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Optimization of Coffee-Gelatin Shot Formulations Based on Physicochemical, Rheological and Sensory Properties Using Response Surface Methodology

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Abstract

The objective of this study was to optimize the coffee content and alcohol content of the formulations of coffee-gelatin shots based on physicochemical, rheological and sensory properties of the products. Because the coffee content and alcohol content influenced those properties of coffee-gelatin shots significantly which were related to the consumers' acceptance. Thirteen different coffee-gelatin shots for nine formulations based on CCRD were developed and the sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots were determined. The regression models were developed to predict the response variables as a function of independent variables. The response surface models were developed to understand the effects of independent variables on the responses. A desirability function was used to determine an optimum formulation using a numerical optimization technique. All contour plots of response surface models were superimposed to visualize an optimum region. The regression models could predict the sensory properties, L-value, pH and viscosity of coffee-gelatin shots as a function of coffee content and alcohol content with an accuracy of 77-99% depending on the properties of coffee-gelatin shots. The coffee content and alcohol content affected the sensory properties, L-value and viscosity of coffee-gelatin shots significantly ($p<0.05$). The optimization results obtained using numerical and graphical optimization techniques indicated that a combination of coffee (2.50 -3.00 g) and alcohol (5.25-6.75 mL) was the optimum formulation of a coffee-gelatin shots that improved the sensory properties, L-value, pH and viscosity of the coffee-gelatin shots. This optimum formulation of coffee-gelatin shots is expected to be useful for commercial manufacturing of consumers' desired coffee-gelatin shots.

Keywords: coffee-gelatin shots, CCRD, RSM, optimization, physiochemical properties, rheological properties, sensory properties

1. Introduction

A gelatin shot is an alcoholic beverage consisting of liquor incorporated into sweetened gelatin dessert and chilled in a small container (Crews, 2015). Scientists characterize gelatin as a thermally reversible hydrochloride compound that turns into liquid when heated and stable at room temperature. Some variations are irreversibly altered, while others can be disintegrated either through chemical reactions or heat (Albaka, 2023). Gelatin is a material that is mostly liquid by weight but behaves like a solid. Adding long molecules, called polymers, or small particles called colloids to a liquid can thicken it. The polymers and colloids stick together for cross-linkages. In this process, the liquid behaves like solid because they no longer flow from each other (Liu, 2019). Gelatin shots are popular, particularly on college campuses, as a playful way to consume alcohol, hiding its unfavorable effects. The combination of gelatin shots and alcohol uses a placebo-controlled setup because these shots efficiently mask alcohol when compared with beverages (Ralevski et al., 2006). The possible combination of flavors for gelatin shot is remarkably diverse, from fruit flavors to creamy flavors making the combinations almost unlimited. Normally popular flavors for gelatin shots tend to be fruitier with a combination of a distilled spirit, because of the usage of already prefabricated flavor gelatins. (Builder, 2018). A more dilute gelatin with a high alcohol content produces a hot sensation in the mouth when tasted, while a denser mixture with a higher gelatin concentration offers a smoother flavor profile. (Albaka, 2023). In this aspect, addition of coffee in the gelation shots showed potential.

Coffee-gelatin shot made of sweetened coffee and gelatin is a popular dessert in Japan. It has a great market for its great flavor and easiness of consumption (Ramjattan, 2021). This gelatin-based product has two layers where one being coffee infused and the other layer being cream infused. Ralevski et al. (2006) investigated the notion of gelatin shots as a method for disguising the taste and effects of alcohol. While the primary focus of the study was on alcohol-based gelatin shots and the same principles may be used for coffee-gelatin shots. The gelatin matrix effectively masks the dominant coffee flavor, making it a suitable vessel for delivering the flavor in a novel and exciting manner. The incorporation of coffee into the gelatin mixture requires a careful consideration for the coffee's intensity as well as potential additives to enhance flavor and aroma. Furthermore, experimenting with varying concentrations of gelatin might affect the shots' firmness, matching with preferences for a specific mouthfeel (Albaka, 2023).

The introduction of a coffee gelatin alcoholic dessert into the market could facilitate the consumption of caffeine and alcohol and the market for both could thrive with innovative products that could attract consumers (Samoggia, 2019). Global coffee consumption is estimated to increase, particularly in non-traditional coffee-drinking countries in Africa, Asia, and Oceania, which is by 4.1%. Demand in traditional markets is estimated to grow by 1% in Europe and by 2.5% in North America (ICO, 2021). Leading drivers for coffee market growth are innovations in out-of-home consumption, online commerce opportunities, and innovative brewed coffee beverage types (Samoggia, 2019). The addition of a creamy sweet flavor to balance the bitterness of coffee is a major selling point in today's market. Sweet flavors tend to do better in the alcohol market nowadays, allowing the consumer to ingest a greater quantity compared to more hard liquors. The beer industry has lost a 10% market share to wine and liquor drinkers in the last decade, with only 40% of young drinkers saying their favorite drink is beer, compared to 70% in 1992-1993 (Taylor, 2016).

The alcohol and caffeine market needs innovations that will attract new consumers. However, the amount of alcohol content and the amount of coffee significantly influence the physical, chemical, rheological and sensory properties of coffee-gelatin shots which are related to the consumers' acceptance. It is necessary to optimize the alcohol content and coffee content in the coffee-gelatin shot formulations based desired physicochemical and rheological properties of developed deserts.

The objective of this study was to optimize the alcohol content and coffee content in the formulations of coffee-gelatin shots based on the physicochemical, rheological, and sensory properties of the products using response surface methodology.

2. Materials and Method

2.1 Materials

Gelatin unflavored (Great value brand), sweetened condensed milk (Great value brand), Baileys Irish cream (Baileys), Dunkin Donuts dark roast coffee were purchased from the local Walmart.

2.2 Experimental Design of Coffee-Gelatin Shots

The two independent factors coffee content (0.60-3.40 g, X_1) and alcohol content (2.95-17.05

mL, X_2) and the coded values of five levels for two independent variables -1.41, -1, 0, 1 and 1.41 were counted in this study. In order to design the experimental points, the Central Composite Rotatable Design (CCRD) was considered for the coffee-gelatin shots development. There were 13 experimental points ($n=2^k + 2k + m$, where n= total experimental points, independent variables, k=2 and replicated central points, m=5). The total 13 experimental points were divided into 4 factorial points, 4 axial points and 5 replicated center points (Mitra et al., 2023) as shown in Table 1.

2.3 Manufacturing of Coffee-Gelatin Shots

The coffee-gelatin shots contained two layers consisting of cream layer and coffee-alcohol layer. The cream layer was standardized and was not changed with all the samples tested. On the other hand, coffee-alcohol layer was changed as per the CCRD design as mentioned in the Table 1. The cream layer was produced first allowing it to set at the bottom of a portion cup container. Then the coffee-alcohol layer was place on the cream layer in the portion cup. The position cups with the cream layer and coffee-alcohol layer were kept at 5ºC for 24 hours to develop coffee-gelatin shots. The physicochemical, rheological and sensory properties of 13 different coffee-gelatin shots were determined to optimize the coffee content and alcohol content in the coffee-gelatin formulations.

2.3.1 Preparation of Cream Layer

First, the water (250 mL) was heated to 90ºC, and the condensed milk (396 mL) was added to the heated water, and stirred until a homogenous mixture was obtained to prepare a condensed milk mix. Then a half cup of water (118 mL) was heated to 90ºC and the gelatin (7 g) was added to the heated water. A half cup of cold water (118 mL) was added gradually to the gelatin and hot water mix and was stirred until the gelatin was dissolved completely to prepare the gelatin mix. The condensed milk mix was added gradually to the gelatin mix and stirred until a homogeneous texture was obtained. The cream layer mixture was cooled to room temperature (20°C). The room temperature cream layer mixture was poured into a plastic cup (30 mL) and stored at 5ºC for 24 hours to form the cream layer.

2.3.2 Preparation of Coffee-Alcohol Layer

The water (118 mL) was heated to 90ºC, and the gelatin (7g) was added gradually to the hot water. A half cup of cold water (118mL) was added to the gelatin and hot water mix and stirred until the gelatin dissolved completely. The coffee and alcohol (Baileys Espresso) as per the CCRD (Table 1) were mixed with the hot gelatin mix. Then the coffee-alcohol layer was cooled to room temperature (20°C) and was poured into a clear plastic cup (30 mL). The coffee-alcohol cups were stored at 5ºC for 24 hours to form the coffee-alcohol layer.

2.4 Characterization of the Coffee-Gelatin Shots

2.4.1 Physicochemical Properties of Coffee-Gelation Shots

The L-value (white/black) of the coffee-alcohol layer of all samples was determined using a Hunter Lab Color Flex-EZ Colorimeter (Hunter Associates Laboratory Inc., Reston, Virginia, USA.). Ten replications per sample were used to calculate an average L-value of the coffee layer of coffee-gelatin shots. The pH of the 13 coffee-gelatin shots was determined using a pH meter (Fisher Scientific, AB15 Plus). The probe of the pH meter was calibrated with standard solutions of pH 4, pH 7 and pH 10 before measuring the pH of the samples to ensure the accurate pH results. Three replications of pH measurement for each sample were done and an average pH value of the samples was documented.

2.4.2 Rheological Properties of Coffee-Gelatin Shots

In order to measure the rheological properties of the gelatinized products a viscometer is generally used. A rheological property (dynamic viscosity) of coffee-gelatin shots was determined at room temperature (20°C) using a Brookfield DV-III ULTRA programable Rheometer (Brookfield, Chicago, IL). The dynamic viscosity which is frequently called 'viscosity,' or 'absolute viscosity,' is the internal friction of a liquid or its tendency to resist flow (Mitra et al., 2022). The ULA spindle with a rotational speed of 100 rpm was used to determine the viscosity(cP) of the coffee-gelatin shots. Three replications of each sample were conducted and the average viscosity of each sample was reported.

2.4.3 Sensory Evaluation of Coffee-Gelatin Shots

The sensory evaluation of 13 coffee-gelatin shots were conducted using a 5-point Hedonic Scale (1-Dislike Extremely, 2-Dislike Slightly, 3-Neither Like nor Dislike, 4-Like Slightly and 5-Like Extremely). The sensory test of coffee-gelatin shots was conducted by a taste panel. The sensory taste panelist consisted of 21 panelists (students, faculties and staffs of the Department of Kinesiology, Health, Food and Nutritional Sciences, University of Wisconsin-stout). There were 9 males and 12 females in the sensory evaluation taste panel. Sensory evaluation of coffee-gelatin shots was conducted to optimize the coffee content and alcohol content in the gelatin shots on the basis of color flavor, texture and overall acceptability of coffee-gelatin shots. The thirteen samples were coded (a 3-digit code for each sample) randomly to ensure no biasness in the panelists' decision. All samples were laid out with each respective label for the panelists to consume. Each panelist ingested each sample and gave a score on each property tested. The responses from the twenty-one participants were collected and the average response value for each sensory property was calculated.

2.5 Regression Modeling, Response Surface Modeling (RSM and Optimization)

The Response Surface Methodology (RSM) was applied to determine the relationship between the independent variables (coffee content and alcohol content) and response variables of sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots. The RSM technique was also used optimize the coffee content and alcohol content of coffee-gelatin shots on response variables of coffee-gelatin shots to achieve a desired formulation of coffee gelatin-shots. The analysis of the data was performed assuming a second order polynomial equation 1 (Mitra et al., 2023) for the response variables of overall acceptability, color, texture and L-value and a third polynomial cubic equation 2 (Mitra et al., 2020) for the response variables of flavor, pH and viscosity of coffee-gelatin shots as a function of the coffee content (X_1) and alcohol content (X_2):

$$Y = B_0 + B_1 X_1 + B_2 X_2 + B_{11}X_1^2 + B_{22}X_2^2 + B_{12}X_1X_2 \quad (1)$$

$$Y = B = B_0 + B_1 X_1 + B_2 X_2 + B_{11}X_1^2 + B_{22}X_2^2 + B_{12}X_1X_2 + B_{111} X_1^3 + B_{222} X_2^3 \quad (2)$$

Table 1. Experimental design (CCRD) and the experimental results of sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots

Samples	Coffee (g)	Alcohol (mL)	Overall acceptability	Color	Flavor	Texture	L-Value	pH	Viscosity (cP)
	X1	X2							
1	2 (0)	17.05(1.41)	3.4±1.07	3.3±1.16	3.2±0.91	3.2±1.03	49.16±0.07	5.6±0.10	1240±226.20
2	0.60 (-1.41)	10 (0)	3.4±1.17	2.4±1.07	3.1±1.20	3.3±0.95	52.92±0.10	6.0±0.10	4300±1343.00
3	3 (1)	5 (-1)	3.3±1.49	4.5±0.85	3.0±1.56	3.4±1.35	34.51±0.17	5.7±0.10	6740±1046.00
4	2 (0)	2.95 (-1.41)	1.2±1.10	3.5±0.85	3.2±1.03	3.5±0.85	34.57±0.35	5.9±0.10	6290±14.14
5	1(-1)	5 (-1)	3.0±1.15	2.7±0.95	3.0±1.33	3.2±0.63	49.81±0.34	6.0±0.1	540±28.28
6	1(-1)	15 (1)	4.1±0.99	3.0±1.25	3.6±0.84	3.0±0.99	53.99±0.24	6.1±0.10	5400±1131.00
7	3 (1)	15 (1)	3.9±1.10	3.6±1.35	3.1±1.97	3.3±0.95	48.73±0.05	6.0±0.10	1205±106.10
8	3.40 (1.41)	10 (0)	4.2±0.92	4.0±0.67	4.6±0.51	3.8±0.63	42.95±0.67	5.8±0.10	102±2.83
9	2(0)	10 (0)	3.5±1.27	3.1±0.87	3.4±0.70	3.5±0.97	43.44±0.06	5.8±0.10	3040±1895.00
10	2(0)	10 (0)	3.5±1.27	3.1±0.87	3.4±0.70	3.5±0.97	43.84±1.02	5.8±0.10	3133±1272.00
11	2 (0)	10 (0)	3.5±1.27	3.1±0.87	3.4±0.70	3.5±0.97	43.50±0.34	5.8±0.0	2946±351.00
12	2 (0)	10 (0)	3.5±1.27	3.1±0.87	3.4±0.70	3.5±0.97	43.35±0.59	5.9±0.10	3033±1273.00
13	2 (0)	10 (0)	3.5±1.27	3.1±0.87	3.4±0.70	3.5±0.97	43.34±0.42	5.8±0.00	2998±848.00

X_1= (C-2)/1, X_2=(A-10)/5, C = grams of coffee content, A = mL of alcohol content.

Where, *Y* represents the experimental response variable (overall acceptability, color, flavor, texture, L-value, pH and viscosity), B_0, B_1, B_2, B_{11}, B_{22}, and B_{12} were constants and regression coefficients of the model and X_1 (coffee content and X_2 (alcohol content) were the independent variables.

The software used to solve the second order polynomial equation/cubic equation to create the regression models, response surface models, numerical, and graphical optimization processing was the design-expert (Version 6.0.2). The ANOVA (Analysis of Variance) was used to assure that the models obtained were statistically significant. The regression models were justified using *F* value > *Fcrit* (F value at critical point), $P < 0.05$, R^2 and adequate precision> 4. A three-dimensional response surface model was generated by producing a response as a function two independent variables. The numerical optimization of the coffee-gelatin shots was conducted using a trial-and-error method based on a desirability function. The optimum region was obtained by a graphical visualization (superimposing of all contour plots together/overlay plots) using the design-expert software (Mitra et al., 2023).

3. Results and discussion

3.1 Experimental Data and Regression Modeling

According to CCRD design (Table 1), thirteen coffee-gelatin shots were developed by varying coffee content and alcohol content. The physiochemical (L-value and pH), rheological (viscosity), and sensory (overall acceptability, color, flavor and texture) properties of coffee-gelatin shots as response variables were determined to characterize the coffee-gelatin shots and the results were presented in Table 1. The overall observations of the results shown in Table 1 revealed that the L-value (34.51-53.99), pH (5.6-6.10), viscosity (102-6740 cP) and the sensory properties of overall acceptability (1.2-4.2), color (2.4-4.5), flavor (3.0-4.6) and texture (3.0-3.8) varied with the coffee contents and alcohol contents of coffee-gelatin shots. The results showed that the combination of coffee content and alcohol content affected the L-value, viscosity and sensory properties of coffee-gelation shots significantly ($p<0.05$). The increment of coffee content to 3.40 g and alcohol content to 10 mL increased the sensory properties of overall acceptability, color, flavor and textures. Increasing coffee content to 3 g and decreasing alcohol content to 5 mL increased the viscosity of the coffee-gelatin shots. However, further increasing coffee content to 3.40 g and alcohol content to 10 mL sharply decreased the viscosity. The darkness of coffee-gelatin shots increased with coffee contents. The whiteness and pH of coffee-gelatin shots increased with the decreased coffee content and increased alcohol content. The overall results in Table 1 indicated that the coffee-gelatin shots with a higher coffee content and moderately higher alcohol content improved the overall acceptability of the coffee-gelation shots. This could occur because the coffee flavor was prominent giving it a more uniform taste and mouthfeel.

Table 2. Regression models for the prediction of sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots

Response variable	Predictive Regression Models
Overall Acceptability	$3.50 + 0.15 X_1 + 0.61 X_2 + 0.28 X_1^2 - 0.47 X_2^2 - 0.12 X_1 X_2$
Color	$3.10 + 0.58 X_1 - 0.11 X_2 + 0.087 X_1^2 + 0.19 X_2^2 - 0.30 X_1 X_2$
Flavor	$3.40 - 0.78 X_1 + 0.35 X_2 + 0.14 X_1^2 - 0.19 X_2^2 - 0.12 X_1 X_2 + 0.66 X_1^3 - 0.17 X_2^3$
Texture	$3.50 + 0.15 X_1 - 0.091 X_2 - 0.031 X_1^2 - 0.13 X_2^2 + 0.025 X_1 X_2$
L-Value	$43.49 - 4.33 X_1 + 4.88 X_2 + 2.69 X_1^2 - 0.35 X_2^2 + 2.51 X_1 X_2$
pH	$5.82 - 0.13 X_1 + 0.31 X_2 + 0.071 X_1^2 - 0.0037 X_2^2 + 0.050 X_1 X_2 + 0.029 X_1^3 - 0.21 X_2^3$
Viscosity	$3030 + 2486.72 X_1 + 1447.94 X_2 - 292.44 X_1^2 + 489.56 X_2^2 - 2598.75 X_1 X_2 - 1985.47 X_1^3 - 1616.69 X_2^3$

The experimental results (response variables shown in Table 1) of sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots were considered to develop the regression models using response surface methodology (RSM) to predict the sensory properties, L-value, pH and viscosity of coffee-gelatin shots as a function of independent variables (X_1- coffee content and X_2-alcohol content). In this regard, the second-order polynomial equation (quadratic) was solved for overall acceptability, color, texture and L-value and the third-order polynomial equation (cubic) was solved for flavor, pH and viscosity of coffee-gelatin shots to determine the coefficients and constants of the quadratic/cubic equation by the utilization of experimental data for overall acceptability, color, flavor, texture, L-value, pH and viscosity of the coffee-gelatin shots. A statistical analysis ANOVA was used to validate the efficiency of the prediction capacity of the regression models. The regression models for sensory properties, L-value, pH and viscosity of coffee-gelatin shots as a function of coffee content (X_1) and alcohol content(X_2) are shown in Table 2.

The adequacy of regression models for sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots was justified by the statistical analysis of variance (ANOVA). The ANOVA results shown in Table 3 indicated a significant effect of the independent variables on the overall acceptability, color, flavor, texture, L-value and viscosity of coffee-gelatin shots due to p-value for all the response variables was less than 0.05 ($p < 0.05$). The p-value of pH was greater than 0.05 ($p>0.05$) which indicated that pH was not significant statistically (Mitra et al, 2020). The ANOVA results (Table 3) indicated that the F-value was larger than the critical F-value (F-crit) for sensory properties, L-value, pH and viscosity of coffee-gelatin shots of coffee-gelatin shots. So, the null hypothesis for all response variables was rejected because the F-value surpassed the F-value at a critical point (F-crit). The F-values indicated that the regression models with higher F values can predict the response variable significantly as a function of independent variables (Mason et al., 2003). The R^2 of the regression models of response variables (overall acceptability, color, flavor, texture, L-value, pH and viscosity of coffee-gelatin shots) varied from 0.77 to 0.99 (Table 3). The R^2 results showed that 77 to 99% changeability of the determined properties of coffee-gelatin shots was described by the developed regression models.

Table 3. Analysis of variance (ANOVA) for the regression models of sensory properties (overall acceptability, color, flavor and texture) L-value, pH and viscosity of coffee-gelatin shots

Model source	Sum of squares	DF	Mean Square	F-value	F-crit value	P value	Adequate precision	R^2
Overall Acceptability	5.60	5	1.12	8.14	3.12	<0.05	10.28	0.85
Color	3.45	5	0.69	80.54	3.12	<0.05	30.50	0.98
Flavor	1.80	7	0.26	5.26	2.91	<0.05	8.64	0.88
Texture	0.37	5	0.01	4.79	3.12	<0.05	6.85	0.77
L-Value	419.45	5	83.89	45.43	3.12	<0.05	22.62	0.97
pH	0.19	7	0.03	3.49	2.91	>0.05	6.12	0.83
Viscosity	$5.22x10^7$	7	$7.47x10^6$	75.33	2.91	<0.05	25.26	0.99

The R^2 value of a model falls between 0 and 1. The R^2 value closer to 1 is considered a better fit of a model [Mitra et al., 2023]. The adequate precisions for all the response variables of coffee-gelatin shots were larger than 4 (Table 3). An adequate precision larger than 4 is needed for the adequate signals of the accuracy of a model for the calculation of overall acceptability, color, flavor, texture, L-value, pH and viscosity of coffee-gelatin shots) because the adequate precision measured the range of the predicted values at a design point to the average prediction error (Mitra et al., 2020). The results of adequate precision indicated that the regression models could predict the response variables effectively due to the adequate precision for overall acceptability, color, flavor, texture, L-value, pH and viscosity of coffee-gelatin shots was higher than 4 (Table 3). Overall, the ANOVA analysis (Table 3) revealed that the regression models developed using RSM were in a good agreement with experimental data for predicting overall acceptability, color, flavor, texture, L-value and viscosity of coffee-gelatin shots as a function of coffee content (X_1) and alcohol content (X_2).

Figure 1. Coffee-gelatin shots developed in this study using an optimized formulation (3 g coffee and 5.25 mL alcohol)

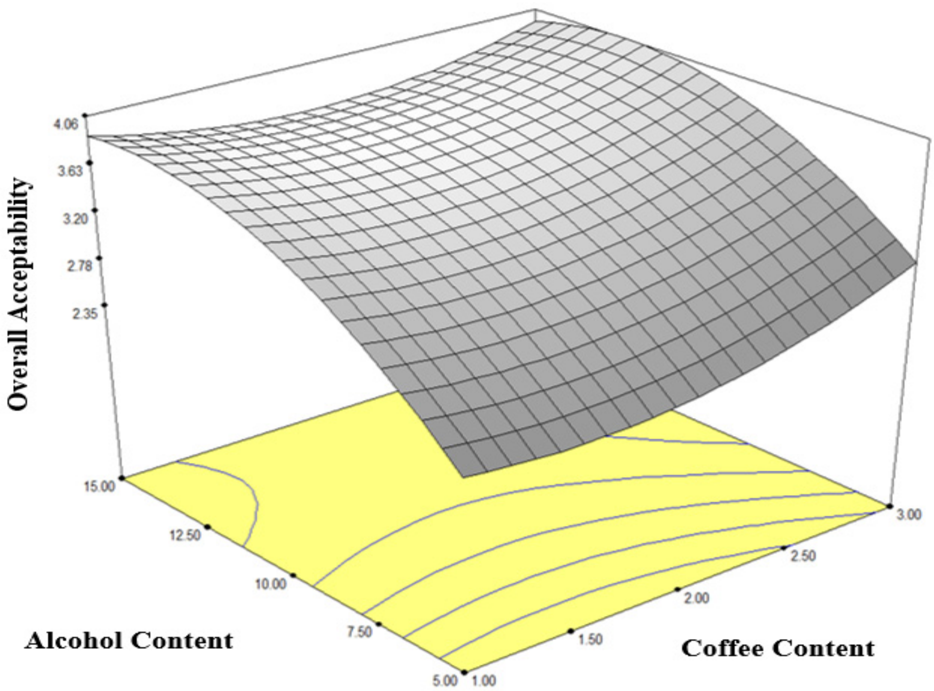

Figure 2. Effect of coffee content and alcohol content on the sensory property of overall acceptability of the coffee-gelatin shots

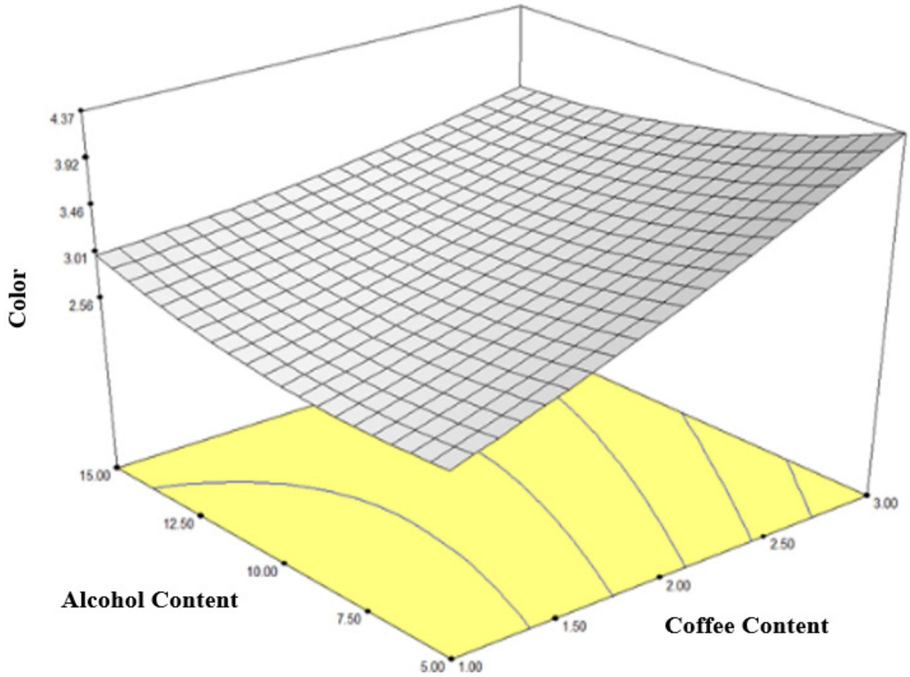

Figure 3. Effect of coffee content and alcohol content on the sensory property of color of the coffee-gelatin shots

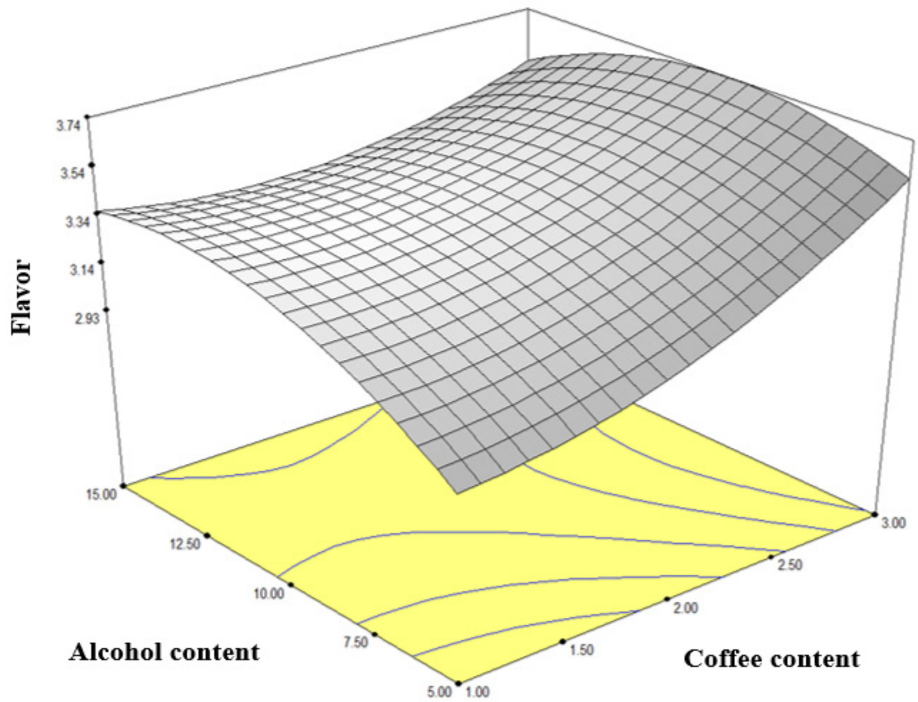

Figure 4. Effect of coffee content and alcohol content on the sensory property of flavor of the coffee-gelatin shots

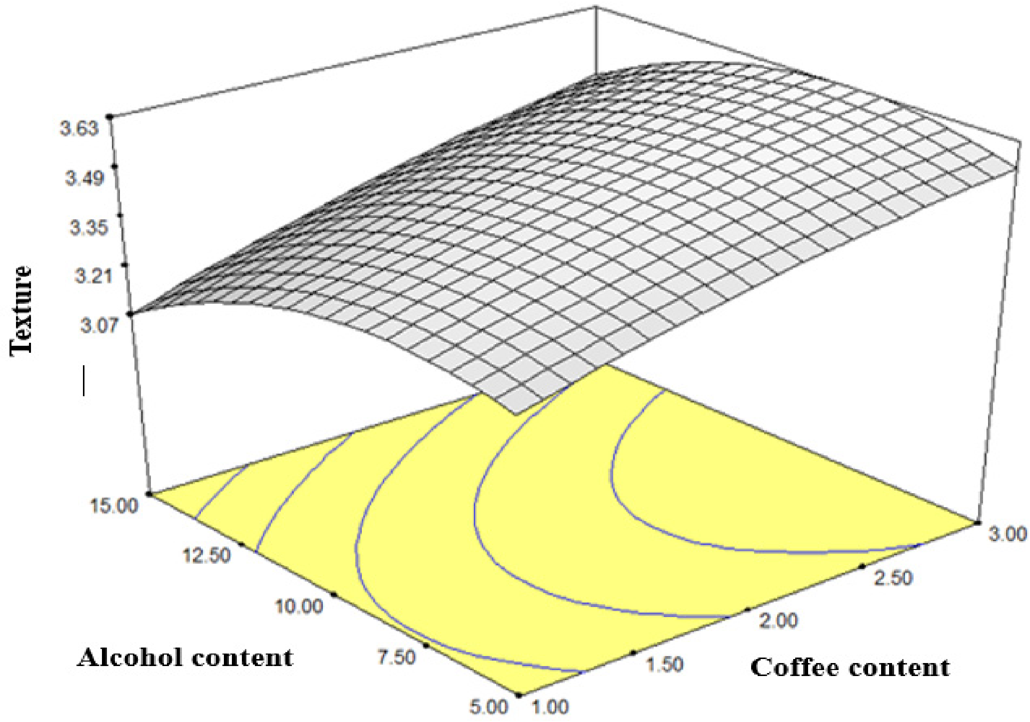

Figure 5. Effect of coffee content and alcohol content on the sensory property of texture of the coffee-gelatin shots

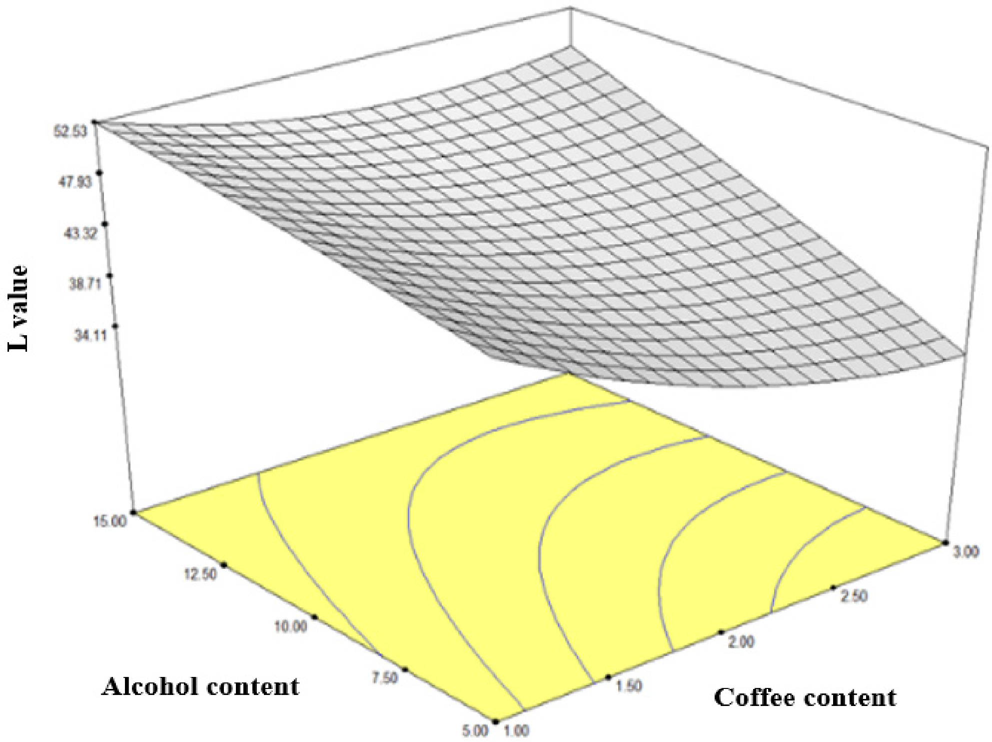

Figure 6. Effect of coffee content and alcohol content on the L-value of the coffee-gelatin shots

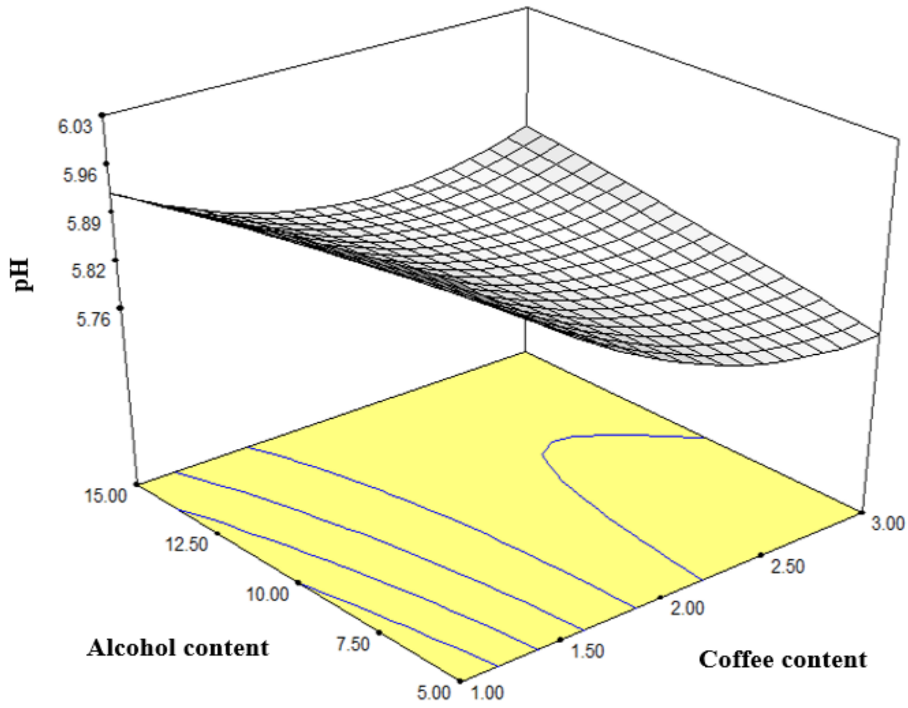

Figure 7. Effect of coffee content and alcohol content on the pH of the coffee-gelatin shots

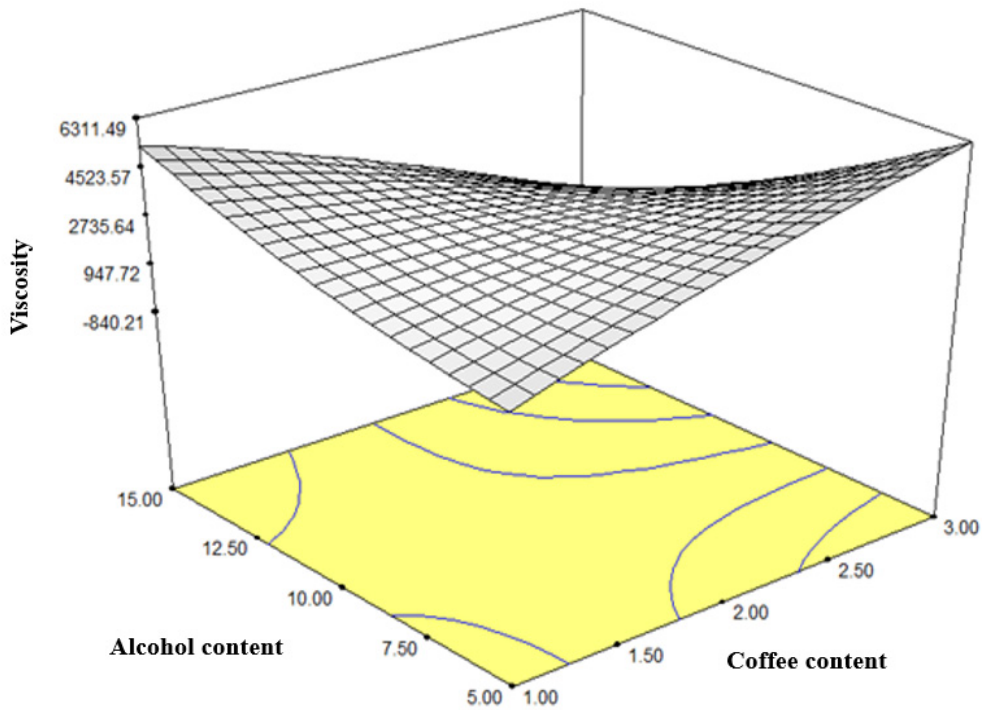

Figure 8. Effect of coffee content and alcohol content on the viscosity of the coffee-gelatin shots

3.2 Effect of Independent Variables on Response Variables: Response Surface Modeling

The coffee-gelatin shots developed using an optimized formulation (3 g coffee and 5.25 mL alcohol) are shown in Figure 1. The effect of the independent variables (coffee content, X_1 and alcohol content, X_2) on the response variable of sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots can be grasped by the 3-demensional response surface models. In this process, a design expert software was used to measure a relationship between independent variables of coffee content and alcohol content and the response variables of sensory properties, L-value, pH and viscosity of the coffee-gelatin shots and visualize this relationship as 3-D graphs created by varying two independent variables (coffee content and alcohol content) for each response (Mitra et al., 2020).The 3-dimensional graph (response surface graphs) elucidated the direction of variation made in response variables (overall acceptability, color, flavor and texture, L-value, pH and viscosity) with the change of coffee content and alcohol content of the coffee-gelatin shots (Mitra et al., 2023). The response surface graphs (effect of coffee content and alcohol content on response variables of coffee-gelatin shots) are shown in Figure 2 (overall acceptability), Figure 3 (color), Figure 4 (flavor), Figure 5 (texture), Figure 6 (L-value), Figure 7 (pH) and Figure 8 (viscosity).

Coffee content had a linear effect on the sensory properties (overall acceptability, color, flavor and texture, Figures 2-5) and viscosity (Figure 8) of the coffee-gelatin shots and an inverse linear effect on the L-value and pH (Figures 6-7) of the coffee-gelatin shots. These response surface modeling results indicated that the sensory properties (overall acceptability, color, flavor and texture) and viscosity of coffee-gelatin shots increased with the coffee content of the coffee-gelatin shots. These results were in agreement with a coffee-alcohol beverage (Wang et al., 2021) and coffee- espresso beverage (Boeneke et al., 2007). The main senses of coffee are sourness, sweetness, bitterness, and saltiness tastes. The sourness, bitterness, astringency, and saltiness tastes were relieved in the gelatin shots during processing and this might lead to the relatively more prominent aroma typicality of coffee and a soft taste. Acids from coffee might play a vital role to enhance the flavor of the gelatin shots. The acids such as citric acid, malic acid, tartaric acid and chlorogenic acid are provided the sour and astringent tastes of coffee (Wang et al., 2021). All these factors of coffee influenced the sensory quality of the coffee-gelatin shots positively and increased the overall acceptability of the coffee-gelatin shots with coffee content in the coffee-gelatin shots. The L-value decreased with increased coffee content in the coffee-gelatin shots. This study showed that whiteness of the coffee-gelatin shots decreased with coffee content and coffee-gelatin shots were darker with coffee content. Boeneke et al., (2007) found a similar result in the coffee-espresso beverage. The pH of the coffee-gelatin shots decreased with increased coffee content because the higher amount of coffee in the gelatin shots increased the acidity of the coffee-gelatin shots by increasing different organic acids. The viscosity of the coffee-gelatin shots increased with coffee content due to increased suspended solids from the increased coffee content (Boeneke et al., 2007).

Alcohol content had a quadratic effect on the sensory properties (overall acceptability, color, flavor and texture, Figures 2-5) and a linear effect on L-value (Figure 6) and pH (Figure 7) and a slightly inversely linear effect on viscosity (Figure 8) of the coffee-gelatin shots. These response surface modeling results indicated that the sensory properties (overall acceptability, color, flavor and texture) of coffee-gelatin shots increased with the increase of alcohol content up to the center point (10 mL alcohol) and further increased the alcohol content decreased the sensory properties of coffee-gelatin shots. The taste characteristic of alcoholic beverages depended on the balance and coordination of all taste attributes (sourness, astringency, umami and saltiness) of a coffee-alcohol beverage (Wang et al., 2021). Moderate amount of alcohol (up to 10 mL) combined with higher coffee content might balance the taste attributes of coffee-gelatin shots. Thus, the alcohol content of up to 10 mL increased the sensory attributes of coffee-gelatin shots. Further increasing of alcohol content in the coffee-gelatin shots might imbalance the taste attributes of coffee-gelatin shots which might cause the further increased alcohol content decreased the sensory qualities of coffee-gelatin shots. The L-value (whiteness) and pH of the coffee-gelatin shots increased with alcohol content. This phenomenon might be the alcohol content diluted the coffee-gelatin formulations which might cause a lower coffee content ratio and less organic acid content ratio in the coffee-gelatin shots. The less coffee content decreased the darkness and increased the whiteness of the coffee-gelatin shots. The less organic acids decreased the acidity and increased the pH of the coffee-gelatin shots. Similarly, the diluted formulations of coffee-gelatin shots with higher alcohol content might reduce the suspended solids content in the formulations of coffee-gelatin shots. This reduced suspended solids contents might decrease the viscosity with higher alcohol content of the coffee-gelatin shots (Boeneke et al., 2007).

3.3 Optimization of the Formulations of Coffee-Gelation Shots

3.3.1 Numerical Optimization

The design expert software (version 6) was used to determine a desirability function using a mathematical technique. All responses (overall acceptability, color, flavor, texture, L-value, pH and viscosity) of the coffee-gelatin shots were transferred to as one response. The transferred single response called desirability function was determined as a geometric mean which was expressed with a scale of 0-1 and the mean value of the desirability function close to 1 showed the highest satisfaction to optimize the formulations. The individual desirable level can be a target, maximum, minimum, or in range that can be varied with the optimization goals of the independent variables and response variables (Mitra et al, 2023). The optimization goals of this study were to maximize coffee content, minimize alcohol content, maximize overall acceptability, maximize color, maximize flavor, maximize texture, minimize L-value, minimize pH and maximize viscosity of coffee-gelatin shots. A trial-and-error method was implemented to calculate optimum conditions of the coffee-gelatin shots (Mitra et al., 2020). Two solutions are shown in Table 4. The results presented in Table 4 implied that solution number 1 (desirability 0.70) was an optimum condition to develop the desired quality of coffee-gelatin shots. The optimum coffee content (3.00 g) and alcohol content (5.25 mL) improved the overall acceptability (3.05), color (4.33), texture (3.56), flavor (3.18), L-value (34.51), pH (5.63), and Viscosity (6162.11 cP) of the coffee-gelatin shots. In order to validate the optimum condition, A coffee-gelation shot was made using 3 g coffee and 5.25 mL alcohol as the optimum condition (Table 4). The sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of the optimum formulation of coffee-gelatin shots were determined. The ANOVA was conducted between the predicted sensory properties, L-value, pH and viscosity of the optimum numerical condition (Table 4) and the experimental sensory properties, L-value, pH and viscosity of a coffee-gelatin shot made with an optimum condition (3 g coffee and 5.25 mL alcohol). The ANOVA indicated no significant difference between predicted response variables and the experimentally made coffee-gelation shot response variables as the p-value was larger than 0.05 and F-value was lower than F-value at a critical point.

Table 4. Results of numerical optimization using a desirability function of coffee-gelatin shots

Parameter	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
Coffee content	Maximize	1	3	1	1	3
Alcohol content	Minimize	5	15	1	1	3
Overall Acceptability	Maximize	1.17	4.2	1	1	3
Color	Maximize	2.4	4.5	1	1	3
Flavor	Maximize	3	4.6	1	1	3
Texture	Maximize	3	3.8	1	1	3
L-Value	Minimize	34.51	53.99	1	1	3
pH	Minimize	5.6	6.1	1	1	3
Viscosity	Maximize	102	6740	1	1	3

Solutions

No	Coffee content	Alcohol content	Overall Acceptability	Color	Flavor	Texture	L -Value	pH	Viscosity	Desirability
1	**3.00**	**5.25**	**3.05**	**4.33**	**3.18**	**3.56**	**34.51**	**5.63**	**6162.11**	**0.70**
2	2.23	9.19	3.44	3.27	3.18	3.54	41.76	5.74	3428.29	0.50

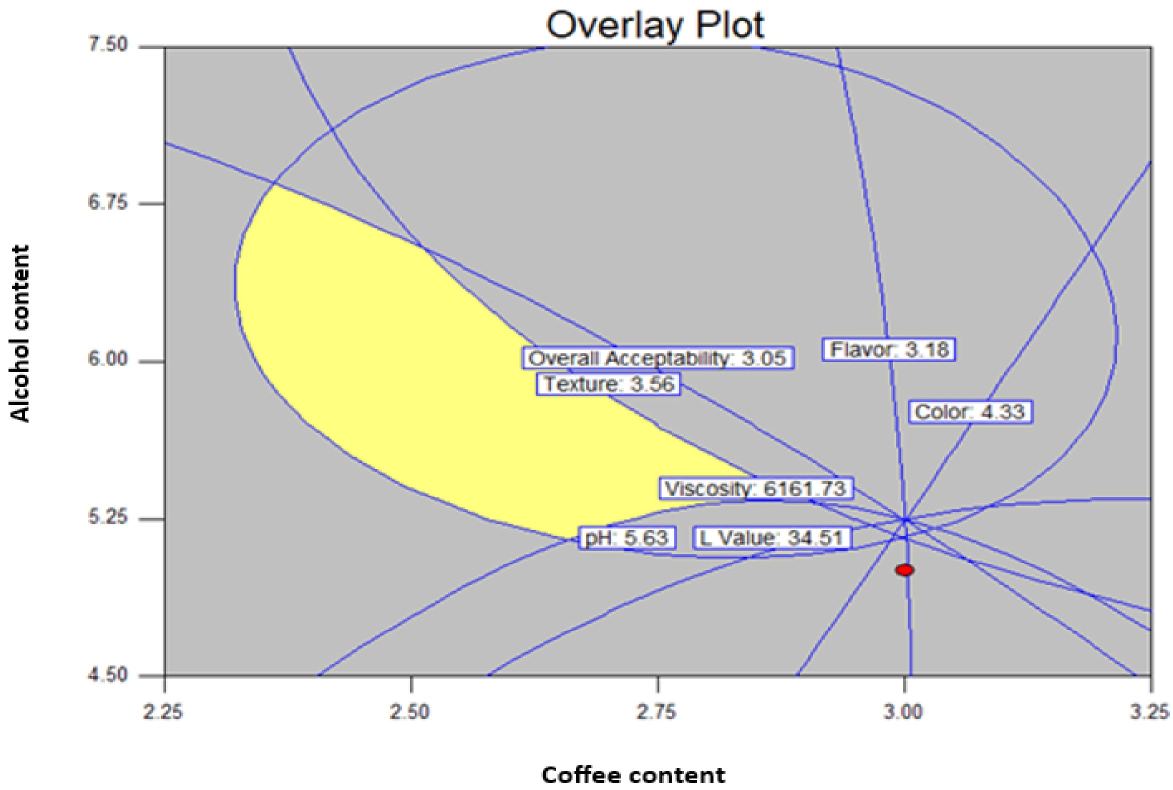

Figure 9. Graphical optimization (yellow shaded area) of coffee content (g) and alcohol content (mL) for the sensory properties (overall acceptability, color, flavor, and texture), L-value, pH, and viscosity of coffee-gelatin shots

3.3.2 Graphical Optimization

A crucial understanding can be established to calculate an optimum region of the independent variables of coffee content and alcohol content of the coffee-gelatin shots with a graphical representation using a combination of numerical optimization and graphical optimization (Mitra et al., 2020). The optimized numerical solution (Table 4) was visualized graphically to conclude the optimum regions where all constraints were fulfilled. The contour plots of overall acceptability, color, flavor, texture, L-value, pH and viscosity as a function of coffee content and alcohol content of coffee-gelatin shots were superimposed all together and determine an optimum region (shaded areas in the overlaid plots) as shown in Figure 9 (Mitra et al., 2023). The contour plots of all response variables with a shaded yellow region (Figure 8) indicated an optimum range 2.50-3.00 g coffee content and 5.25 – 6.75 mL alcohol content.

4. Conclusions

The combination of numerical optimization and graphical optimization revealed that 2.50-3.00 g coffee and 5.25-6.75 mL alcohol could be used to desired quality of coffee-gelatin shots. The regression models developed using response surface methodology

(RSM) were able to predict the sensory properties (overall acceptability, color, flavor and texture), L-value, pH and viscosity of coffee-gelatin shots as a function of coffee content and alcohol content with a 77-99% accuracy depending on the properties of coffee-gelatin shots. The response surface models indicated that coffee content increased the sensory properties and viscosity and decreased the L-value and pH of the coffee-gelatin shots. Whereas the alcohol content increased L-value and pH and decreased viscosity. The alcohol content showed a quadratic effect on the sensory properties of coffee-gelatin shots. The CCRD and RSM were very effective in developing regression and response surface models to predict the sensory properties, L-value, pH and viscosity of coffee-gelatin shots as a function of coffee content and alcohol content and to arrive at an optimum coffee-gelatin formulation for improved quality of coffee-gelatin shots. The results of this study are expected to be useful to develop consumers' desired coffee-gelatin shots.

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Conflict of Interest

Authors declare no conflict of interest.

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