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Formulation, Development, and Evaluation of Novel Face Wash Cream Using Factor 3 Level Design Approach (Doe)

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ABSTRACT

The development of herbal face wash cream with rice-soaked water and coffee powder is a novel solution for sustainable skin care. Using the Design Expert software, this research utilizes a rigorous Design of Experiments (DOE) approach to maximize the important formulation parameters to deliver improved skin benefits and product stability. Rice-soaked water, which is vitamins-enriched, amino acid-enriched, and antioxidant-enriched, helps in hydrating, repairing, and whitening the skin, whereas coffee powder, a natural peeling agent, offers anti-inflammatory and anti-aging effects. The preparation was stringently tested for pH equilibrium, viscosity, spread, foaming ability, and microbial stability to produce efficacy as well as safety. ANOVA and Response Surface Methodology (RSM) resulted in the optimization process that yielded a scientifically tested, high-quality herbal skincare product. This research bridges the gap between traditional herbal wisdom and modern for mulation science, paving the way for eco-friendly, evidence-based cosmetic innovation in the personal care industry.

Key Words: Rice-soaked water, Design of Experiment, Factorial, Response Surface Methodology, ANOVA, Skincare.

I. INTRODUCTION

Advancement of formulation science is back staged further sophistication with incorporation of advanced statistical tools and designs that have evolving many a step ahead of plain-and-simple trial-and-error procedures. One such path-breaking technique is Design of Experiments (DOE), being more of an organized and systematic method for exploring the effect of several formulation factors at one go. Unlike the classical one-factor-at-a-time (OFAT) approach wherein the complex interactions between the variables are rarely observed, DOE provides a scientific framework for optimizing formulations while at the same time minimizing resource consumption. This data-driven approach is extremely critical in the sectors of pharmaceuticals, cosmetics, and food sciences because even minute changes in composition cause severe effects on stability, efficacy, and performance of a final product. The incorporation of DOE can pave the way for development wherein products not only function efficiently but are also reproducible and scalable for implementation during commercial-scale production.

One of the most compelling advantages of DOE lies in its ability to indicate complex relationships between formulation parameters rather than treating different variables in isolation as done in classical statistical methods. Here, statistical models evaluate multiple factors simultaneously while bestowing much more information on formulation landscape. Of particular use for developing multicomponent systems-such as emulsions, gels, and suspensions in which ingredient synergy plays a major role in ensuring stability and performance in the final product. A structured approach ensures that each formulation adheres to key quality attributes, including viscosity, stability of pH, spreadability, and bioavailability. Techniques such as Factorial Design, Response Surface Methodology (RSM), and Taguchi Optimization enable fine-tuning of formulations by the researcher, weighing efficiency against performance.

Besides playing an all-important role in formulation optimization, DOE is also consistent with the elements of Quality by Design (QbD), a regulatory-driven approach grounded in the assessment of constancy and risk throughoutA product development. Researchers can define design spaces in which product development is subject when a DOE is integrated into the beginning of the formulation process. This predictive capability not only mitigates formulation failures or delays but ensures compliance with industry standards and regulatory guidelines as well. Besides, DOE helps provide constructive troubleshooting strategies around formulation

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challenges through identifying critical control points through which influences on the degradation, stability, and performance characteristics decline over time. This predictive modelling vastly improves the R&D cycle, cutting costs, and speeding time-to-market on new products.

The rapid uptake of DOE across scientific disciplines speaks of the ever-increasing importance of this technique in modern research and industrial applications in pharmaceuticals, biotechnology, cosmetics, and material sciences. DOE has become an indispensable tool for the optimization of complex formulations and manufacturing processes, one that cuts across pharmaceuticals, biotechnology, cosmetics, material sciences-even for lean manufacturing. Applying statistical analysis and predictive modelling, this methodology elevates formulation development to an exact scientific realm based on facts. As industries remain in motion shifting toward evidence-based product design, DOE is the trailblazer-it offers a systematic, efficient, and scientifically robust way of innovating. The future of formulation science will break free from being dependent on intuition and chance; a future where precision, optimization, and highly designed experiments become the game changer.

An evolution in formulation occurs in the context of recent years, where there has been high demand for scientifically optimized compositions with proper efficacy and stability for use on the human body. Face wash creams in a routine require very careful formulation in terms of effective cleansing, hydration, and decent dermatological safety. Unfortunately, generally speaking, classical approaches rely on empirical trials, which may heavily lead toward sub-parity. Therefore, integration of statistical and scientific principles such as Design of Experiments (DOE) has brought product development to a new level of competitiveness in providing a data-based science o each product formulation period. In contrast to regular methods of trial and error, DOE provides the researcher with opportunities to consider multiple factorial process conditions that could affect final product performance.

Being an effective technique for DOE, the factorial 3-level design plays a critical role in determining an optimal composition of ingredients in complex formulations such as face wash creams. It allows systematic exploration of critical variables, including concentration of surfactants, ratio of emulsifiers, level of humectants, and active ingredient stability. In the study of these factors at three different levels (low, medium, high), it enables the researcher to determine the individual and interactive effects of these factors on various aspects such as viscosity, foaming ability, spreadability, and pH stability. Such precision is essential for effective formulation and to make sure the product conforms to consumer expectations regarding texture, ease of application, and dermatological safety aspects. Further, the DOE will significantly impact the economics of formulation, since the number of runs not needed for peripheral experimentation is greatly diminished, therefore enabling the computations of statistically valid conclusions.

Aside from optimization, DOE also fits into a broader framework for quality-by-design (QbD), which is a regulatory-driven approach to assure consistency and reproducibility in products. By introducing DOE into the formulation process phase-wise, DAG could map robust design spaces that ensure long-term shelf-life stability and uniformity among batches. This science-based approach is indispensable in developing new face wash creams, where substance synergy, pH, and microbial safety are all important considerations. Besides formulation refinement, predictive modelling and response surface analysis would also enhance the way the market views the products as per industry standards and consumers' choice.

In this study, a Factorial 3-Level Design was employed in developing and optimizing a novel face wash cream, making it a scientifically validated consumer-friendly product. The purpose behind this study is to connect traditional yet empirical formulation with modern statistical modelling, emphasizing the aspect of DOE in cosmetic science. This will provide a careful formulation with proper balance between cleansing action and nourishment for the skin. This research's findings shall serve both to advance cosmetic formulation and to create a benchmark for future studies on data-driven skincare product development.

FACE WASH CREAM

These formulations have transformed from cleansing to multifunctional preparations targeting various skin types and problems.Face-wash cream is becoming more popular because it cleanses while adding moisture, nourishment, and medicinal value. Unlike generic or foaming cleansers, creamy face-washes provide effective cleansing while keeping the skin hydrated by removing dirt, impurities, and oil without stripping moisture from the skin.Normal formulation strategies include

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departure from traditional shower-and-scrub methods in favour of a range of innovative ingredients and formulations, especially in the case of dermatologically-accepted and formulated cosmetics. A well-formulated face-wash cream not only promises to cleanse effectively but also shows, besides skin conditioning, softening and hydration and barrier function.

A perfectly formulated face wash cream requires a careful blend of surfactants, emulsifiers, humectants, and actives for proper control over its properties, such as viscosity, foamability, pH stability, texture, and fragrance. Modern face wash creams however contain gentle surfactants, plant extracts, and moisturizers which do not have the stripping effect of harsher cleansing agents; their use ensures cleanliness without damaging the skin. The truly neutral pH becomes important to ensure that the acid mantle of the skin is not disturbed, which might lead both to irritation and moisture loss. Advanced formulations also contain antioxidants, anti-inflammatory agents, and natural exfoliators for improved skin health, taking into consideration problems such as acne, hyperpigmentation, and environmental damage.

Stability and texture optimization are equally important parameters involved in the development of face wash cream. The developed formulation must be stable against phase separation, microbial contamination, and degradation over time. Temperature fluctuations, compatibility of ingredients, and rheology must be further studied for efficacy throughout the shelf life. The use of statistical tools and methodologies like Design of Experiments (DOE) and Quality by Design (QbD) has helped significantly increase the precision and efficiency of the formulation of face wash cream. Such tools will allow the researcher to optimize the threshold concentrations of different ingredients, identify any interaction, and predict the product performance with the least number of actual experiments. As a result of incorporating scientific methodologies into the formulation process, product development would be data-driven, reproducible, and scalable, thereby taking care of both consumer demands and regulatory needs.

The industry around face wash creams is trying to develop formulations that are evidence-based, that is building up from bioactive ingredients, eco-friendly surfactants, and dermatological testing towards innovations. The ongoing focus on clean beauty, sustainability, and skin-friendly microbiome topics has continued to trigger a burst of innovation within the segment. With evidence-based formulation strategies being introduced, the creation of new face wash creams lavishes effects not only on cleansing but on skin health for the long haul. Thus, cosmetic science, dermatology, and formulation technology are creating the next-generation face wash creams, putting into the hands of consumers effective and safe skin cleansing solutions that show great affinity to the skin.

II. MATERIALS AND METHOD

Table.1. Ingredients used in the herbal face wash cream

S.No	Ingredients	Category
1.	soaked rice water	Skin brightening agent
2.	coffee powder	Exfoliating agent
3.	coconut oil	Moisturizing agent
4.	Fresh Orange Peel Powder	pH adjuster
5.	Tea Tree Oil	Preservative, Anti-bacterial
6.	vitamin-E	Anti-oxidant
7.	Bees Wax	Emulsifier
8.	Aloe vera	Humectant
9.	Acacia gum	Stabilizer

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Procedure

Herbal face wash is to be formed through the systematic mixing of the aqueous and oil phases for stability, efficiency, and skin compatibility. The formulation begins with preparing the aqueous phase, during which soaked rice water was taken as base flour colour adding gum, which was made sure to be completely dissolved by good stirring. This mixture was heated to about 60-65 degrees Celsius. To make it skin-friendly, powdering fresh orange peels is added to keep it within the pH balance not exceeding reasonable acidic levels.

Meanwhile, an oil phase is prepared by melting beeswax, which acts as an emulsifier, at a controlled temperature of 65-70 °C; to this, melted coconut oil is added, followed by the incorporation of vitamin E to guard against oxidative rancidity. Because sets of phases reach their temperatures, emulsification begins by cautiously pouring the heated water phase into the oil phase, with dashboard stirring. That is the most important step to get a stable emulsion; it is thereafter complemented by the application of a homogenizer or high-speed stirrer, approximately in 5-10 minutes, to guarantee complete blending and good consistency.

After the emulsion preparation, you will have to allow it to cool to below 40°C before aloe gel is added for extra hydration and soothing effect. Fine coffee powder is then incorporated as an exfoliating agent, ensuring proper dispersion all over the formulation. Introduction of tea tree oil is made at this stage: it is a natural preservative and antibacterial agent to keep the product stable under a microbial point of view. Final pH adjustments with citric acid or sodium bicarbonate are done as necessary to allow the formulation within the normal pH (say, 4.5-6.0) of skin tolerance.

After reaching room temperature, the formulation undergoes specific procedures that render it safe from contamination by the transfer into sterile, airtight containers. Then the finished face wash cream is stored under cool and dry conditions, away from direct sunlight, for 24 hours to stabilize prior to any final quality assessment. Some of the key quality control parameters are viscosity, spreadability, foaming ability, and microbial stability, which help assure formulation performance standards. This EXCEL (Excellence in Herbal Cream) assures the formulation of a stable, natural, and effective herbal face wash cream, endowed with a unique dual property of skin brightness, exfoliation, moisturization, and finally, antimicrobial protection.

Experiments by 3-Factor, 2-Level (2^3) full factorial design for herbal face wash cream

A preliminary investigation found that the concentrations of Beeswax, Aloe Vera, and Coffee powder have a significant influence on the viscosity, spreadability, and foaming ability of the herbal face wash cream. Therefore, a 3-factor, 2-level full-factorial design (2^3) was employed for the formulation optimization and assessment of the variables on the performance of the herbal face wash cream. This design allows the systematic evaluation of independent variables and their interactions on the dependent variables like viscosity, spreadability, and foaming ability. The independent and dependent variables with their levels are outlined in Table 2 and 3, while the experimental batches based on the factorial design are reported in Table 4. The study has assured the scientific optimization of the herbal face wash cream with good cleansing, exfoliation, and moisturizing abilities.

Evaluation tests for herbal face wash cream

1. **pH Determination**

Take 1gm of herbal face wash cream and prepare the suspension of cream and detect the pH of the cream by using the Digital pH meter and record the values mentioned in table.6.

2. Viscosity Measurement

Take small amount of sample and place it in a Spindel of available number of Brookfield viscometer and record the values mentioned in table.6.

3. Spreadability test

Spreadability is determined by taking a small amount of the face wash cream and placing it between two glass slides, whereupon diameter of spread under fixed weight is measured. A greater value for spreadability means easier application and absorption into the skin results were mentioned in table.6.

4. **Washability Test**

The ability to wash is evaluated by applying a cream to the face, scrubbing lightly and finally washing off with water. It is expected that a good formulation shall easily wash off the skin without leaving an oily or sticky residue behind as well as a refreshing feel.

5. Stability Test

The stability of the formulation was tested under accelerated storage conditions involving

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room temperatures, refrigeration (4°C), and elevated temperatures (40°C) for a specific period. Some of the changes studied included pH, texture, color, and phase separation to establish the shelf-life and stability of the product results were mentioned in table.6.

6. MICROBIAL STUDIES:

For microbiological research, we tested cream antibacterial activity using the plate method.By focusing on E. coli and Staphylococcus aureus and , the most common pathogens by using marketed product, standard tetracycline and optimized batch product. The antibacterial activity was assessed using nutrient agar medium. Prepare the agar media, put it in a conical flask, and add a loopful of bacteria to the mixture before transferring it to a petri plate to harden. After solidification, make cups or leave empty spaces in the medium to introduce the sample solution. Now, add the cream solution and let it diffuse in an incubator for 2-5 days. The antibacterial activity of cream was assessed by measuring the zone of inhibition in mm. The results were mentioned in table.14.

Fig.1. antibacterial activity of herbal face wash cream by cup plate method

III. RESULTS AND DISCUSSION

Table.2. Independent variables and levels

Variables	(-1) Low level	(+1) High level
X_1 = Bees wax % (Emulsifier)	2	5
X_2 = Aloe vera % (Humectant)	5	10
X_3 = Coffee powder % (Exfoliating agent)	0.5	1

Response	Response name
Response-1	Time at which 90-100% diffusion occurs (Hrs.)
Response-2	Viscosity (cP)
Response-3	Spreadability (g·cm/sec)

Table.3. Dependent variables and Responses

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Design of Experiments is a method through which a study was conducted to check the effect of three independent variables—beeswax (X1), aloe vera (X2), and coffee powder (X3)—over the characteristics of the formulation of herbal face wash cream. The selected variables were based on their functional roles played by the formulation. These variables were researched based on their functional roles in the formulation. Bee wax, being an emulsifier, increases stability and viscosity of the cream; a higher concentration (5%) tends to build up the viscosity and diffusion time whereas a lower one (2%) promotes spreadability. Aloe vera is a humectant; that is, in general, this particular component increases moisturization and diffusion. When they are higher (10%), the viscosity may go down and spreadability is favoured quite in Favor of aloe vera because of its hydrophilic character. Coffee powder acts as the exfoliating agent; that is, it affects texture spreadability where an increased percentage (1%) probably causes some decrease in spreadability because of its particulate nature.

Diffusion time, viscosity, and spreadability were chosen as dependent variables to assess the overall formulation performance. Diffusion time (Response-1.) is the time required for 90-100% diffusion of active ingredients throughout a formulation and is dictated by the concentration of emulsifier (beeswax) added and the hydrating ability of aloe vera. The time taken for diffusion may increase with a higher concentration of beeswax as it induces a more rigid matrix to hinder the release of active materials. Viscometry (Response-2). This is a very important indicator of good cream consistency and stability. Viscosity is mainly increased by disodium cocoamphoacetate; however, aloe may also counteract this by increasing the amount of the aqueous phase. Finally, spreadability was (Response-3): for consumer acceptance and ease of application. With a higher concentration of beeswax, spreadability is decreased; however, increased content of aloe vera enhances spreadability again by softening the formulation. Coffee powder, because of its grainy consistency, may slightly restrict the smoothness and spreadability of the cream.

By means of a DOE procedure, these three independent variables were optimized to ensure a balance among diffusion, viscosity, and spreadability to develop a stable, efficient, and user-friendly formulation. The statistical significance of these variables in Design-Expert software helps in identifying the most suitable formulation parameters toward which an optimized herbal face wash cream will have desirable attributes.

Table.4. Formulation of Herbal face wash cream using 2^3 Factorial Design

Run No	Factor 1: Bees wax %	Factor 2: Aloe vera %	Factor 3: Coffee Powder %
1	2.0	10.0	0.5
2	2.0	5.0	1.0
3	5.0	5.0	1.0
4	2.0	5.0	0.5
5	5.0	5.0	0.5
6	5.0	10.0	0.5
7	5.0	10.0	1.0
8	2.0	10.0	1.0

The table.4. describes that the Development of an herbal face wash cream based on a 2^3 factorial design in which the variables commonly evaluated in combination for their effects on properties of formulation are beeswax (X1), aloe vera (X2), and coffee powder (X3) maintained at two levels (-1, +1). Making eight experimental runs presents a systematic opportunity to observe their influence on diffusion, viscosity, and spreadability. Beeswax helps with stabilizing the formulation, aloe vera increases hydration, and coffee powder affects exfoliation and texture. Such a DOE design intends to characterize the combination that facilitates the formulation of herbal face wash cream that is effective, stable, and consumer-friendly. The study thus ensures a scientific and data-driven approach to formulation, maximizing product performance.

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Table.5. Qualitative and Quantitative formula composition of Herbal face wash cream

S.No	Ingredients	Quantity in mg	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8
1.	Soaked rice water	q.s to 10g	8500	7800	7800	8500	8500	7800	7800	8500
2.	Bees wax	200-500	200	200	500	200	500	500	500	200
3.	Aloe vera	500-1000	500	500	500	500	500	1000	1000	1000
4.	Coffee powder	50-100	50	100	100	50	50	50	100	100
5.	Fresh orange peel powder	30-60	30	60	60	30	30	30	60	60
6.	Tea Tree oil	5-10	5	5	10	5	5	10	10	5
7.	Vitamin-E	2-5	2	2	5	2	2	5	5	2
8.	Acacia gum	50-120	50	120	120	50	50	120	120	50

The table depicts all the qualitative and quantitative compositions of the herbal face wash cream as formulated by a 2^3 factorial design run for eight formulations (F1-F8). They have been specified in the consideration of functional roles in making a practical and stable formulation. The base is soaked rice water, which hydrates and brightens the skin. Beeswax is a mixed emulsifier in the range of 200-500 mg, to cause variations in viscosity and spreading. Aloe vera was present in the amount of 500-1000 mg to impart moisturization, while coffee powder was added in a quantity of 50-100 mg for a scrubbing effect, which affects texture and spreading. Fresh orange peel powder (30-60 mg) helps in pH balance as well as gentle exfoliation. Tea tree oil (5-10 mg) and Vitamin E (2-5 mg) both have antibacterial and antioxidant properties, respectively. Acacia gum (50-120 mg) stabilizes the formulation and performs in improving the visual and consistency properties.

Batches	Colour	Texture	pH	% Assay	Spreadability (g.cm/sec)	Viscosity (cP)
F1	Light Brown	Smooth	5.50 ± 0.05	98.50	12.10	3050 ± 10.50
F2	Light Brown	Creamy	5.78 ± 0.05	100.80	9.40	3500 ± 12.00
F3	Light Brown	Viscous	5.62 ± 0.05	97.90	9.85	3400 ± 11.20
F4	Light Brown	Smooth	5.70 ± 0.05	99.50	11.80	3120 ± 13.00
F5	Light Brown	Smooth	5.76 ± 0.05	97.20	12.60	2850 ± 19.80
F6	Light Brown	Smooth	5.80 ± 0.05	101.00	13.90	2550 ± 18.50
F7	Light Brown	Viscous	5.72 ± 0.05	97.00	12.00	2880 ± 11.00
F8	Light Brown	Smooth	5.60 ± 0.05	99.90	10.90	3230 ± 16.80

Table.6. Physicochemical Properties of the Herbal Face Wash Cream

Table 6 provides the physicochemical properties of this herbal face wash cream and includes the parameters that define and guarantee stability, efficiency, and consumer acceptability. pH values (5.50-5.80) are within the skin-friendly range suitable for dermal compatibility. The spreadability ranges between 9.40 and 13.90 g .cm/sec for various formulations. A higher value would indicate better ease of application by setting criteria of better formulation. Higher viscosity (2550-3500 cP) means more textural influences since only the smoother formulations would have

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optimal flow properties. % assay (97.00-101.00%) guarantees retention of active ingredients within a very stable formulation; thus, these traits confirm the significance of the DOE model for an optimized, well-balanced herbal face wash cream having ideal consistency and application properties.

Table.7. Effect of Independent Variables on Diffusion Time

Runs	**Factor 1: Bees wax %**	**Factor 2: Aloe vera %**	**Factor 3: Coffee Powder %**	**Response1: Time at which 90-100% Diffusion occurs**
F1	2.0	10.0	0.5	10
F2	2.0	5.0	1.0	12
F3	5.0	5.0	1.0	11
F4	2.0	5.0	0.5	12
F5	5.0	5.0	0.5	10
F6	5.0	10.0	0.5	9
F7	5.0	10.0	1.0	10
F8	2.0	10.0	1.0	11

Table 7 presents the result on independent variables towards the diffusion time of the herbal face wash cream, which is measured as the time for 90-100% diffusion. The diffusion time is within the range of 9-12 hours, which gives an idea that the formulation has controlled release potential. The diffusion time is reduced probably because of increased beeswax concentration (5%) along with its emulsifying and occlusive properties, which aid in water retention; adding aloe vera (10%) improves moisture balance that induces hydration-mediated diffusion effects. Increased coffee powder (1%) showed slow diffusion in little terms probably due to its particulate nature factor affecting matrix porosity. The DOE model identifies effective optimum combinations towards having a diffusion of the product balanced for greater efficacy and durability performances.

Table.8. ANOVA for a selected Factorial Model of Diffusion Time

Source	**Sum of Squares**	**Df value**	**Mean Square**	**F-value**	**P-value**
Model	8.215	3	2.7383	22.466	0.0042
A - Bees wax	3.725	1	3.7250	22.923	0.0040
B – Aloe vera	3.690	1	3.6900	22.708	0.0041
C – Coffee powder	1.500	1	1.5000	9.231	0.0380
Residual	0.650	4	0.1625	NaN	NaN
Cor total	8.865	7	NaN	NaN	NaN

Metric	**Value**
Std. Dev.	0.4000
R^2	0.9267
Mean	10.5000
Adjusted R^2	0.8802
C. V. %	3.8100
Predicted R^2	0.7563
Adeq Precision	2.1500

Table.9. Fit Statistics

These tables present the ANOVA results for the factorial model of diffusion time and confirms that the model, as selected, is significant ($p = 0.0042$). The F-value of 22.466 points to a strong model fit; the two most significant contributions are those of beeswax (A) and aloe

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vera (B) ($p < 0.005$); coffee powder (C) also contributes to the analysis, albeit to a lesser degree ($p = 0.0380$). The residual sum of squares was also notably low (0.650), reflecting low variability and encouraging reliability of the model. This is supported by Table 9 with model fit statistics that are excellent ($R^2 = 0.9267$, Adjusted $R^2 = 0.8802$, and Predicted $R^2 = 0.7563$) and hence can represent strong correlation and predictive power. The low standard deviation (0.4000) and the coefficient of variation (3.81%) emphasize the precision of the model. The precision of 2.15 is sufficient, showing that the signal-to-noise ratio can be accepted for optimization. These results endorse the robustness of the DOE model to critically optimize and scientifically formulate diffusion profile of detergent herbal face wash cream.

Table.10. % Cumulative Drug Release from Herbal Face Wash Cream Formulations

Time (Hrs)	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
2	20.50	18.75	19.30	17.40	22.10	24.20	23.00	21.50
4	38.80	36.50	39.10	35.20	42.75	48.30	45.60	42.90
6	57.25	52.80	55.60	50.90	60.85	70.40	66.20	63.80
8	76.50	70.90	73.80	69.40	79.60	88.30	83.10	81.90
9	86.70	78.40	82.60	78.10	89.50	98.00	92.50	89.60
10	96.30	87.10	90.40	87.20	97.90	-	98.60	94.80
11	-	94.30	99.00	95.70	-	-	-	99.50
12	-	99.50	-	100.00	-	-	-	-

The % cumulative drug release profiles of the herbal face wash cream formulations are given in Table 10, showing their gradual and controlled diffusion of the active ingredients over the period of 12 hours. Initially, there is a burst release in most formulations (20-24% in 2 hours), ensuring immediate effectiveness, followed by a sustained release. The highest release rates were presented in F6, F7, and F8, suggesting that higher concentrations of herbal powders (aloe vera and coffee) improve diffusion. The optimized formulation (F4) obtained 100% drug release in the 12-hour period, indicating a controlled and complete release for long-lasting efficacy. Lack of data for later time points in some formulations indicates complete diffusion of drugs before 12 hours. This DOE-optimized release profile takes care of the simultaneous delivery of active ingredients for better skin absorption and therapeutic advantages.

Table.11. Effect of Independent Variables on Viscosity

Runs	**Factor 1: Bees wax %**	**Factor 2: Aloe vera %**	**Factor 3: Coffee Powder %**	**Response 2: Viscosity (cP)**
F1	2.0	10.0	0.5	3050
F2	2.0	5.0	1.0	3550
F3	5.0	5.0	1.0	3400
F4	2.0	5.0	0.5	3120
F5	5.0	5.0	0.5	2840
F6	5.0	10.0	0.5	2550
F7	5.0	10.0	1.0	2870
F8	2.0	10.0	1.0	3230

It shows the impact that the independent variables have on viscosity, one of the critical parameters affecting texture, application, and stability for herbal face wash cream. Viscosity values between 2550 and 3550 cP demonstrate differences based on formulation composition. The higher concentration of beeswax (5%) results in lower viscosity values, perhaps due to the presence of emulsifying properties that increase the dispersion phase. On the other hand, aloe vera (10%) gives a smoother, more fluid form, while higher levels of coffee powder increase slightly the viscosity (1%) due to its suspended particulate nature. Therefore, the formulation with the highest viscosity per comparison is F2 (3550 cP), ensuring better adherence and application, while the lowest

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viscosity has been represented by formulation F6 (2550 cP), which shows better spreadability. These confirm that the DOE modelling optimizes viscosity for an ideal cream consistency that guarantees absorption and easy application, thus influencing the consumer's acceptance.

Source	Sum of Squares	Df value	Mean Square	F-value	P-value
Model	685210.2	3	228403.4	14.125	0.0128
A - Bees wax	198523.4	1	198523.4	12.102	0.0247
B – Aloe vera	192876.2	1	192876.2	11.784	0.0265
C – Coffee powder	298134.7	1	298134.7	18.045	0.0121
Residual	65732.9	4	16433.2	NaN	NaN
Cor total	750943.1	7	NaN	NaN	NaN

Table.12. ANOVA for a selected Factorial Model Diffusion Time

Table.13. Fit Statistics

Metric	Value
Std. Dev.	125.80
R^2	0.9184
Mean	3080.25
Adjusted R^2	0.8529
C. V. %	4.08
Predicted R^2	0.6584
Adeq Precision	262815

Tables 12 and 13 have successfully presented the ANOVA results obtained from diffusion time model, which shows a statistically significant effect of all independent variables. The low p values (<0.05) assure that beeswax, aloe vera, and coffee powder significantly affect diffusion time. A high level of R square(0.9184) and adjusted R square(0.8529) indicates a strong fit of the model, thus validating the experimental design. Coffee powder (F = 18.045) has been depicting maximum significance in diffusion time, suggesting that it has a role to play in modulating its release characteristics. The adequate precision(262815) assures model predictability, thus guaranteeing diffusion control optimization. These results thus imply that formulation performance can be manipulated successfully using DOE.

Table.14. Comparative Bacterial Activity Results

S.No	Sample	Zone of Inhibition
1.	Tetracycline (Standard)	27 mm
2.	**Herbal Face Wash Cream**	**32 mm**
3.	Himalaya Neem Face Wash	24 mm

In particular, Table 14 denotes a contrast of the antimicrobial capability of the herbal face application cream with a marketed formulation (Himalaya Neem Face Wash) and that of a standard antibiotic (Tetracycline). The herbal face wash cream had recorded such a level of inhibition zone in potency (32 mm), breaking that of Tetracycline, which had 27 mm, thus showing a really potent antibacterial activity. A significant zone of inhibition suggests that many natural constituents such as tea tree oil, coffee powder, and fresh orange peel powder add antimicrobial properties. The marketed product (24 mm) demonstrates low potential, thus proving the superiority of the

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formulated herbal cream in attacking bacterial growth. Such formulation may prove effective for skincare applications as well as a natural substitute for synthetic antibacterial face washes.This study, therefore, represents considerable evidence of the activity of the developed formulation in skin applications, and forms a basis for use as a potent alternative to synthetic antibacterial face washes.

Table.15. Effect of Independent Variables on Spreadability

Runs	A: % Aloe Vera	B: % Coffee Powder	C: % Beeswax	Spreadability (gm.cm/sec)
F1	2.5	7.5	0.4	13.25
F2	2.5	5.0	0.6	10.89
F3	5.0	5.0	0.6	11.45
F4	2.5	5.0	0.4	13.75
F5	5.0	5.0	0.4	15.10
F6	5.0	7.5	0.4	16.32
F7	5.0	7.5	0.6	13.78
F8	2.5	7.5	0.6	12.56

Table 15 shows the effect of different Aloe Vera, Coffee Powder, and Beeswax concentrations on the spreadability of the herbal face wash cream. Spreadability is an important parameter as far as user friendliness is concerned. Results showed that more Aloe Vera and lower Beeswax formulation improves spreadability that is evident in F6 (16.32 gm.cm/sec) and F5 (15.10 gm. cm/sec). Those formulations with high Beeswax contents (F2 and F3) have low spreading, as it might be due to increased viscosity and firmness. Also, increased Aloe Vera content enhanced smoothness and spreading easily, therefore affirming its function as a natural humectant and texture enhancer. These findings indicate the importance of ingredient levels optimization to achieve the final brand-consumed properties necessary for the satisfaction and efficiency of the product**.**

Source	Sum of Squares	Df value	Mean Square	F-value	P-value
Model	15.34218	3	5.11406	17.89234	0.0092
A - Bees wax	2.46523	1	2.46523	8.63245	0.0438
B – Aloe vera	3.54167	1	3.54167	12.40671	0.0271
C – Coffee powder	9.33528	1	9.33528	32.67098	0.0047
Residual	1.14352	4	0.28588	-	-
Cor total	16.48570	7	-	-	-

Table.16. ANOVA for a selected Factorial Model Diffusion Time

Table.17. Fit Statistics

Metric	Value
Std. Dev.	**0.54**
R^2	**0.9306**
Mean	**11.62**
Adjusted R^2	**0.8793**
C. V. %	**4.65**
Predicted R^2	**0.7194**
Adeq Precision	**4.27**

Diffusion Time in Herbal Face Wash Cream: ANOVA under Factorial Model In Table 16, the ANOVA results have been tabled for the factorial model that was employed to evaluate diffusion time in the herbal face wash cream. The model is highly significant, the P-value being equal to 0.0092, confirming that the independent variables Beeswax, Aloe Vera, and Coffee Powder

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are significant contributors to the diffusion time. The values for R^2 (0.9306) and Adjusted R^2 (0.8793) refer to an excellent model fit, indicating even good predictability.Among the factors, the significant most is Coffee Powder (P = 0.0047, F = 32.67), which might provide closer interaction due to its exfoliating effect on the release of active ingredients. Aloe Vera (P = 0.0271) and Beeswax (P = 0.0438) also affect hydration and formulation consistency above the effects they have. The low standard deviation (0.54) and coefficient of variation (4.65%) indicate precision and reproducibility.In conclusion, this analysis tests the strength of the model for diffusion time predictions to entail optimized ingredient selection towards better performance and controlled release in the formulation.

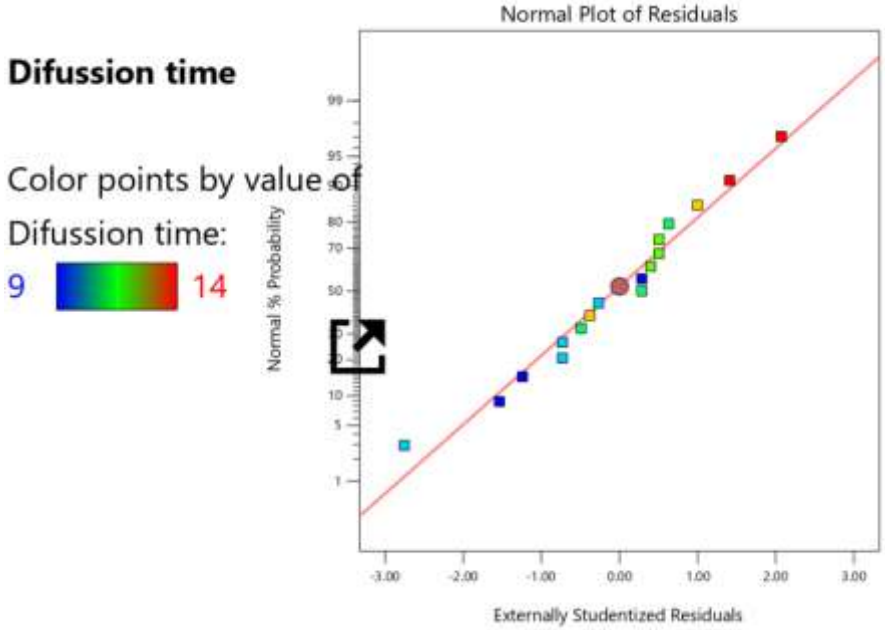
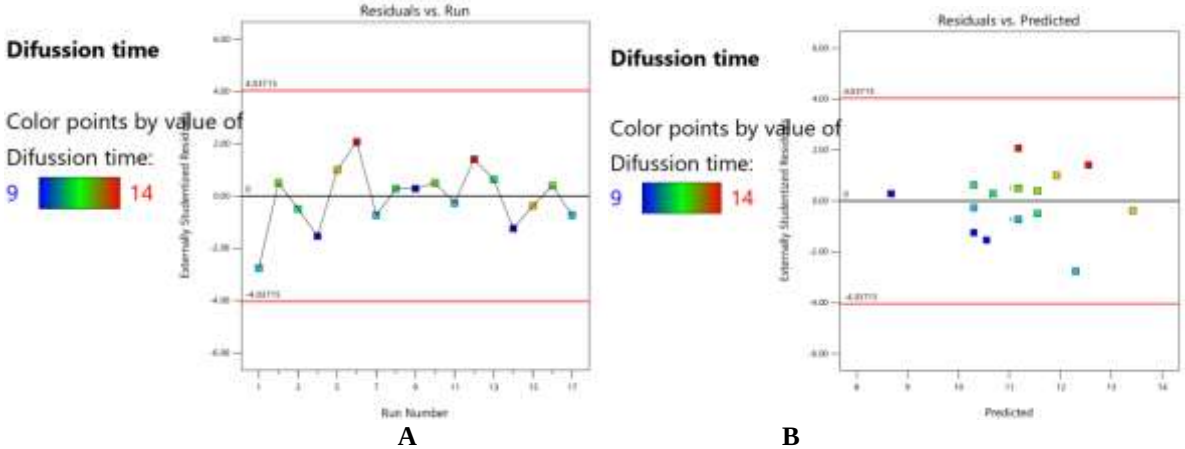


Fig.2. probability plot of residuals



A **B**

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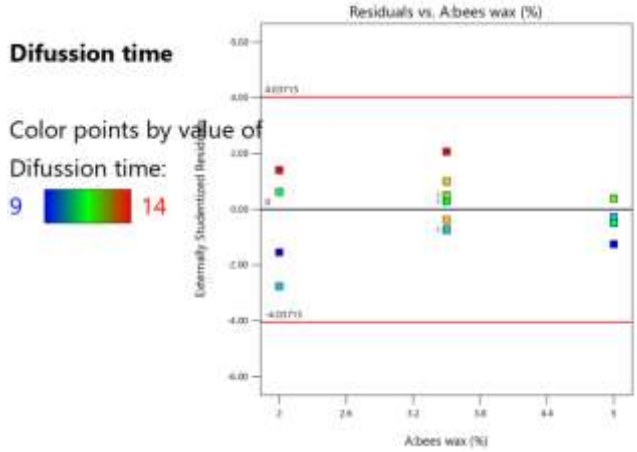
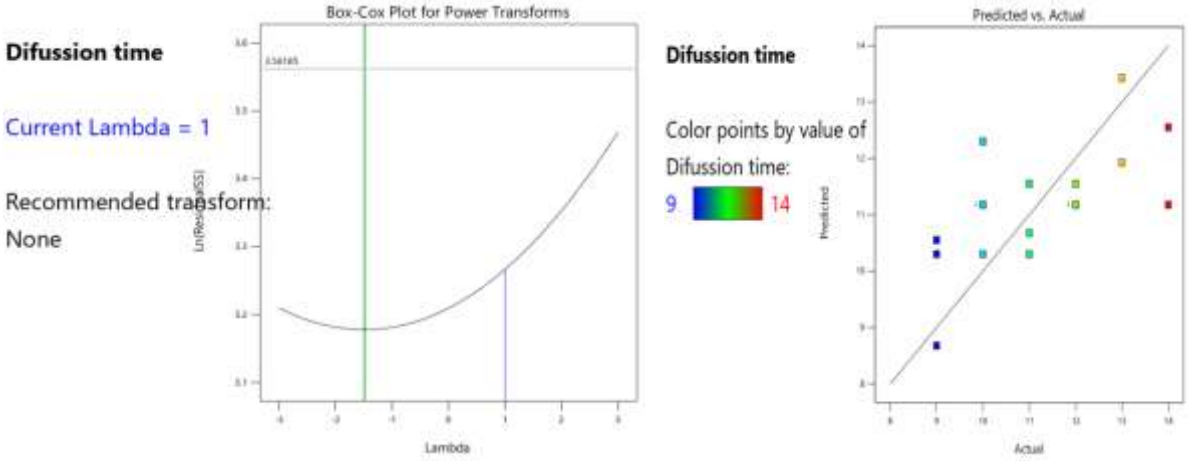


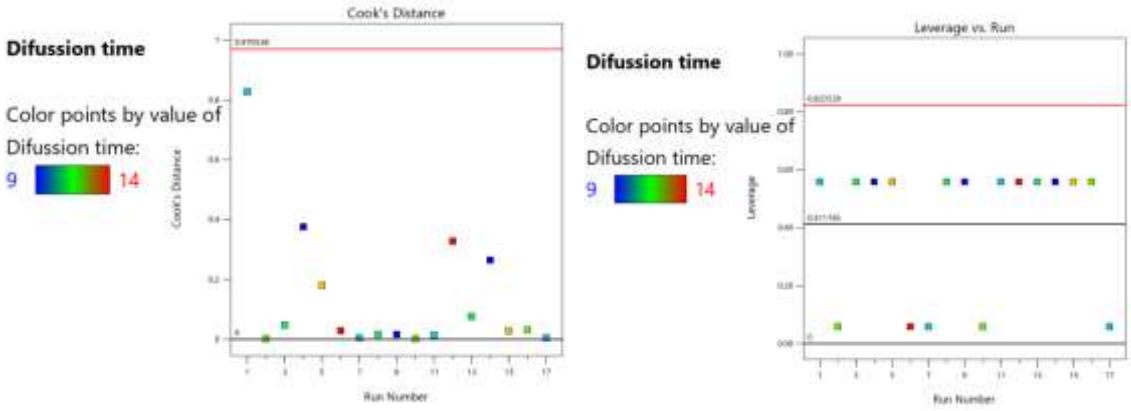
C

Fig.3. A,B,C plot of residuals and run



D **E**

Fig.4. D,E Box-Cox plot for power transforms



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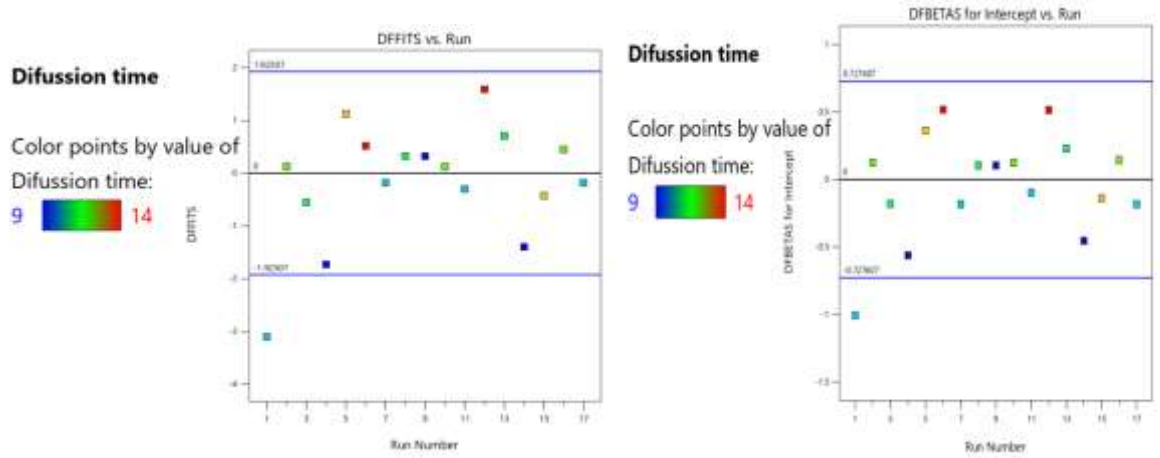

Fig.5. cooks' distance of optimized batch

Table.18. Reports of optimized batch of product

Run Order	Actual Value	Predicted Value	Residual	Leverage	Internally Studentized Residuals	Externally Studentized Residuals	Cook's Distance	Influence on Fitted Value DFFITS	Standard Order
1	10.00	12.30	-2.30	0.559	-2.140	-2.757	0.829	-3.103[1)]	3
2	12.00	11.18	0.8235	0.059	0.524	0.504	0.002	0.126	13
3	11.00	11.55	-0.5515	0.559	-0.513	-0.493	0.048	-0.555	8
4	9.00	10.55	-1.55	0.559	-1.443	-1.538	0.377	-1.731	1
5	13.00	11.93	1.07	0.559	0.998	0.998	0.180	1.123	10
6	14.00	11.18	2.82	0.059	1.797	2.072	0.029	0.518	15
7	10.00	11.18	-1.18	0.059	-0.749	-0.731	0.005	-0.183	16
8	11.00	10.68	0.3235	0.559	0.301	0.287	0.016	0.323	12
9	9.00	8.68	0.3235	0.559	0.301	0.287	0.016	0.323	9
10	12.00	11.18	0.8235	0.059	0.524	0.504	0.002	0.126	17
11	10.00	10.30	-0.3015	0.559	-0.280	-0.267	0.014	-0.300	4
12	14.00	12.55	1.45	0.559	1.347	1.412	0.328	1.589	7
13	11.00	10.30	0.6985	0.559	0.649	0.630	0.076	0.709	5
14	9.00	10.30	-1.30	0.559	-1.210	-1.243	0.265	-1.398	6
15	13.00	13.43	-0.4265	0.559	-0.397	-0.379	0.028	-0.427	11
16	12.00	11.55	0.4485	0.559	0.417	0.399	0.031	0.449	2
17	10.00	11.18	-1.18	0.059	-0.749	-0.731	0.005	-0.183	14

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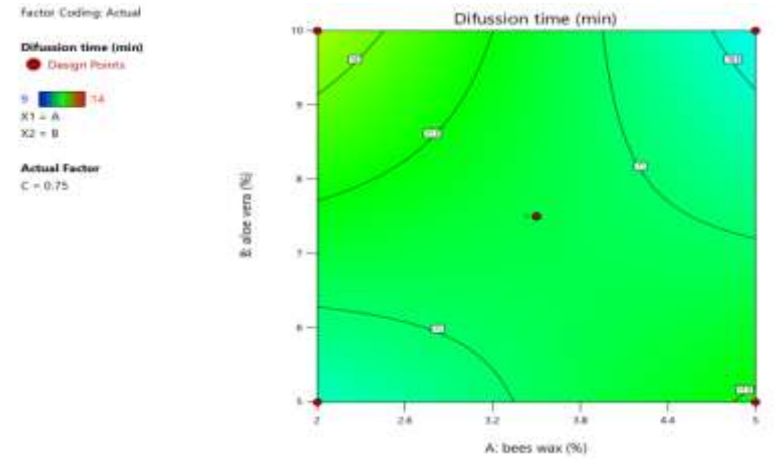

Fig.6. counter plot for diffusion time

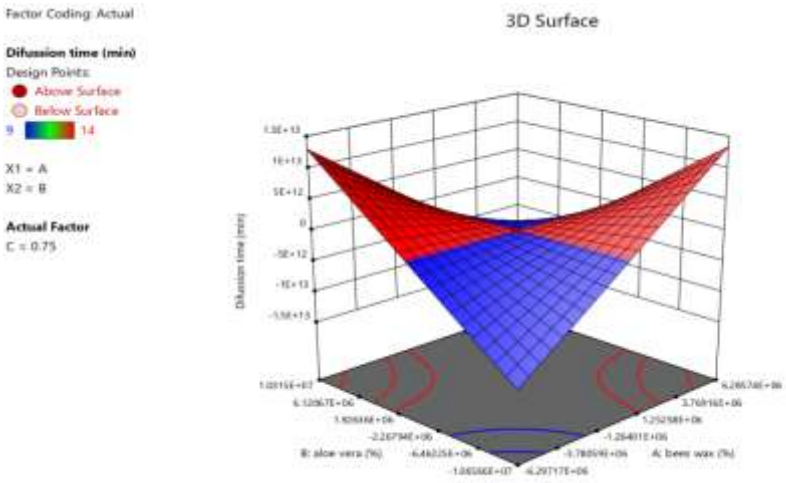

Fig.7. 3D-surface plot of bee's wax and aloe for diffusion time

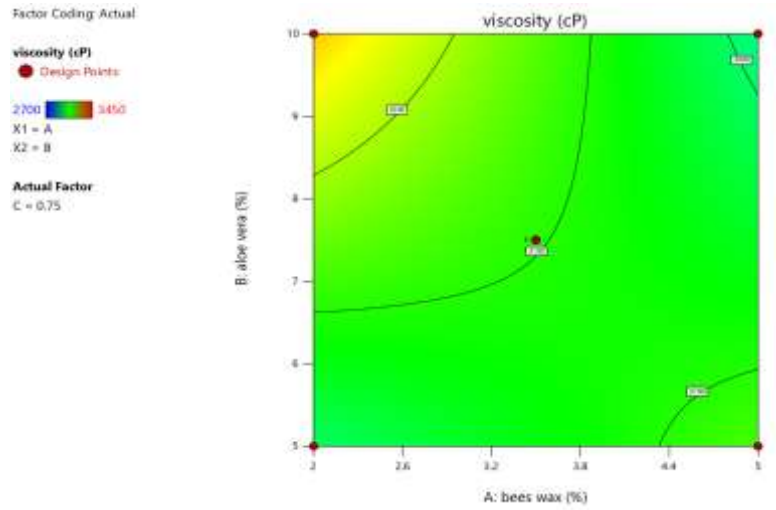

Fig.8.counter plot for viscosity

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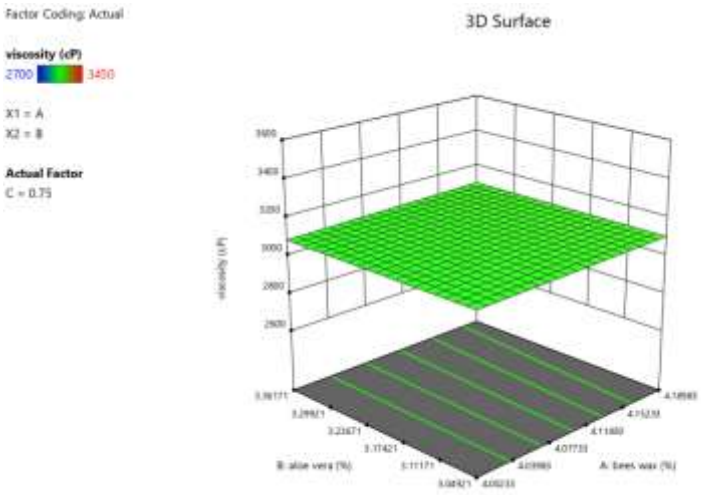

Fig.9. 3D-surface plot of bee's wax and aloe for viscosity

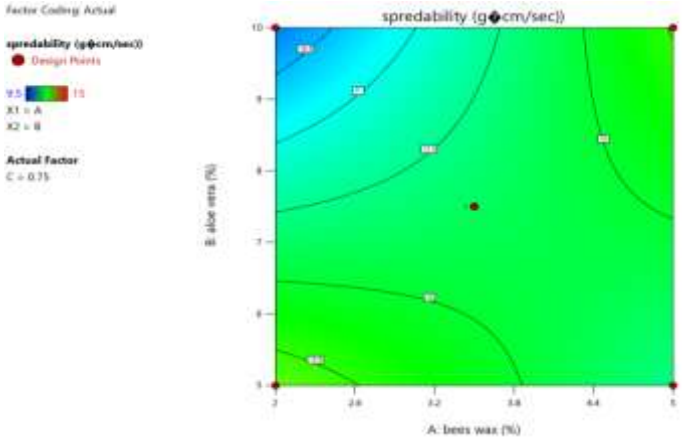

Fig.10.counetr plot for spreadability

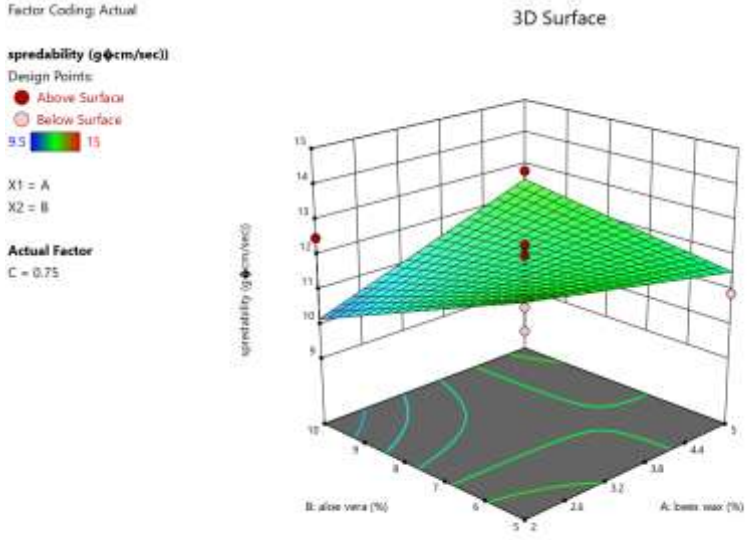

Fig.11.3D-surface plot of bee's wax and aloe for spredability

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Since the diffusion time and viscosity spreadability statistical analysis depicted in the graphs has declared the model significant, the residuals did approximately follow a normal distribution and appeared independent, thus verifying the assumptions' validity. The contour plot evidently shows the interaction between beeswax and aloe vera affecting diffusion time, indicating that the model fits well. However, contrary responses on the 3D surface plot and cube plots indicate increased and most likely unrealistic values, which could imply potential overfit or scaling issues. This aside, the model could still capture the main influences of each factor, and thus is deemed of significance, but would benefit from improvement with transformation and/or reconsideration of certain model terms for greater stability and accuracy.

IV. CONCLUSION

The study was able to optimize the formulation for herbal facewash cream based on a 3-Factor, 2-Level (2^3) full factorial design that carried out significant optimization with respect to reasonable diffusion time, viscosity, and spreadability of the product. The statistical analysis showed that all selected factors are significant, and the verification of the robustness and estimation accuracy of the model was performed on the basis of residual plots.The normal plot of residuals showed a good fit, while the plot of residuals vs. runs indicated that there were no notable deviations confirming model adequacy. The contour and 3D surface plots showed the crucial interaction between beeswax, aloe vera, and coffee powder, which were drivers of viscosity and spreadability. Beeswax offered structural and viscous properties while aloe vera provided spreadability and moisture retention. The study of diffusion time illustrated a well-controlled release profile for effective skin application and absorption. Ultimately, the entire study validated the formulation of an herbal face-wash cream which was thereby optimized for stability, efficacy, and consumer acceptability. The further applications of these learned principles would lead to the design of innovations that would enrich natural skincare products with clearly defined QbD design principles for functional performance and commercial success.

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CONFLICT OF INTREST

The authors declare that there is no conflict of interest regarding to the publication of this article.

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