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Research Article

DEVELOPMENT AND CHARACTERIZATION OF NASAL *IN-SITU* GEL OF SUMATRIPTAN AND NAPROXEN FOR EFFCTIVE TREATMENT OF MIGRAINE USING 3^2 FACTORIAL DESIGNS

Suraj Nanaware*, Amit Nayak, Alok Pal Jain

Sarvepalli Radhakrishnan University, NH-12 Hoshangabad Road, Misrod, Bhopal, Madhya Pradesh, India

**Corresponding author: surajxl@yahoo.com*

ABSTRACT

Over a few decades, advances in the *in-situ* gel technologies have spurred development in may medical and biomedical applications including controlled drug delivery. For locally acting intra nasal drugs, an extended residence time in the nasal cavity is desirable and related to a prolonged effect. The aim of the present work was to design a nasal delivery system with improved mucoadhesive properties that could provide prolonged retention time for the treatment of the migraine. A 3^2 factorial design was used to investigate the effect of the amount of Gellan Gum, CMC and Tween 80 as independent variables. Gelling time (sec.), Viscosity (cps) and percentage drug content were taken as dependent variables. The formulations were tested for mucoadhesive strength In-vitro drug release study. The study shows that administering Sumatriptan and Naproxen using *in-situ* gel is feasible. As a result, the created *in-situ* gel formulation could be a potential carrier for Sumatriptan and Naproxen, especially given its ease of manufacture and scale-up.

Keywords: Controlled drug delivery, Tween 80, Viscosity, Migraine

1. INTRODUCTION

Headache disorders, which are characterized by chronic headaches, are one of the most prevalent nervous system disorders. Headache is a debilitating and incapacitating feature of a few primary headache disorders, including migraine, tension-type headache, and cluster headache [1]. The migraine headache is the most common, prevalent, debilitating, and largely treatable of these, but it is nevertheless under-appreciated and under-treated [2]. Migraine is a common chronic headache disease characterized by frequent attacks lasting 4-72 hours, with a pulsating quality, mild or extreme intensity, and nausea, vomiting, photophobia, or phonophobia [3].

Migraine is the world's second most common headache and the most prevalent cause of headache-related and neurologic disability [4]. The term "migraine" derives from the Greek word "hemicrania," which means "half of the head," and it refers to one of the most prominent features of the condition: in many cases, the pain only affects half of the head. However, the pain can sometimes be felt bilaterally, in the back or front of the head, and on rare occasions all over the body and face ('migrainous cor-palgia'). The pain is often throbbing and pulsatile in nature, and it is exacerbated by any type of movement of the body or head [5].

In-situ gel forming polymeric formulations are drug delivery systems that are in a sol or suspension form before being administered in the body and then go through a gelation process in the body. *In-situ* gel forming systems have received a lot of attention as vehicles for long-term drug delivery [5].

In order to contain the dispersed drug and other excipients, an *in-situ* gel system requires the use of a gelling agent that can form a stable sol/suspension system. This sol/suspension system would gel in a gastric environment, triggered by ionic complexation caused by a pH change. A gellan gum or sodium alginate solution containing calcium chloride and sodium citrate is used, which complexes free calcium ions and only releases them in the stomach's acidic environment. As a gelling agent, gellan gum or sodium alginate may create a range of textures in the final product, from hard, non-elastic, brittle gels to fluid gels [6]. The free calcium ions become entrapped in the polymeric chains of gellan gum or sodium alginate, inducing crosslinking and the formation of a matrix structure. The formation of double helical junction zones is accompanied by the re-aggregation of double helical segments to form a three-dimensional network through

cation complexation and hydrogen bonding with water [7].

In the present research work, *in-situ* gel was prepared containing naproxen and sumatriptan. *In-situ* gel was prepared using gellan gum as geling agent. Additionally, a mucoadhesive polymer *e.g.* Sodium CMC and surfactant (Tween 80) was also incorporated in the same formulation. The preparation will be liquid before administration but it becomes gel on administration. The gel formation will occur which may be due to the ionic interaction of pectin or gellan gum or change in pH and temperature. Mucoadhesive polymer will increase the retention time by providing strength to adhere the formulation with mucosa in nasal cavity. After gelling, the formulation will release the drugs in sustained manner and will provide symptomatic reliefs from migraine pain. *In-situ* gel containing both drugs is a novel approach which will deliver both drug in sustained and controlled manner and maintain therapeutic level in the body for effective management of migraine pain. The formulation will definitely reduce the side effect associated with both drug and minimizing the drug loss due to first pass effect which was more in case of oral delivery. It will also reduce the cost. The proposed formulation will definitely improve the health of patient as well as our society members who suffered from the disease.

2. MATERIAL AND METHODS

2.1. Material

Sumatriptan and Naproxen were obtained from Sun Pharmaceuticals Ltd. Vadodara, Gujarat as gift sample. Gellan Gum was obtained from Himedia Pvt. Ltd. Sodium Carboxymethyl cellulose From Merck Ltd, Mumbai, Sodium chloride from Loba chemicals, Tween 80 from Central Drug House, Mumbai, India. All other chemicals and solvents were of analytical grade and used as received. Distilled water was prepared in laboratory using all glass distillation apparatus.

2.2. Formulation development of *In-situ* gel

Gellan gum was weighed and dispersed in ultra-pure water. The dispersions were then stirred by mechanical stirrer (Remi motors ltd, Mumbai, India,) for 30 min at 90°C in a water bath and then cooled to room temperature. Tween 80 and sodium CMC were weighed and dissolved in ultra-pure water, which was then heated to 900°C and cooled to room temperature. It was diluted with 10 mL of chilled water. Sumatriptan and Naproxen were sonicated for 30 minutes in a small amount of ultra-pure water. Slowly, with constant stirring, sodium CMC and tween 80 drug solutions were applied to the gellan gum solution. Simultaneously, appropriate amounts of benzalkonium chloride were added [8]. Bottles are packed with the formulations. The formulation layout for the factorial design batches (F1 to F17) are shown in table 1.

Table 1: Composition of *In-situ* gel on the basis of Box behnken design

F. Code	Std	Run	Factor 1: A Gellan Gum % w/v	Factor 2: B Sodium CMC % w/v	Factor 3: C Tween 80 %w/v
F1	8	1	0.4	0.75	0.3
F2	6	2	0.4	0.75	0.1
F3	15	3	0.3	0.75	0.2
F4	16	4	0.3	0.75	0.2
F5	3	5	0.2	1	0.2
F6	10	6	0.3	1	0.1
F7	7	7	0.2	0.75	0.3
F8	2	8	0.4	0.5	0.2
F9	11	9	0.3	0.5	0.3
F10	17	10	0.3	0.75	0.2
F11	9	11	0.3	0.5	0.1
F12	12	12	0.3	1	0.3
F13	1	13	0.2	0.5	0.2
F14	4	14	0.4	1	0.2
F15	13	15	0.3	0.75	0.2
F16	14	16	0.3	0.75	0.2
F17	5	17	0.2	0.75	0.1

2.3. Experimental Design

The present study consisted of a 2-level three-factorial (3^2 design for experimentation. Statistical experimental design was performed using a software DESIGN EXPERT® trial version (Stat-Ease Inc., Minneapolis, USA). Response surface graphics were used to show the factor interaction between the considered variables. Selected independent variables studied were the concentration of Gellan Gum (X_1); Sodium CMC (X_2); and Tween 80 (X_3) added to the formulation. Three factorial levels coded for low, medium, and high settings (−1, 0 and +1, respectively) were considered for three independent variables. The selected dependent variables investigated were Gelling time (sec.) (Y_1), Viscosity (cps) (Y_2) and Drug Content % (Y_3). The number of trials required for the study is based on the number of independent variables selected. A total of 17 experimental runs were required for analyzing the interaction of each level on formulation characters and to optimize. Table 1 shows the factors chosen and different factor level settings. The box behnken design was used to test for critical formulation and process variables in the production of In situ gels. Table 2 shows the high and low levels of different variables that were tested for their effect on the growth of Sumatriptan and Naproxen in situ gels.

Table 2: Screening of Influential Variables

Factor	Name	Units	Type	Minimum	Maximum	Coded Low	Coded High
A	Gellan Gum	% w/v	Numeric	0.2000	0.4000	-1 ↔ 0.20	+1 ↔ 0.40
B	Sodium CMC	% w/v	Numeric	0.5000	1.0000	-1 ↔ 0.50	+1 ↔ 1.00
C	Tween 80	% w/v	Numeric	0.1000	0.3000	-1 ↔ 0.10	+1 ↔ 0.30

2.4. Final Equation in Terms of Coded Factors

Gelling Time = +3.32 +0.4125 A +0.3125 B-0.2250 C-1.08 AB+0.7500 AC-0.0500 BC+0.4775 A^2+ 0.6775 B^2+0.6525 C^2

Viscosity = +62.60+10.50 A+2.25 B-2.25 C-13.50 AB+7.50AC+3.00BC+10.20 A^2+10.70 B^2-3.30 C^2

Drug Content = +96.25 +0.6875 A +0.5000 B-0.2625 C -1.35 AB -0.1250 AC +1.20 BC +0.0855 A^2+0.0105 B^2-0.0645C^2

For given levels of each factor, the equation in terms of real factors may be used to make assumptions about the result. For each factor, the levels should be specified in the original units. Since the coefficients are scaled to match the units of each factor and the intercept is not at the middle of the design space, this equation cannot be used to calculate the relative effect of each factor.

2.5. Evaluation of *in-situ* gel

2.5.1. Gelation study

The Simulated Nasal Fluid, SNF (aqueous solution containing 8.77 mg/ml NaCl, 2.98 mg/ml KCl and 0.59 mg/ml $CaCl_2$ per liter), having the cationic composition of nasal secretions, was prepared according to the report [9]. Gellan gum is a polymer which undergoes change from sol to gel in the presence of cations. Gelation is the process by which the liquid phase (sol) makes a transition into gel. Sumatriptan and Naproxen in situ gel and simulated nasal fluid were mixed in 1:1v/v ratio. The gelation study was done on magnetic stirrer (Magnetic stirrer, Remi). The gelation point was determined when the magnetic bar stopped moving due to gelation. The consistency of formed gel was checked and graded, as indicated in table 5.

2.5.2. Viscosity and rheological study

The viscosity of nasal *in-situ* gel formulation before and after gelation was determined using Brookfield Rheometer R/S-CPS +1600, Lauda Ecoline Staredition RE-204, having cone-and-plate geometry by using spindle coaxial CP75-1. The shear rate was varied from 1 to 1000/s. Samples were applied to the plate using a spatula(approximately 2 ml) to ensure that formulation shearing did not occur. Each point is the average of at least three readings [10].

2.5.3. pH study

pH of all formulations was determined by using pH meter (Electronic India).

2.5.4. Mucoadhesive strength study

The procedure mentioned [11] was used to assess the mucoadhesive strengths of the gel. Nasal mucosal tissue was carefully separated from the nasal cavity of sheep and placed on a glass surface using adhesive tape, while another mucosal segment was attached inverted to the cylinder obtained from a nearby slaughterhouse (Aurangabad). On the mucosal surface, 50mg of gel was added. To ensure intimate interaction, the glass

mounted mucosal surface with gel formulation and the mucosal surface connected to the cylinder were kept in contact for 2 minutes. The weights were raised in the second pan until the two mucosal tissues separated from one another. For each measurement, the nasal mucosa was replaced.

The mucoadhesive force expressed as the detachment stress in dynes/cm^2 was determined from the minimal weight that detached the mucosal tissue from surface of each formulation.

Mucoadhesive Strength (dynes/cm 2) = mg/A (1)

Where, m = weight required for detachment in gram,

g = Acceleration due to gravity (980cm/s2),

A = Area of mucosa exposed.

2.5.5. Drug content

A double beam UV visible spectrophotometer (Labindia 3000+) was used to determine the drug quality of formulations in triplicate. One milliliter of formulation was placed in a volumetric flask with a capacity of 10 ml, diluted with double distilled water, and the volume was changed to 10 ml. A milliliter of this solution was mixed once more with 10 milliliters of double distilled water. Finally, a UV visible spectrophotometer was used to determine the absorbance of the prepared solution.

2.6. *In vitro* drug release

In vitro drug diffusion study of various formulations was performed using Franz diffusion cell [11]. Dialysis membrane having molecular weight cut-off range of 12000-14000 kDa was used as diffusion membrane. Until the experiment, the dialysis membrane was soaked in phosphate buffer pH 6.4 for 6 hours. The dialysis membrane was placed on the diffusion cell, which was packed with 21 mL of phosphate buffer pH 6.4. The donor chamber was coated with a gel containing 10 mg of material. A rotating water bath was used to keep the temperature between 32 and 34 degrees Celsius. At various time periods, 1 ml samples were withdrawn, replaced with the same volume of fresh solution, filtered, and the quantity of drug was estimated using a newly developed simultaneous estimation method.

3. RESULTS AND DISCUSSION

Table 3 includes the value of gelling time, viscosity and drug content. The gelling time of all formulation varied between 2.2±0.2 and 5.7±0 sec. whereas viscosity was found between 52±2cps to 108±5cps. The drug content of all formulations was found 94.2±0.3 to 97.9±0.4 percentage.

Table 3: Evaluations of *in-situ* gel formulations of box-behnken design

F. Code	Gelling time (sec.)	Viscosity (cps)	Drug Content %
F1	5.3±0.1	83±5	96.6±0.4
F2	3.9±0.2	69±4	97.3±0.6
F3	2.8±0.2	58±7	96.3±0.5
F4	3.2±0.2	61±6	96.2±0.4
F5	5.4±0.1	86±5	97.5±0.2
F6	5.2±0.1	72±3	95.8±0.7
F7	3.5±0.2	55±5	95.5±0.8
F8	5.7±0.2	108±5	97.9±0.4
F9	4.2±0.1	62±3	94.2±0.3
F10	4.2±0.3	68±2	96.2±0.2
F11	4.9±0.2	76±4	97.2±0.3
F12	4.3±0.3	70±3	97.6±0.4
F13	2.2±0.2	52±2	93.8±0.5
F14	4.6±0.3	88±4	96.2±0.3
F15	3.2±0.2	63±3	96.2±0.4
F16	3.2±0.2	63±5	96.2±0.2
F17	5.1±0.1	71±4	95.7±0.7

3.1. Response surface plots for Gelling time

The response surface diagrams, known to facilitate an understanding of the contribution of the variables and their interactions.

3.2. Response surface plots for Viscosity

The response surface diagrams, known to facilitate an understanding of the contribution of the variables and their interactions.

3.3. Response surface plots for Drug Content

The response surface diagrams, known to facilitate an understanding of the contribution of the variables and their interactions.

3.4. Experimental results with predicted responses

On the basis of DOE formulation, four formulations were selected as optimized formulation for preparation of *in-situ* gel because the results of experimental values for composition of gels are more similar to the predicted values and also these are within limit (Table 4).

The prepared *in-situ* gels were examined to measure pH and kept. The pH of prepared *in-situ* gels ranged from 5.86±0.04 to 6.82±0.05. These findings prove that those gels were acceptable and physiologically compatible to be used in the nose cavity.

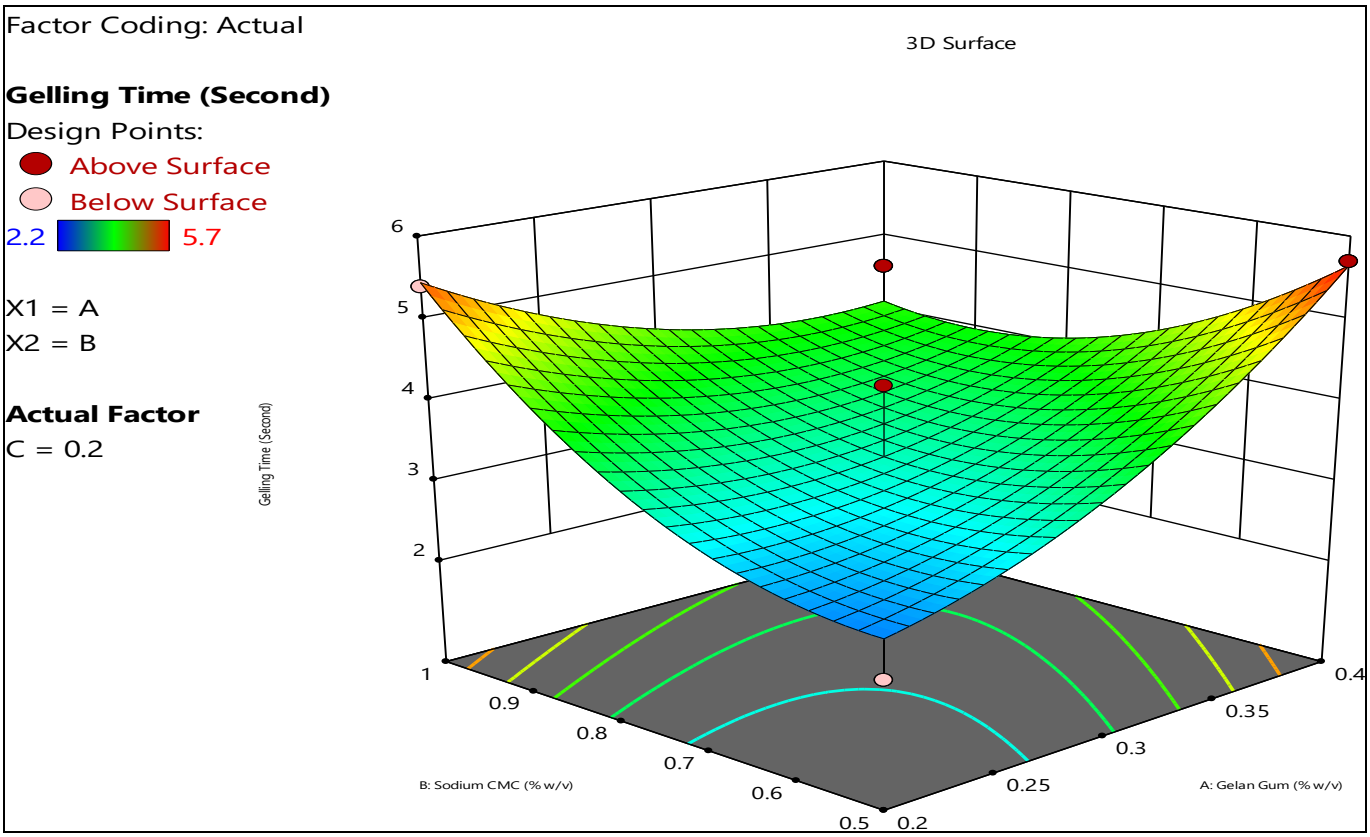

Fig. 1: 3D Surface pot (Gallan gum and Sodium CMC)

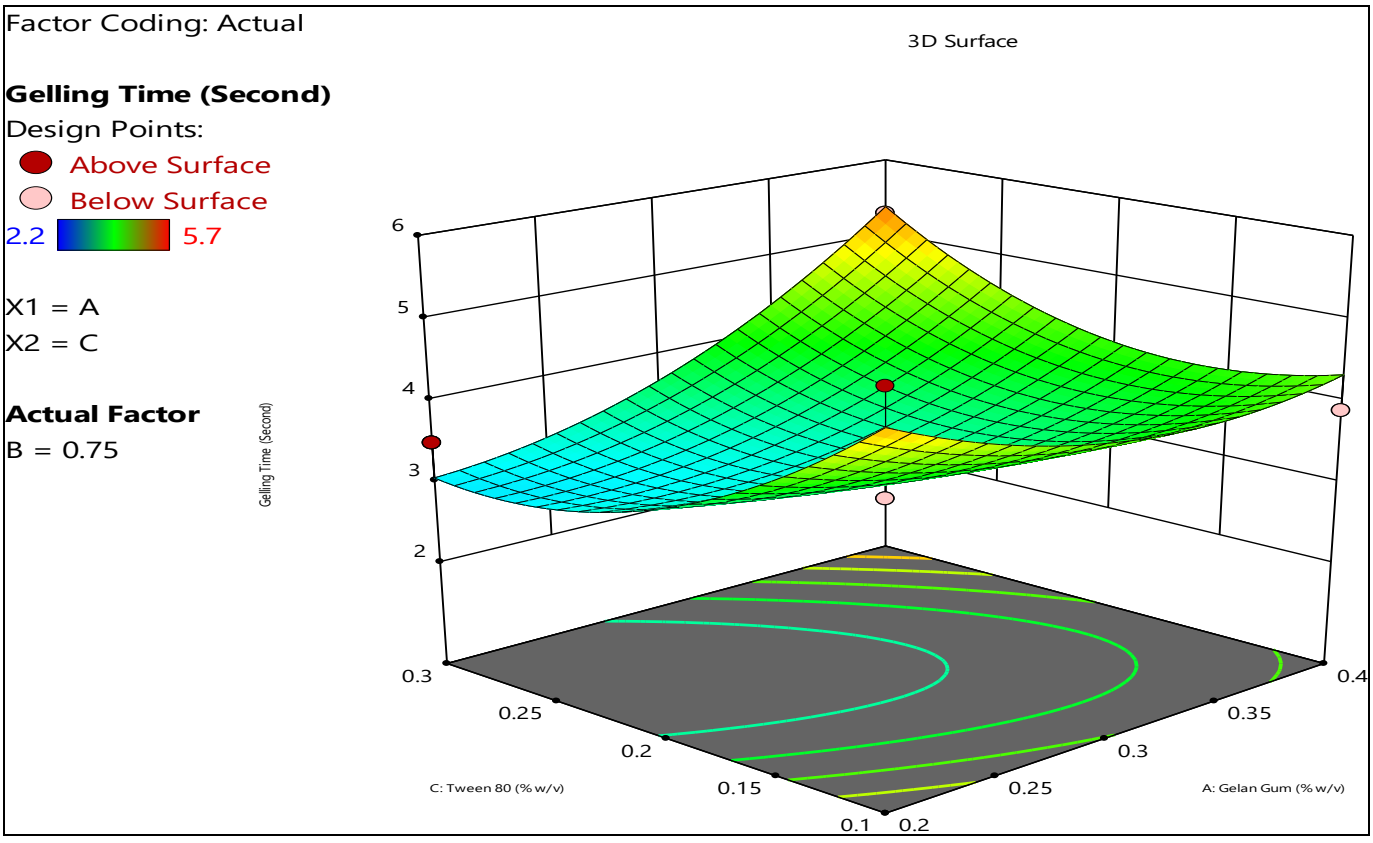

Fig. 2: 3D Surface pot (Tween 80 and Gallan gum)

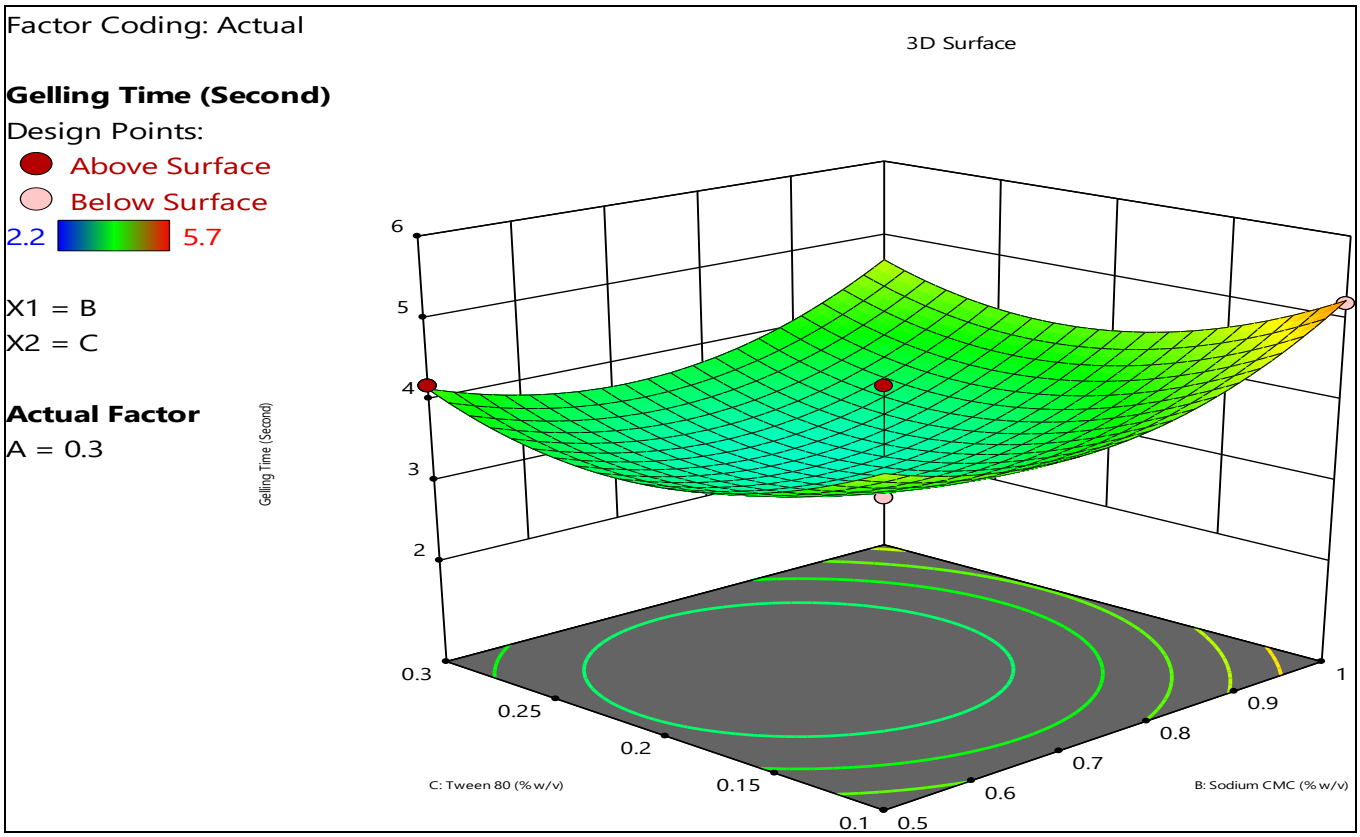

Fig. 3: 3D Surface pot (Tween 80 and Sodium CMC)

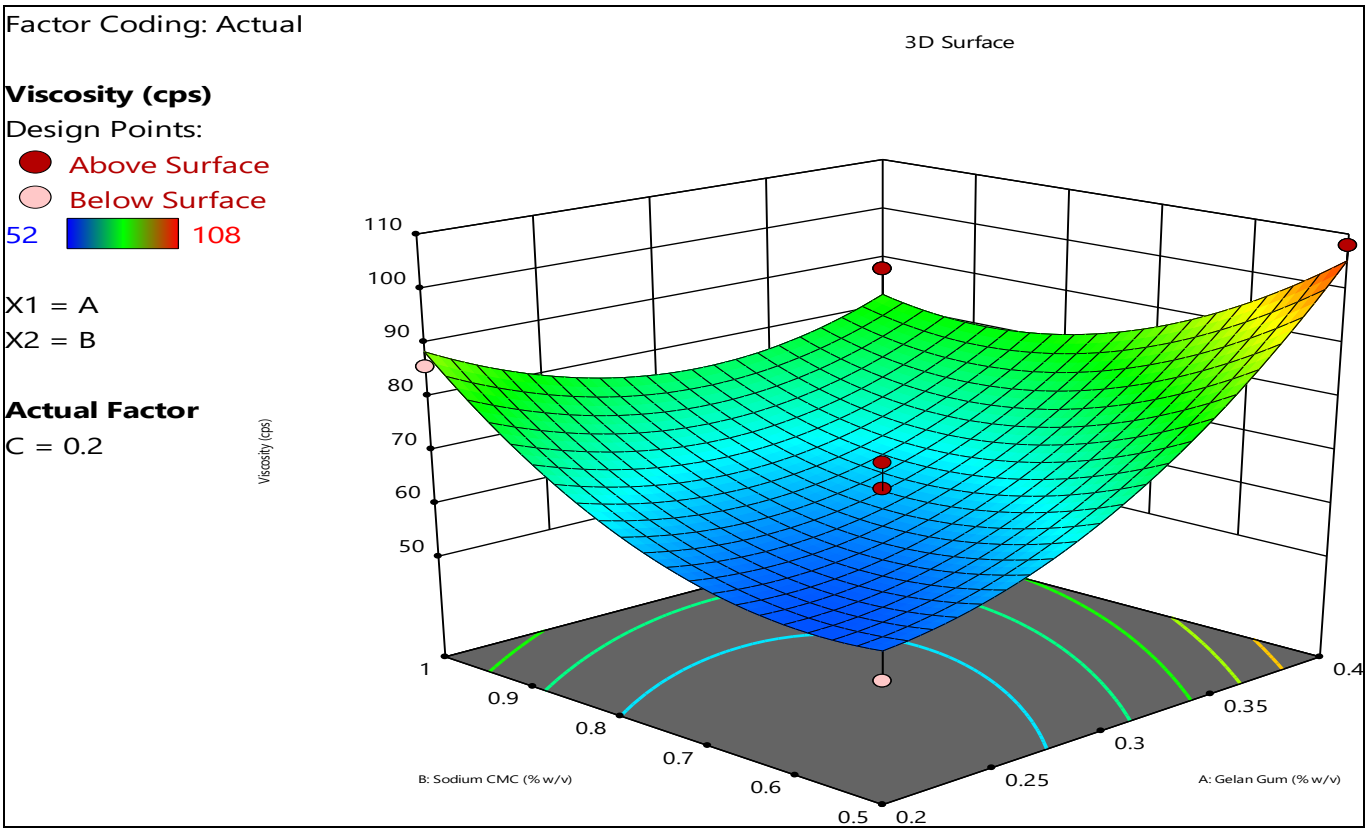

Fig. 4: 3D Surface Plots (Gallan gum and Sodium CMC)

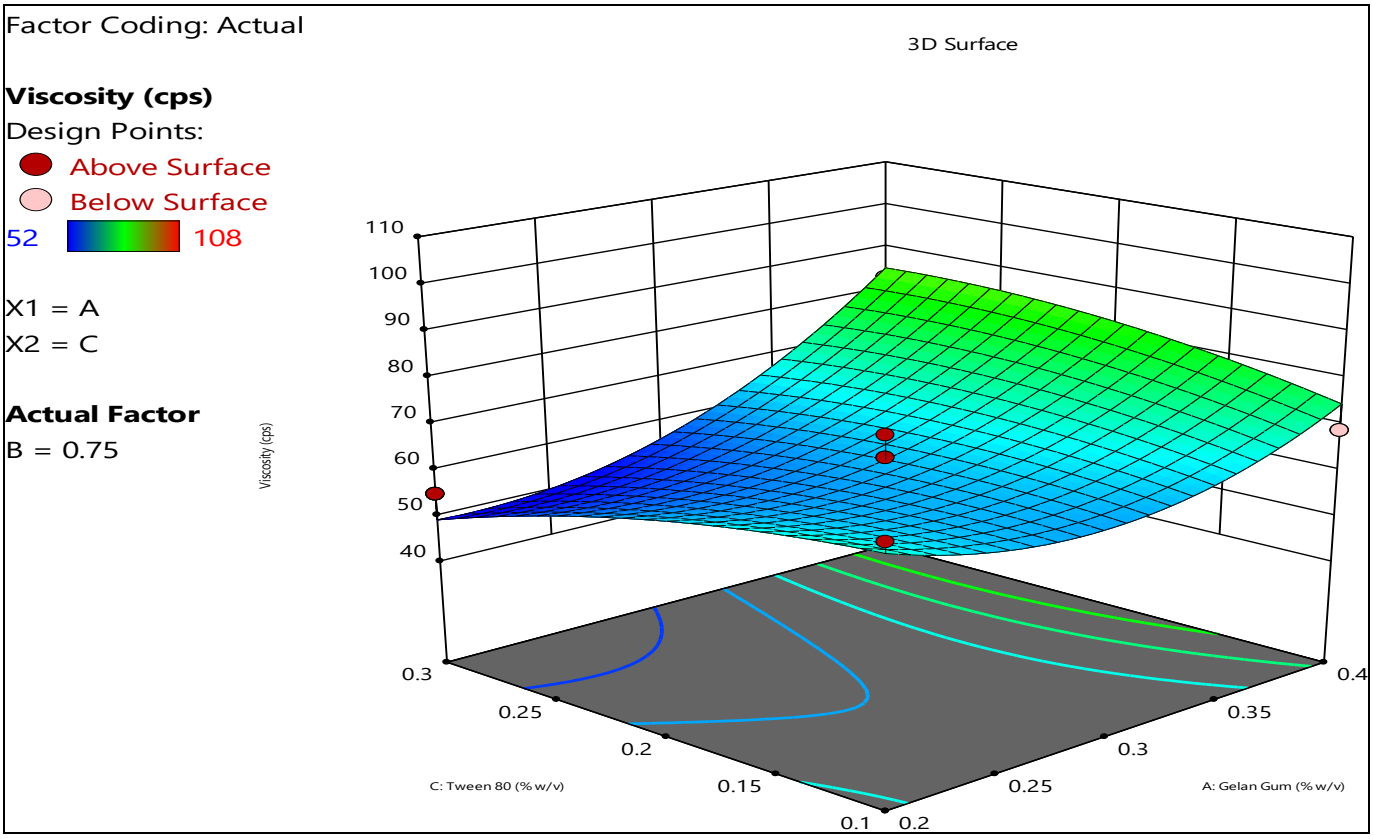

Fig. 5: 3D Surface Plots of (Gallan gum and Tween 80)

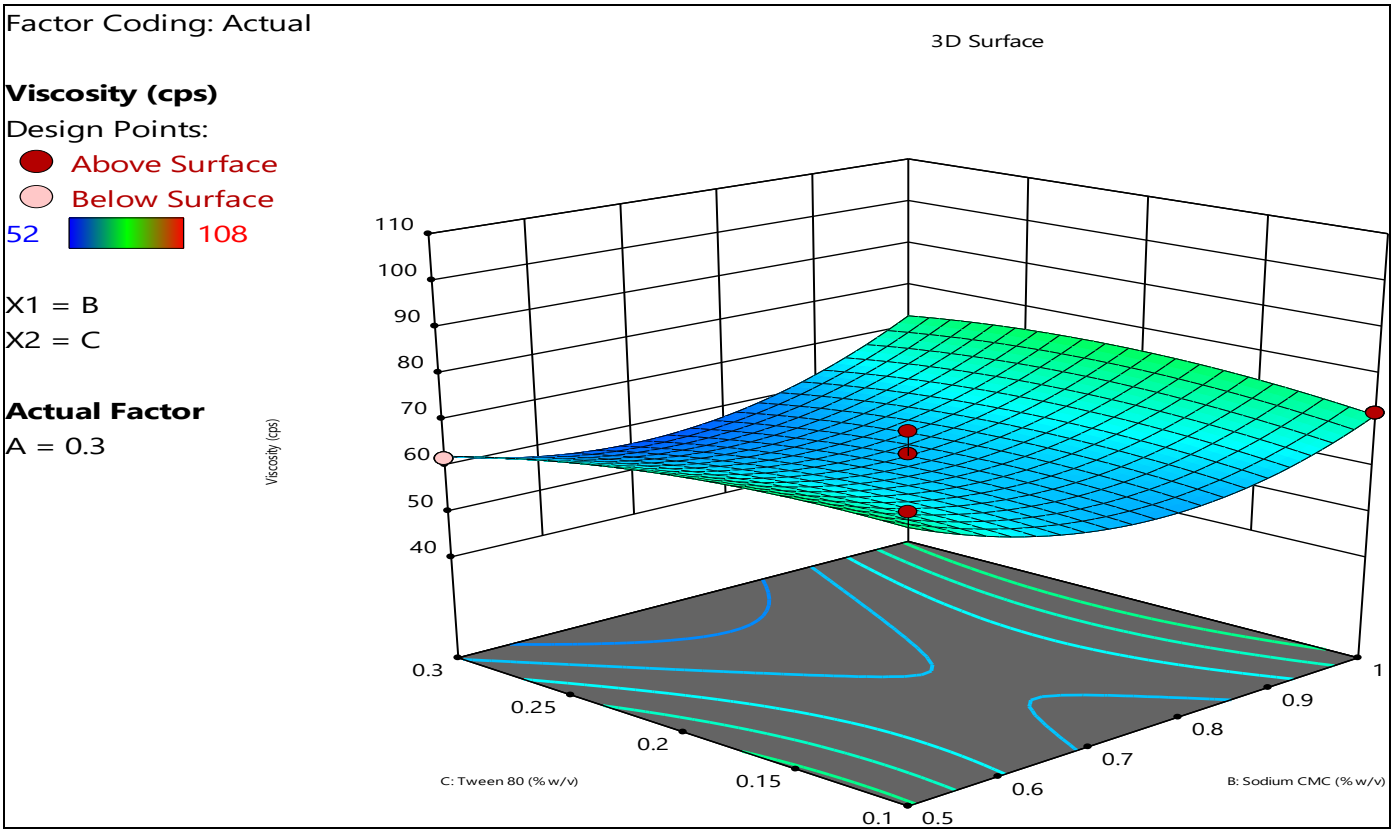

Fig. 6: 3D Surface Plots (Sodium CMC and Tween 80)

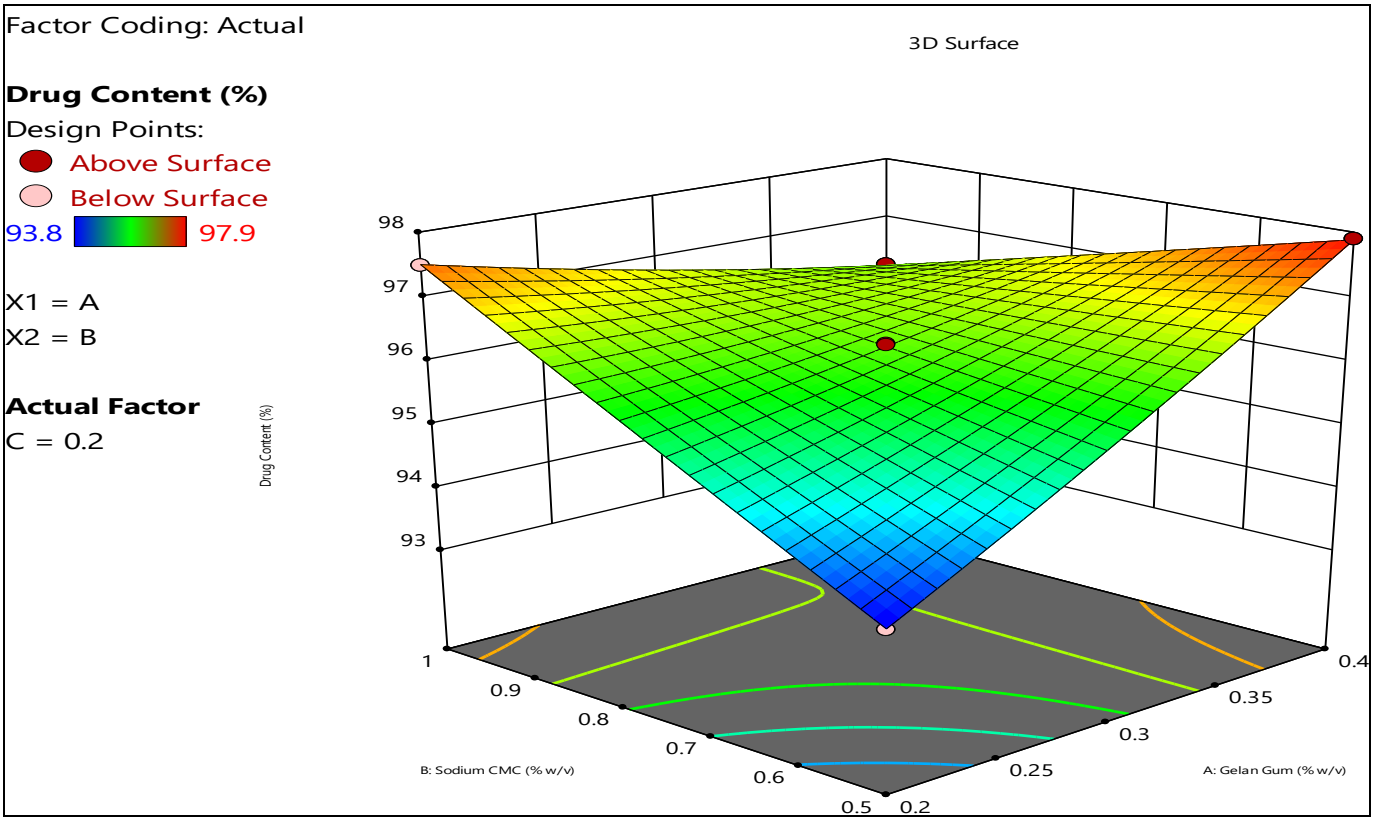

Fig. 7: 3D Surface plot of (Gallan Gum and Sodium CMC)

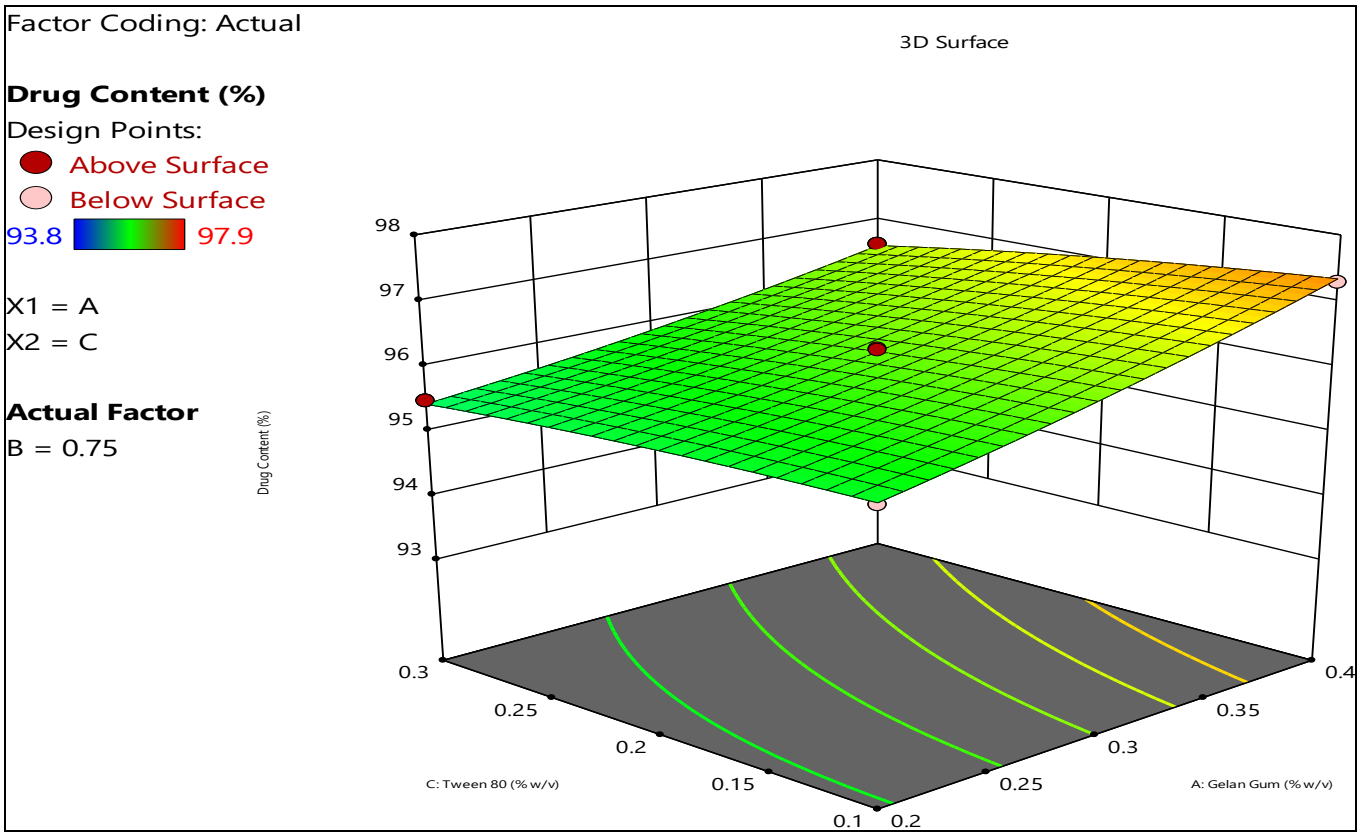

Fig. 8: 3D Surface plot (Gallan Gum and Tween 80)

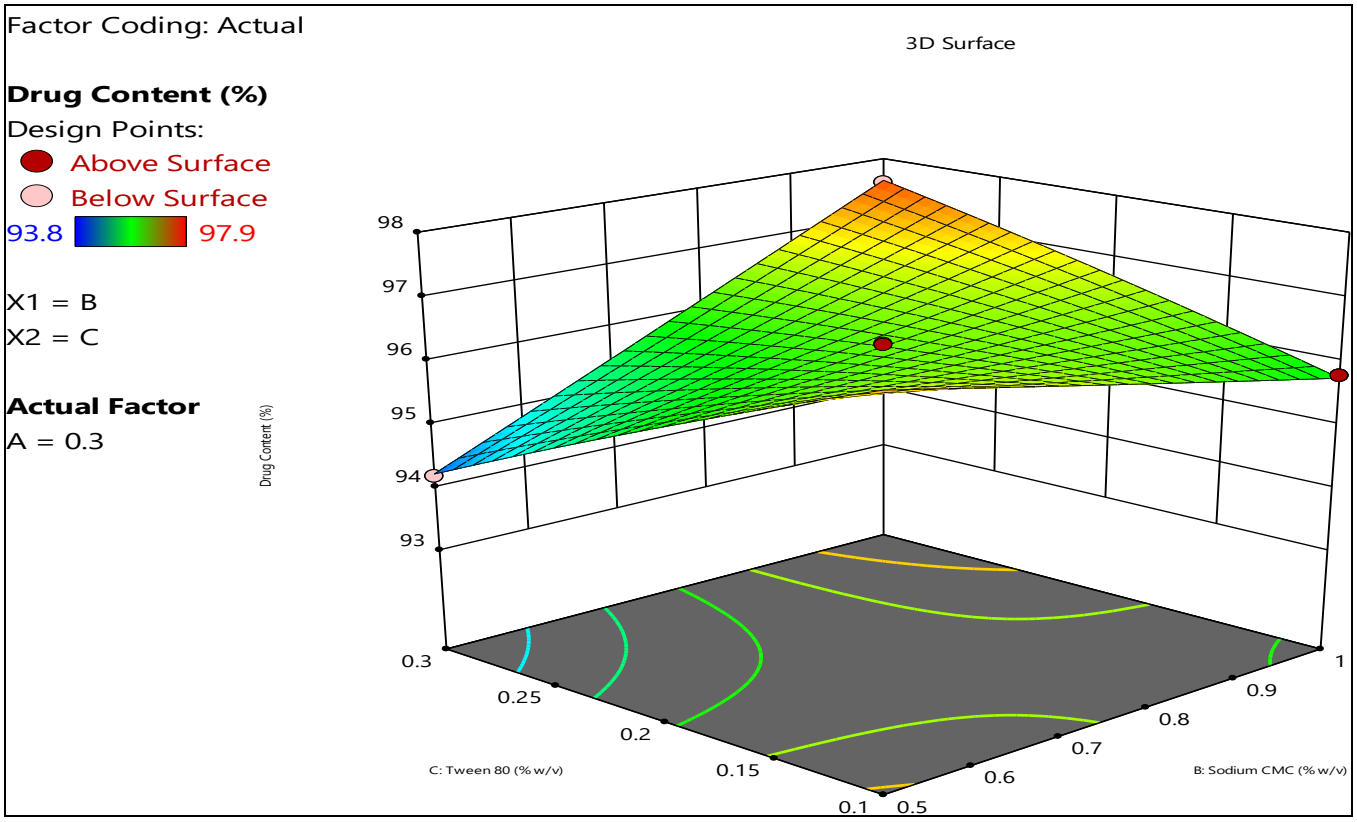

Fig. 9: 3D Surface plot (Sodium CMC and Tween 80)

Table 4: Experimental results with predicted responses

Formulation	Composition (% w/v) Gallan Gum/Sod. CMC/ Tween 80	Response	Predicted value	Experimental value
IGOF1	0.4/0.75/0.3	Gelling time	5.39	5.3
		Viscosity	85.25	83
		Drug content (Sumatriptan)	96.58	96.6
		(Naproxen)	97.45	-
IGOF2	0.3/1.0/0.1	Gelling time	5.24	5.2
		Viscosity	71.50	72
		Drug content (Sumatriptan)	95.76	95.8
		Drug content (Naproxen)	96.54	-
IGOF3	0.4/0.5/0.2	Gelling time	5.65	5.7
		Viscosity	105.25	108
		Drug content (Sumatriptan)	97.89	97.9
		Drug content (Naproxen)	98.25	-
IGOF4	0.3/0.5/0.3	Gelling time	4.16	4.2
		Viscosity	62.50	62
		Drug content (Sumatriptan)	94.24	94.2
		Drug content (Naproxen)	96.65	-

Table 5: Results of pH of optimized formulation

Formulation Code	pH*
IGOF1	6.82±0.05
IGOF2	5.86±0.04
IGOF3	5.76±0.03
IGOF4	6.21±0.05

**Average of three readings*

3.5. Mucoadhesive strength

Evaluation of mucoadhesive strength is very important because of its great impact on elongation of residence time and decrease of formulation leakage. Mucoadhesive strength is defined as a quantity of formulation binding to the mucous membrane at nose temperature; 34°C. To overcome nasal clearance, the mucoadhesive strength of the intranasal formulation should be high enough. Otherwise, the mucous membrane can be damaged when the mucoadhesive strength is too high.

In the experiment process, the optimum contact time for giving the optimum mucoadhesive strength was 2 minutes. Any decrease in the contact time led to a sharp decrease in the mucoadhesive strength due to incomplete polymers chains entanglement with mucin. However, an increase of contact time has an insignificant effect on the mucoadhesive strength. The highest mucoadhesive strength was recorded by the gel formula IGOF2. So, this was selected to be the gel base for the optimized formulation.

Table 6: Results of Mucoadhesive strength of optimized formulation

Formulation Code	Mucoadhesive strength* (dyne/cm^2)
IGOF1	3215
IGOF2	3045
IGOF3	3126
IGOF4	2854

**Average of three readings*

3.6. *In-vitro* drug release study

In-vitro diffusion study of the optimized *in-situ* formulation (IGOF3) was performed using modified Franz diffusion cell with dialysis membrane in phosphate buffer pH 6.4 for a period of 6 hours. The data obtained from diffusion studies are summarized in table 7. The *In vitro* release data were fitted into different kinetic models viz Zero-order, First order, Higuchi model and Korsmeyer Peppas equation. *In-situ* gel formulation released drug in controlled release manner in 6 hour.

Table 7: *In-vitro* drug release data of both the drugs

Time (h)	Square Root of Time(h)$^{1/2}$	Log Time	Cumulative*% Drug Release	
			Sumatriptan	Naproxen
0.5	0.707	-0.301	27.78	28.89
1	1.000	0.000	41.25	39.98
2	1.414	0.301	58.89	55.65
3	1.732	0.477	71.12	69.95
4	2.000	0.602	86.65	79.98
6	2.449	0.778	96.12	95.45

**Average of three readings*

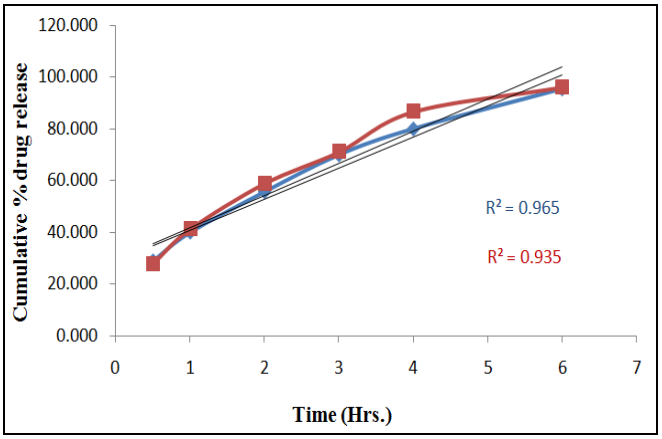

Fig. 10: Cumulative % drug released Vs Time

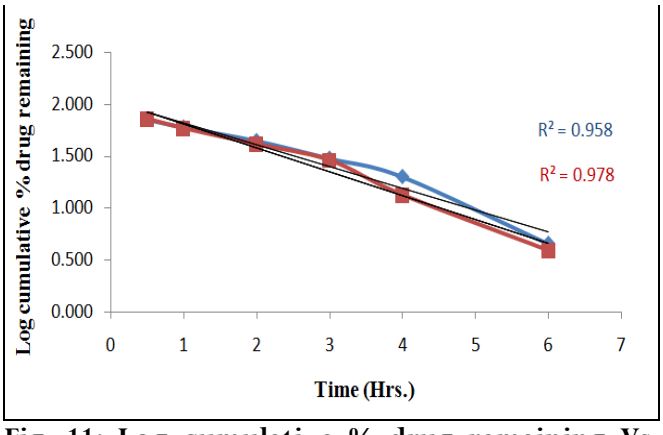

Fig. 11: Log cumulative % drug remaining Vs Time

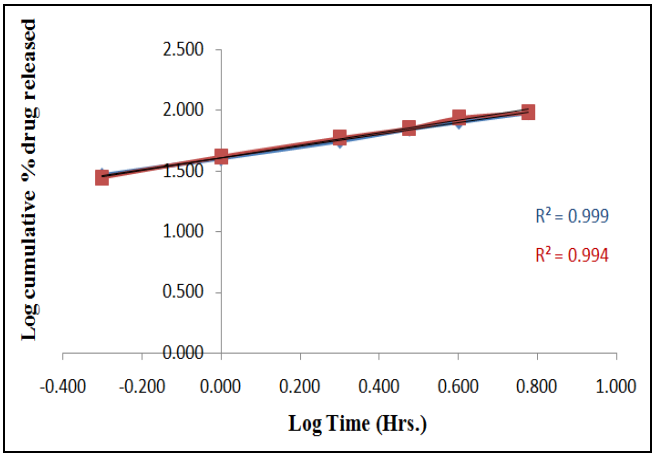

Fig. 12: Cumulative % drug released Vs Square root of Time

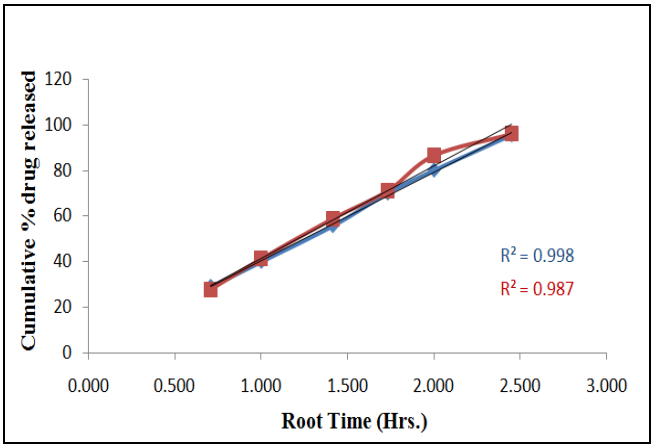

Fig. 13: Log cumulative % drug released Vs log Time

It was observed from the data shown that polymer concentration affected the release of drug from the dosage form. It was found that cumulative drug release from formulation was reduced insignificantly when concentration of polymers increased. Formulation IGOF3 showed better release as compared to other formulations. Formulation IGOF3 showed 95.45% drug release sumatriptan and 96.12% for naproxen after 6 hrs. When the regression coefficient values were compared, it was observed that 'r' values of Higuchi's Model was maximum hence indicating drug release from formulations was found to follow Higuchi's release kinetics.

4. CONCLUSION

The *in-situ* gels of Sumatriptan and Naproxen worked well as a non-invasive medication delivery device via the nasal route. Finally, it was determined that a promising non-invasive medication delivery system with increased patient compliance had been devised. The study shows that administering Sumatriptan and Naproxen using *in-situ* gel is feasible. As a result, the created *in-situ* gel formulation could be a potential carrier for Sumatriptan and Naproxen, especially given its ease of manufacture and scale-up.

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