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Research Article

Optimization Using Central Composite Design and The Desirability Function For W/O Transparent Cosmetic Hair Wax

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ABSTRACT

The objective of this study was to design and optimize a w/o transparent cosmetic hair wax by using a central composite design and desirability function. A preliminary trial was conducted for screening the fixative agent and emulsifier. A preliminary trial study acryset FS and ceteareth 20 was taken as a fixative agent and emulsifier. The prepared hair wax was evaluated for phase separation, homogeneity, grittiness, pH, transparency, viscosity, curl retention, flaking test, humidity resistance of treated hair tresses, and stability study. A central composite design was employed to study the effect of acryset FS (X_1) and ceteareth 20 (X_2) on transparency (Y_1), viscosity (Y_2), and curl retention (Y_3). In this present study, the following constraints were arbitrarily used for the selection of an optimized batch: transparency> 90%, viscosity=1,25,000 to 1,50,000 cps and curl retention = 81% to 86%. Multiple linear regression analysis, ANOVA, graphical representation of the influence factor by 3D plots, and desirability plot were performed by using design expert 12. To validate the evolved mathematical models, a checkpoint was selected from its desirability value 1. ANOVA results suggested that calculated F values calculated of all dependent variables are greater than tabulated values. Prepared checkpoint batch evaluated values were found to be similar to the predicted values, and it was found to be stable in the stability study. Unique hair styling transparent hair wax delivers high humidity resistance, excellent curl retention, and no flakes, and it meets today's market trend.

INTRODUCTION

Haircare cosmetics for conditioning and repairing hair from damage contain amino acids, hydrolyzed proteins, ceramides, moisturizing agents, sterols, ingredients for accelerating the penetration and adhesion of the efficacious ingredients the hair, and components for improving the sensory characteristics. Products for styling and setting hair are designed by combining setting polymers or waxes of high melting points and considering the sensory characteristics and tackiness. Leave-on hair care cosmetics are applied directly on hair and are not rinsed off, and thus the sensory characteristics of the constituents are directly felt. It is thus important to have a thorough knowledge of the sensory characteristics of the ingredients to be combined, such as oils, glycerols, and polymers.[1,2] Leave-on hair care products include hair tonics, hair oils, hair creams, hair gels, and hair waxes, and hair conditioners.

Hair mists mainly consist of cationic surfactants and glycols. Hair wax contains oils, silicone, fatty acids (as emulsifiers), and either anionic or cationic surfactants. Hair mists and creams also contain nonionic surfactants for emulsification. Hair waxes contain microcrystalline waxes, fatty acids, nonionic surfactants, and glycols. Polymers are added to achieve hair setting and styling performances. Hairstyling agents are gels, wax, or liquids that contain polymers. Fixative, emulsifier, and polymers play a crucial role in hair styling products, and it provides

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the desired styling to the end-users. Many cosmetic raw materials suppliers provide different types of polymers as a hair styling aid. These polymers are helpful to increase the hair volume, stiffness value, curl retention, and film-forming. Hairstyling product performance is rated based on the stiffness, curl retention and flake issue. Fixative and emulsifiers give a significant effect on the hair wax quality. Therefore, the present investigation aims to develop an effective and acceptable, w/o transparent cosmetic hair wax using a statistical approach.[3, 4]

Material and Methods

Materials and Reagents

Acryset FS was received as a generous gift from Corel Pharma Chem, Ahmedabad, India. Ceteareth 20 (Ginonic CSA 20) was obtained from Godrej Industries, Mumbai, India. Polyvinyl pyrrolidone was purchased from Loba Chemicals, Mumbai. Disodium edetate and triethanolamine was obtained from Finar Limited, Ahmedabad, India. All other materials and chemicals used were of either pharmaceutical or analytical grade.

Preliminary Screening of Hair Fixative and Emulsifier for W/O Transparent Hair Wax

The development of transparent hair wax by selecting ingredients in appropriate amounts and the hair fixative and emulsifier optimized thereafter. Transparent hair wax was prepared by the w/o emulsion method. The preliminary trial batches T1 to T8 were formulated as shown in table 1. Trial batches were evaluated for phase separation, homogeneity, grittiness, pH, transparency, viscosity and curl retention. Batch T1 and T6 were prepared by using a different concentration of hair fixative. Batch T7 and T8 were prepared to check the effect of ceteareth 25 and ceteareth 20, respectively.[5-7]

Development of transparent hair wax

All the required ingredients of the hair wax were weighed accurately. The aqueous phase of the formulation was prepared by demineralized water. The required quantity of disodium edetate, propylene glycol, and hair fixative was dissolved in water. A milky dispersion is neutralized with triethanolamine up to pH 7.0–7.5, and the low viscous gel was obtained. The oil phase of hair wax was prepared by using an emulsifier agent. The required quantity of tween 80 and PEG 400 was dissolved in an emulsifier agent. Heat both the phases up to 75-80°C and mix well. Allow it to cool down at room temperature and add perfume for better aesthetic appeal.[8, 9]

Evaluation of Transparent Hair Wax

All formulations were inspected visually for their phase separation.

Homogeneity: All developed hair wax was tested for homogeneity by visual inspection after the gels have been set in the container. They were tested for their appearance and presence of any aggregates.

Grittiness: All the formulations were evaluated microscopically for the presence of particles. Suppose no appreciable particulate matter is seen under a light microscope. In that case, the gel preparation fulfills the requirement of freedom from particular matter and from grittiness as desired for transparent hair wax.

Measurement of pH: The pH of hair wax was determined by using a digital pH meter. One gram of gel was dissolved in 100 mL of distilled water for pH measurement in triplicate, and average values were calculated.

Table 1: Preliminary screening of hair fixative and emulsifier for transparent hair wax

Ingredients (gm)	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*T7*	*T8*
				Part I				
Demineralized water	61.95	60.95	61.95	60.95	61.95	60.95	60.95	60.95
Disodium edetate	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Propylene glycol	5	5	5	5	5	5	5	5
PVP K30	4	5	-	-	-	-	-	-
Acrysetsuperhold II	-	-	4	5	-	-	-	-
Acryset FS	-	-	-	-	4	5	5	5
				Part II				
Triethanolamine	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S
Ceteareth 30	25	25	25	25	25	25	-	-
Ceteareth 25	-	-	-	-	-	-	25	-
Ceteareth 20	-	-	-	-	-	-	-	25
Tween 80	2	2	2	2	2	2	2	2
PEG 400	2	2	2	2	2	2	2	2
Perfume	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S
Total	100	100	100	100	100	100	100	100

Transparency: The transmission in a 1 cm cuvette at 420 nm using water as blank was recorded using a UV-visible Spectrophotometer through subjective optical assessment.

Viscosity: The viscosity of hair wax was investigated using Brookfield Viscometer. The sample (100 gm) was taken in a glass beaker, and viscosity was tested using spindle No. 7 (20 rpm) at 25°C for 5 minutes. Viscosity and torque measurements were recorded in triplicate.

Curl retention: Curl retention of hair fixatives may claim "long-term curl retention," which has to be substantiated. The test generally used is called the curl snap test. In this test, the 0.9–1.0 gm of hair fixative is applied to the 1-2 gm hair tresses generally 13–15 cm long, which are then wrapped onto curlers and allowed to dry. After drying, the hair tresses are carefully removed from the curler and hung up to a support board. The initial length of the curls is recorded, and then a wide-toothed comb is passed through the tresses. The length (lowermost portion) of the tresses is recorded, which can be used to calculate the curl retention of the hair fixative. Curl retention is calculated as follows:

$$\%Curl\ retention = \frac{length\ of\ uncurled\ hair\ tress\ -\ length\ of\ the\ hair\ at\ the\ time\ of\ reading}{length\ of\ uncurled\ hair\ tress\ -\ length\ of\ the\ curl\ at\ the\ start\ of\ the\ experiment} \times 100$$

Humidity resistance of treated hair tresses:A number of hair fixative formulations claim high holding power even in humid environments. The test is similar to the curl retention test. First, 0.9–1.0 gm of hair fixative is applied to the 1 to 2 gm hair tresses generally 13 to 15 cm long, which are then wrapped onto curlers and allowed to dry. After drying, the hair tresses are carefully removed from the curler and hung up to a support board. The initial length of the curls is recorded, and then they are placed into a high-humidity environment that is 90% relative humidity at 25°C. The length is recorded at predefined time intervals, and then the curl retention is calculated based on the original length and final length as a percentage.

Flaking: The overuse of polymer-based hair fixatives can lead to flaking. The 0.9–1.0 gm fixative is applied to the 1–2 gm hair tresses generally 13–15 cm long and allowed to dry to test flaking. The hair tresses are hung up onto a supporting board and a small-toothed comb is then passed through the hair tresses. The hair, comb, and area under the support stand are inspected to evaluate flaking. The visible flaking is rated on a scale of 1–4 (1 = no flaking, 2 = low flaking, 3 = obvious flaking, 4 = very much flaking; not acceptable). The graduations "+" and "- "indicate slightly better or slightly worse. [10-12]

Stability study for hair wax: The selected formulation was tested for stability which was performed at 25±2 °C for 3 mo. A well-closed container was used for the storage of optimized hair wax at 25 ± 2 °C. Samples were observed at a forethought time interval of 30, 60 and 90 days. At the end of 3 mo, the selected formula was evaluated for phase separation, homogeneity, grittiness, pH, % of transparency, viscosity, % of curl retention, flaking test and % of humidity resistance of treated hair tresses. The selected formula was also evaluated for chemical parameters like change in pH.[13, 14]

Optimization of Variables Using Response Surface Methodology and Central Composite Design

Response surface methodology **(**RSM) is a multivariate statistical tool. It consists of a group of mathematical and statistical techniques that are based on the fit of empirical models to the experimental data obtained in relation to experimental design. It employs lower order polynomials and it has already been proved to be a reliable statistical method for pharmaceutical formulation. In the RSM category, central composite design (CCD) appropriate for fitting second-order polynomial equations has been frequently used to optimize several research problems. A CCD has two-level factorial design points (2^k), consisting of possible combinations of +1 and −1 levels of factor; it has (2K) axial points fixed axially at a distance say ∞ from the center to generate quadratic terms and center points which represent replicate terms; center points provide a good and independent estimate of the experimental error. Considering these points, the number of experiments designed by CCD will be: $N= k^2 + 2k + n$. Where N is the total number of experiments, k is the number of factors studied, and n is the number of replicates. In this study, two independent variables were taken. A total of 13 experiments were sufficient to calculate the coefficients of the second-order polynomial regression model for two variables. Based on preliminary results, the amount of acryset FS (X_1) and ceteareth20 (X_2) were chosen as independent variables in central composite design, while transparency (Y_1), viscosity (Y_2), and curl retention (Y_3) were taken as dependent variables. Multiple linear regression analysis, ANOVA, and graphical representation of the influence of factor by contour plots were performed using Design Expert 12.[15,16] The experimental run batch formulations are shown in Table 2. The measured responses of central composite design batches of hair wax were depleted in Table 3.

Results and Discussion

Preliminary Screening of Hair Fixative and Emulsifier for Transparent Hair Wax

The batches T1–T8 were prepared to achieve an optimized concentration of fixative and emulsifier and the most efficacious one among these fixative and emulsifier incorporated to prepare transparent hair wax. No grittiness was observed in all formulations, and pH of all batches was found 7.10 ± 0.20 to 7.30 ± 0.44. Batch T1 and T2 containing PVP K30, in this batch phase separation, occurred. Batch T3 and T4 showed very less transparency, which is containing acryset super hold II.

Table 2: Formulation of experimental design batches of transparent hair wax

Ingredients (gm)	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}
Part I													
Demineralized water	61	59	56	54	58.9	56	61	54	57.5	57.5	57.5	57.5	57.5
Disodium edetate	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Propylene glycol	5	5	5	5	5	5	5	5	5	5	5	5	5
Acryset FS	5	7	5	7	4.58	7.41	6	6	6	6	6	6	6
Triethanolamine	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S
Part II													
Ceteareth 20	25	25	30	30	27.5	27.5	24	31	27.5	27.5	27.5	27.5	27.5
Tween 80	2	2	2	2	2	2	2	2	2	2	2	2	2
PEG 400	2	2	2	2	2	2	2	2	2	2	2	2	2
Perfume	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S	Q.S
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 3: Preliminary screening of super disintegrating agent

Batch	*Phase Separation*	*Grittiness*	*Homogeneity*	*pH*	*% of Transparency*	*% of Viscosity (cps)*	*% of Curl Retention*
T1	Phase separation	Non gritty	++	7.10 ± 0.20	30.0 ± 1.45	15000 ± 345	40.0 ± 0.98
T2	Phase separation	Non gritty	++	7.14 ± 0.12	35.5 ± 0.98	15920 ± 340	51.2 ± 1.46
T3	Not observed	Non gritty	+++	7.19 ± 0.15	40.0 ± 1.46	200345 ± 456	70.5 ± 1.55
T4	Not observed	Non gritty	+++	7.21 ± 0.45	35.4 ± 1.35	210754 ± 460	80.0 ± 1.47
T5	Not observed	Non gritty	++	7.27 ± 0.40	95.0 ± 1.68	80869 ± 290	76.9 ± 1.16
T6	Not observed	Non gritty	++	7.26 ± 0.55	93.0 ± 1.70	93400 ± 575	77.2 ± 1.18
T7	Not observed	Non gritty	++	7.28 ± 0.56	89.0 ± 1.75	94890 ± 560	78.9 ± 1.55
T8	Not observed	Non gritty	+++	7.30 ± 0.44	87.5 ± 1.80	97560 ± 575	79.3 ± 1.47

(++) Good, **(+++)** Excellent (n=6)

Batch T5 and T6 showed good transparency compared to other fixative agents. Batch T7 and T8 show good transparency, which was containing ceteareth 25 and ceteareth 20, respectively. Ceteareth 20 gives a better viscosity and curl retention compared to ceteareth 30 and ceteareth 25. Hence, further trials were carried out by using a combination of acryset FS and ceteareth 20 to understand their effect and optimize the concentration of both for achieving desirable parameters.

Central Composite Design Model Evaluation

A statistical model incorporating interactive and polynomial quadratic terms was used to evaluate the responses:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{12}X_1X_2 + b_{11}X_1^2 + b_{22}X_2^2$$

Y is the dependent variable, bo is the arithmetic mean response of the 13 runs, and any bi is the estimated coefficients for Xi's related factor. The main effects (X_1 and X_2) represent the average result of changing one factor at a time from its low to high value. The polynomial terms (X_1^2 and X_2^2) are included to investigate nonlinearity. The interaction term "X_1X_2" shows how the response changes when the two factors change simultaneously. Evaluation data for transparent hair wax were presented in Tables 4 and 5. The fitted equations relating the responses, that is, transparency (Y_1), viscosity (Y_2), and curl retention (Y_3) to the transformed factor are shown in Table 6. The polynomial equation is used to draw conclusions after considering the magnitude of the coefficient and the mathematical sign it carries (i.e., positive or negative). Analysis of variance (ANOVA) results suggested that calculated F values calculated for transparency, viscosity, and curl retention were 064.17, 042.61, and 72.78, respectively, shown in Table 7. The tabulated F value was found to be 20.103 at $\alpha = 0.05$. Calculated F values are greater than tabulated for all dependent variables. Therefore, the factors selected have shown significant effects. From the results of multiple regression analysis, it was found that all factors had a statistically significant influence on all dependent variables as $p < 0.05$[17,18] No grittiness and phase separation was observed in all formulations. Low Flaking value was observed in experimental design batches. Humidity resistance of treated hair tresses was observed between 80.70 ± 1.46 to 95.70 ± 1.65.

Full and Reduced Model for Transparency

$$\text{Transparency} = 89.38 - (14.09 * X_1) - (2.17 * X_2) - (2.51 * X_1 X_2) - (7.57 * X_1^2) + (0.66 * X_2^2)$$

Table 4: Runs and measured responses of experimental design batches

Batch Code	*Acryset FS (X_1)*	*Ceteareth 20 (X_2)*	*%Transparency (Y_1)*	*Viscosity (cps) (Y_2)*	*% Curl retention (Y_3).*
F_1	-1	-1	93.51 ± 1.74	103004 ± 234	80.34 ± 1.46
F_2	+1	-1	69.34 ± 1.64	198300 ± 264	90.78 ± 1.75
F_3	-1	+1	93.56 ± 1.94	107080 ± 275	80.75 ± 1.46
F_4	+1	+1	59.35 ± 0.36	230282 ± 575	95.78 ± 1.65
F_5	-∞	0	95.67 ± 1.67	080689 ± 456	75.96 ±1.68
F_6	+α	0	57.23 ± 0.90	225458 ± 134	95.45 ± 1.64
F_7	0	-∞	92.87 ± 1.68	128654 ± 578	82.78 ± 1.54
F_8	0	+α	87.63 ± 1.35	131487 ± 035	88.96 ± 1.16
F_9	0	0	88.57 ± 0.86	130589 ± 234	88.34 ± 1.14
F_{10}	0	0	88.53 ± 1.25	130586 ± 045	87.78 ± 1.56
F_{11}	0	0	89.89 ± 0.84	130525 ±078	86.55 ± 1.25
F_{12}	0	0	89.37 ± 1.74	130489 ± 047	86.87 ± 1.74
F_{13}	0	0	90.56 ± 1.46	130325 ± 456	86.33 ± 1.35

Factors and the levels in the design

Independent variables	*Extreme low (-∞)*	*Low (-1)*	*Medium (0)*	*High (+1)*	*Extreme high (+α)*
Amount Acryset FS (X_1)	4.58	5	6	7	7.41
Amount of ceteareth 20 (X_2)	23.96	25	27.50	30	31.03

(n=6)

Table 5: Evaluation of experimental design batches

Batch	*Phase separation*	*grittiness*	*Homogeneity*	*pH*	*Flaking test*	*Humidity resistance of treated hair tresses*
F_1	Not observed	Non Gritty	+++	7.29 ± 0.13	1 ± 0	80.24 ± 1.46
F_2	Not observed	Non Gritty	++	7.28 ± 0.14	2 ± 0	90.75 ± 1.75
F_3	Not observed	Non Gritty	+++	7.27 ± 0.21	1 ± 0	80.70 ± 1.46
F_4	Not observed	Non Gritty	++	7.30 ± 0.54	2 ± 0	95.70 ± 1.65
F_5	Not observed	Non Gritty	++	7.31 ± 0.21	1 ± 0	74.96 ± 1.68
F_6	Not observed	Non Gritty	++	7.31 ± 0.56	2 ± 0	90.45 ±1.64
F_7	Not observed	Non Gritty	+++	7.30 ± 0.12	1 ± 0	82.80 ±1.54
F_8	Not observed	Non Gritty	++	7.27 ± 0.15	1 ± 0	88.86 ±1.16
F_9	Not observed	Non Gritty	+++	7.30 ± 0.43	1 ± 0	89.34 ± 1.14
F_{10}	Not observed	Non Gritty	+++	7.30 ± 0.43	1 ± 0	88.88 ± 1.56
F_{11}	Not observed	Non Gritty	+++	7.31 ± 0.45	1 ± 0	86.65 ±1.25
F_{12}	Not observed	Non Gritty	+++	7.29 ± 0.88	1 ± 0	86.90 ± 1.74
F_{13}	Not observed	Non Gritty	+++	7.30 ± 0.14	1 ± 0	86.5 5± 1.35

(n=6)

*The visible flaking is rated on a scale of 1 – 4 (1 = no flaking, 2 = low flaking, 3 = obvious flaking, 4 = very much flaking; not acceptable). The graduations "+" and "-"indicate slightly better or slightly worse.

In this analysis, the %transparency range was observed between 57.23 ± 0.90% to 95.67 ± 1.67%. The value of R^2 was found to be 0.9634. Based on the ANOVA the result showed that the developed linear model was highly significant, as was evident from the very low probability value is < 0.0001. The plot of the observed value of % transparency versus the predicted value of % transparency (Fig. 1A) shows a straight line. Therefore, it concluded that the equation has a good predictive ability. Interaction and nonlinearity were not observed. The 3D plot (Fig. 1B) and the regression coefficient values of factors concluded that when acryset FS and ceteareth 20 were increased, transparency decreased. Hair fixative gives a more effect on transparency compared to

Table 6: Summary of regression output of factors for measured responses

		Coefficient of regression parameters						
Responses	*Model*	b_0	b_1	b_2	b_{12}	b_{11}	b_{22}	R^2
Transparency (Y_1),	Coefficient	89.38	-14.09	-2.17	-2.51	-7.57	-0.6695	0.9634
	p value		< 0.0001	0.0457	0.0875	< 0.0001	0.5074	
Viscosity (Y_2)	Coefficient	130502.8	52904.04	5008.06	6976.50	15808.98	4307.48	0.9455
	p value		< 0.0001	0.2286	0.2349	0.0060	0.3251	
Curl retention (Y_3)	Coefficient	87.17	6.63	1.77	1.15	-0.4532	-0.3707	0.9676
	p value		< 0.0001	0.0018	0.0606	0.2826	0.3728	

Table 7: Results of the ANOVA for dependent variables

Source of variation	*DF*	*SS*	*MS*	*F value*	*p value*
			% of Transparency (Y_1),		
Regression	5	2050.99	410.20		
Residual	7	0044.74	006.39	064.17	< 0.0001
Total	12	2095.74	-		
			Viscosity (Y_2)		
Regression	5	24560308365	4912061673		
Residual	7	00806961092	0115280156	042.61	< 0.0001
Total	12	25367269457	-		
			% of Curl retention (Y_3)		
Regression	5	383.97	76.79		
Residual	7	007.39	01.06	072.78	< 0.0001
Total	12	391.36	-		

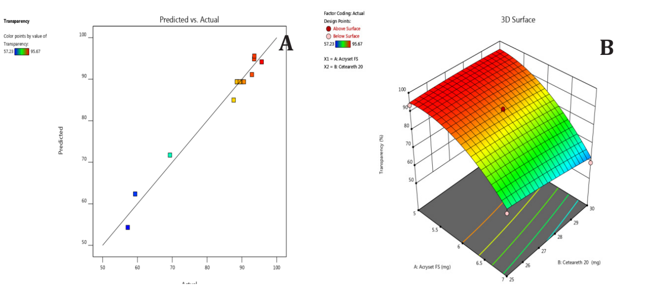

Fig 1: (A) Predicted Vs actual value of transparency; (B) 3D plot showing the effect acryset FS (X_1) and ceteareth 20 on % transparency

emulsifiers. For transparency, the significance levels of the coefficients b_{12} and b_{22} were found to be p = 0.0875 and 0.5074, respectively, so they were omitted from the full model to generate a reduced model. The coefficients b_1, b_2, and b_{11} were found to be significant at p < 0.05; hence, it was retained in the reduced model. The reduced model for transparency

$$\text{Transparency} = 89.38 - (14.09 * X_1) - (2.17 * X_2) - (7.57 * X_1^2)$$

Full and Reduced Model for Viscosity

$$\text{Viscosity} = 130502.8 + (52904.04 * X_1) + (5008.06 * X_2) + (6976.50 * X_1 \; X_2) + (15808.98 * X_1^2) + (4307.48 * X_2^2)$$

Based on the analysis of variance (ANOVA) the result showed that the developed linear model was highly significant, as was evident from the very low probability value is <0.0001. In this analysis, the viscosity range was observed between 080689 ± 456 to 230282 ± 575. The value of R^2 was found to be 0.9455. The plot of the observed value of viscosity versus the predicted value of viscosity (Fig. 2A) shows a straight line. Therefore, it concluded that the equation has good predictive ability. Interaction and nonlinearity was not observed. The 3D plot (Fig 2B) and the regression coefficient values of factors concluded that when acryset FS and ceteareth 20 were increased, the viscosity increased. Acryset FS has a significant effect on % viscosity. For viscosity, the significance levels of the coefficients b_2, b_{12}, and b_{22} were found to be P = 0.2286, 0.2349, and 0.3251, respectively, so they were omitted from the full model to generate a reduced model. The coefficients b_1 and b_{11} were found to be significant at P < 0.05; hence, it was retained in the reduced model. The reduced model for viscosity

$$\text{Viscosity} = 130502.8 + (52904.04 * X_1) + (15808.98 * X_1^2)$$

Full and Reduced Model for Curl Retention

$$\text{Curl retention} = 87.17 + (6.63 * X_1) + (1.77 * X_2) + (1.15 * X_1 X_2) - (0.4532 * X_1^2) - (0.3707 * X_2^2)$$

In this analysis, curl retention was observed between 75.96 ± 1.68% to 95.78 ± 1.65%. The value of R^2 was found to be 0.9547. Based on the ANOVA the result showed that the developed linear model was highly significant, as was evident from the very low probability value is <0.0001.

Table 8: Formulation and evaluation of check point batch

Formulation of check point batches				
	Variable level			
	Coded value		*Actual value*	
Batch Code	*X_1*	*X_2*	*Acryset FS (mg)*	*Ceteareth 20 (mg)*
CP1	0.86	-1.01	6.075	25.049
Evaluation of check point batches and comparison with predicted value				
Parameter	*Actual value*		*Predicted value*	
% Transparency (Y_1),	90.50 ± 0.45		89.949	
Viscosity (Y_2)	132458 ± 256		133286.868	
% Curl retention (Y_3)	87.40 ± 0.88		85.494	

(n=6)

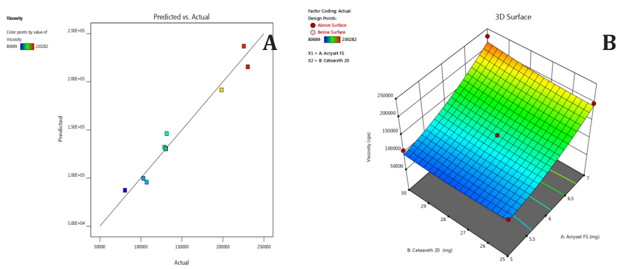

Fig 2: (A) Predicted Vs actual value of % viscosity; (B) 3D plot showing the effect acryset FS (X_1) and ceteareth 20 on viscosity

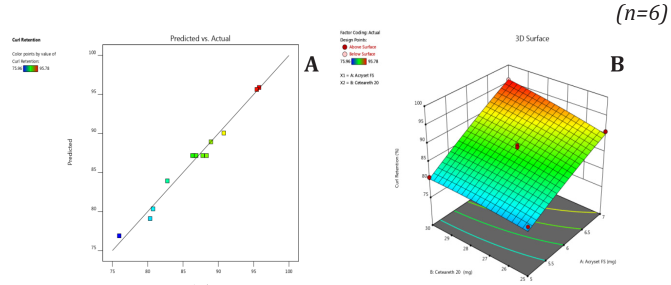

Fig 3: (A) Predicted Vs actual value of curl retention (Y_3); (B) 3D plot showing the effect acryset FS (X_1) and ceteareth20 on curl retention

The plot of the observed value of curl retention versus the predicted value of % of curl retention (Fig. 3A) shows a straight line. Therefore, it concluded that the equation has good predictive ability. Interaction and nonlinearity was not observed. The 3D plot (Fig 3B) and the regression coefficient values of factors concluded that when acryset FS and ceteareth 20 were increased, curl retention also increased. Hair fixative gave a more effect on % of curl retention. For curl retention, the significance levels of the coefficients b_{12}, b_{11}, and b_{22} were found to be p = 0.0606, 0.2826, and 0.3728, respectively, so they were omitted from the full model to generate a reduced model. The coefficients b_1 and b_2 were found to be significant at $P < 0.05$; hence, it was retained in the reduced model. The reduced model for curl retention

$$\text{Curl retention} = 87.17 + (6.63 * X_1) + (1.77 * X_2)$$

Search for the Selection of Optimized Formulation

The optimization of transparent cosmetic hair wax was done by numerical optimization. In the present study, the following constraints were arbitrarily used for the selection of an optimized batch: transparency> 90%, viscosity = 1,25,000 to 1,50,000 cps and curl retention = 81% to 86%. Further, the optimized sustained release layer was demarcated in the design space (overlay plot) shown in Fig 4(A). A check point was selected from its desirability value 1 as shown in Fig 4(B) to validate the evolved mathematical models. Checkpoint batch CP1 was prepared and evaluated. The observed and predicted values for batch CP1 as shown in Table 8. A good correlation was found between observed and predicted values. Hence, it was concluded that the evolved models might be used for the theoretical prediction of responses within the factor space.

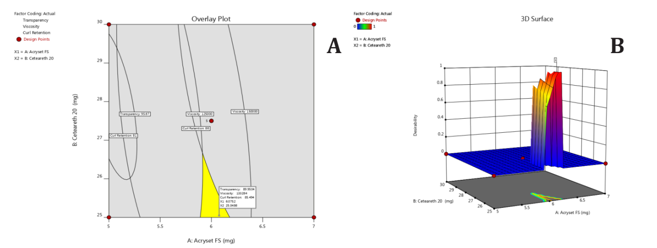

Fig 4: (A) Overlay plot depicting design space and flagged point as the checkpoint batch of hair wax; (B) Desirability values of responses

Stability Study for Checkpoint Optimized Formulation

When the prepared checkpoint optimized batch was kept tightly closed and stored at room temperature for 3 mo, no difference in visual appearance and homogeneity was observed. There was no significant difference in pH, transparency, viscosity, curl retention, and humidity resistance of treated hair tresses after the period of the study, as shown in Table 9. The present study concluded successful preparation and optimization of transparent cosmetic hair wax. The developed hair wax delivers high humidity resistance, excellent curl retention, and no flakes, and it meets today's market trend and consumer needs. Fixative agent and emulsifier concentration finalized based on the properties like percentage of transparency

Table 9: Stability study of transparent cosmetic hair wax

Description	Before storage	After storage
pH	7.30 ± 0.12	7.28 ± 0.17
Homogeneity	High clarity and very good homogeneity	High clarity and very good homogeneity
Transparency (Y_1),	90.50 ± 0.45%	89.50 ± 0.45%
Viscosity (Y_2)	132458 ± 256	132419 ± 458
Curl retention (Y_3)	87.40 ± 0.88%	86.40 ± 0.88%

(n=6)

viscosity and % of curl retention; it helps to minimize the final cost of the formula.

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