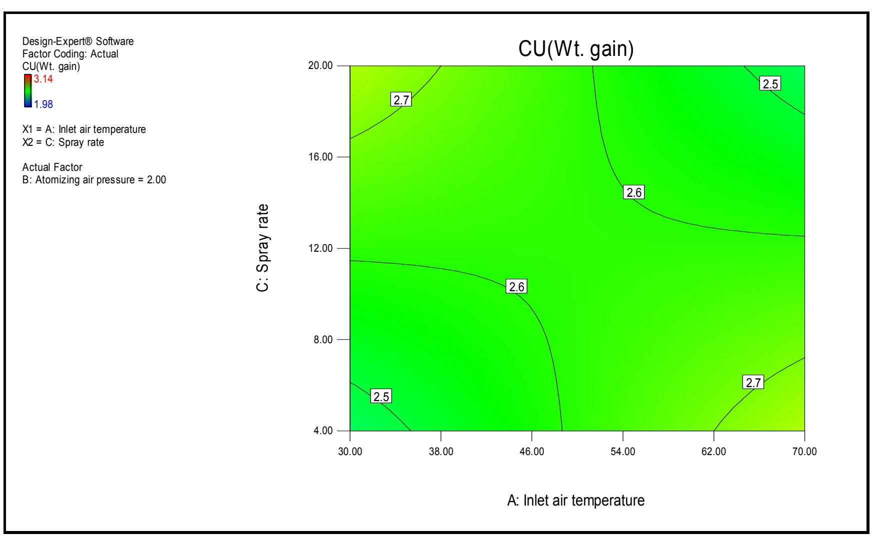

Figure -2.04 Contour plot of weight gain(mg) of of TGA tablets coated with Acetylated Curcumin

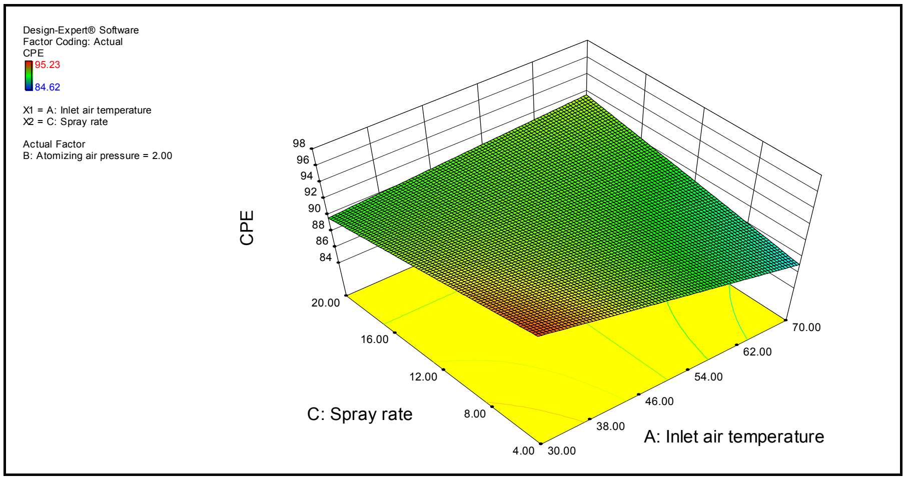

Figure -2.05 Response surface plot of coating process efficiency (%) of of TGA tablets coated with Acetylated Curcumin

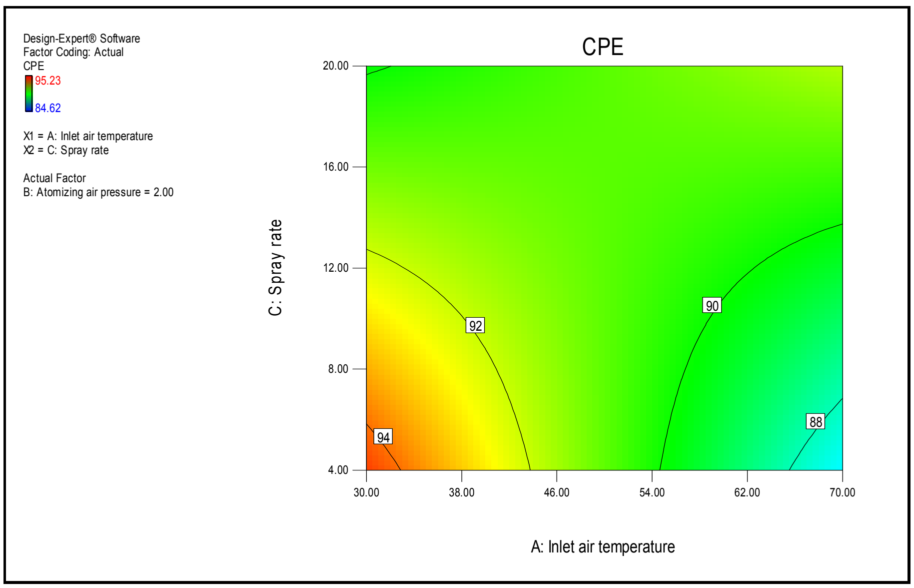

Figure-2.06 Contour plot of coating process efficiency (%) of of TGA tablets coated with Acetylated Curcumin

Model assessment for % weight gain

Table – 8.01					
ANOVAs analysis of weight gain for TGA tablets coated with Acetylated curcumin					
Source	**SS**	**df**	**MS**	**F-value**	**p-value Prob>F**
Modal	1.43	2	0.71	107.55	0.0001
Residual	0.033	5	0.000664		
Total	1.46	7			

The polynomial equation (5) has been derived as above. The fit summary was applied to data, in that Response surface single factorial model had been analyzed with the correlation coefficient (R2 = 0.9773) and *p*-value with 0.0001 ($p<0.05$) from **table-8.01.** Model polynomial equation in coded terms is,

Weight gain (SD)= $+2.61-0.40*X_2-0.15X_1*X_3*$ **………………………………………..(5)**

Results of the equation indicate that the effect of X_2 (atomizing air pressure) is more significant than X_1 (Inlet air temperature) and X_3 (spray rate). In the above equation, the negative coefficient of factor X_2 shows that as its value increases the response weight gain(SD) get decreases, and same as X_1X_3.

Model assessment for coating process efficiency

Table-08.01, 2^3 full factorial design layout for TGA tablet coated with Acetylated Curcumin

Sample No	Variable level in coded form			Weight gain (mg)	Coating process efficiency (%)
	X_1	X_2	X_3	R1	R2
1	-1	-1	-1	2.78	95.23
2	-1	1	-1	1.98	92.10
3	-1	-1	1	3.14	91.98
4	-1	1	1	2.41	89.56
5	1	-1	-1	3.12	88.00
6	1	1	-1	2.37	84.62
7	1	-1	1	2.98	95.11
8	1	1	1	2.10	90.24

Translation of coded level in actual values

Levels of variables	X_1 Inlet air temperature(^{o}C)	X_2 Atomizing air pressure(kg/cm^2)	X_3 Spray Rate (ml/min)
Low (-1)	30	1	4
High(1)	70	3	20

Coating process efficiency (CPE) =+90.86-1.36 X_1*-1.73X_2*+ 2.32X_1*X_3*…………. (6)

Table – 8.02

ANOVAs analysis of Coating process efficiency for TGA tablets coated with Acetylated curcumin

Source	SS	df	MS	F-value	p-value Prob>F
Model	81.53	3	27.18	14.28	0.0133
Residual	7.61	4	1.90		
Total	89.14	7			

The Coating process efficiency for coated tablets varied from 84.62 to 95.23 present in**Table-08**, and showed correlation coefficient (R^2 = 0.9146). Results of the equation indicate that the effect of X_1 (inlet air temperature) and X_2 (Atomizing air pressure) has significant effect than X_3 (spray rate). Moreover, inlet air temperature and atomizing air pressure had a negative effect on coating process efficiency (i.e. inlet air temperature and atomizing air pressure is increased, the coating process efficiency decreased). This might be due to at high temperature water evaporation is very fast and particles get dried before reaching to the tablets. The linear model generated for coating process efficiency was found to be significant with a *p*-value of 0.0133 ($p<0.05$) in **table-8.02.**

Conclusion:

The film coating of Triphala guggul ayurvedic tablets has been carried out by pan coater apparatus with different colorant as CUR, and Ac.CUR to give yellow colour to the tablets, under optimum condition. The results of preliminary trials for this film coating revealed that inlet air temperature, automizing air pressure and spray rate had a major effect on coating processs of tablets. To study the combine effect of process parameters, 2^3 full factorial design has applied on TGA- CUR, and TGA- Ace.CUR, tablets. Fig-1.01to1.06 and 2.01 to 2.06 and from table 07 to 08, it was concluded that model best suit for this 2^3 factorial design and point prediction. The optimum coating condition for TGA-CUR coated are 50^0C inlet air temperature 2 bar atomizing air pressure and 10ml/min spray rate. Similarly for TGA-Ac-CUR tablets 30^0C inlet air temperature 1 bar atomizing air pressure & 8 ml/min spray rate.

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