

**STANDARDIZATION OF PROCESS PARAMETERS FOR LEGUME
BASED JALEBI BATTER**

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ABSTRACT

The study is focussed on the optimization of the fermentation process of a legume based Jalebi (Indigenous fermented sweet) batter. Fermentation is the most important step in Jalebi formulation as it affects the flow behavior of the batter and the flavor profile of the final product. To optimize the pulse flour incorporation (8-92%), inoculum (1.6-18.4%) and fermentation time (0-32 hr) on different properties of batter such as pH, acidity, viscosity, flowability and pourability, response surface methodology was used. Regression equation models explaining the changes of dependent variables with respect to the independent variables (pulse flour, inoculum and fermentation time) were developed with central composite rotatable design. The results indicated that while the fermentation time and inoculum significantly ($P < 0.01$) influenced the acidity and pH of the batter; the pulse flour and fermentation time, mainly affected the flow behavior of the Jalebi batter ($P < 0.01$). The compromised optimum experimental condition obtained for Jalebi batter was; pulse flour 26%, inoculum size 8%, and fermentation time 10 hr with pH 5.47, acidity 0.46 %LA, viscosity 41.5 Pa, flowability 0.067 sec^{-1} and pourability 0.23 mm sec^{-1} , which bear non-significant difference with the predicted values.

Keywords: *Jalebi; fermentation; flowability, pourability, viscosity, RSM*

PRACTICAL APPLICATIONS

Fermentation is the most important step in Jalebi formulation as it affects the flow behavior of the batter and the flavor profile of the final product. Addition of legume flour will affect the nutritional profile as well as the rheological properties of the batter. This calls for the optimization of the process parameters so as to obtain desirable properties of the batter in order to get optimum texture of the final product. The optimization will help in process scale up for commercial production.

1 | INTRODUCTION

The Indian subcontinent is well known for its cultural diversity and varied cuisines influenced by this diversity (Nawale, 2010). As a home for a large number of traditional delicacies, Indian cuisine has a unique place in the world culinary scenery (Krishnaswamy, 2008). These traditional food delicacies have undergone dramatic transformations over time to reach its current form. Many historical incidents such as trade relations, foreign invasions, and globalization played very important role in introducing many types of food to the country's food basket (Arya, 2014). Amongst these traditional foods, deep fried sweets are popularly consumed. Served primarily during festivals, wedding ceremonies, feasts, and religious auspicious occasions, these foods act as an emblem of happiness and prosperity (Pagote & Jayaraj, 2012).

Owing to its vastness and diverse cultural heritage the food in India is mainly categorized into two; North Indian and South Indian dishes (Krishnaswamy, 2008). The traditional North Indian foods include *Kulcha*, *Bhatura*, *Baati*, *Kheer*, *Churpi*, *Rajma*, *Barfi*, *Gulab Jamun*, *Panipuri*, etc. The main South Indian dishes include *Avial*, *Dosa*, *Halva*, *Bonda*, *Idli*, *Uttapam*, *Vada*, *Payasam* and *Appam* (Arya, 2014; Madhu & Sharma, 2009). However,

Jalebi is the most popular sweet, consumed all over India, despite cultural differences (Singhariya, 2011). It has a distinct spiral shape, a chewy texture, and a sweet taste making it irresistible to the sweet tooth (Chaudhary, 2014). Although, the origin of *Jalebi* could be tracked to Iran, it has become the primary sweet delight of the population in the Indian subcontinent (Pagote & Jayaraj, 2012) and thus is often regarded as the queen of sweets in India (Chitale, 2000).

The method of preparation of *Jalebi* is well established, but may minimally vary with change in place, culture and communities. Primarily, three variants of *Jalebi* are reported; *Chhana Jalebi*, *Khoa Jalebi* and *Maida Jalebi* (Nawale, 2010).

Typically, *Jalebi* is made from a batter of a flowable consistency prepared using *Maida*, water, and *dahi* (curd) as ingredients. This batter is fermented and then extruded using a cloth hole into a hot vegetable oil, and fried. Earlier the frying temperature and time of *Khoa Jalebi* was optimized and reported by Nawale (2010). These fried *Jalebi* coils are then soaked in hot sugar syrups, where sugar penetrates into the *Jalebi* coils which provide the sweetness to the product (Singhariya & Pagote, 2012). For *Channa Jalebi* the batter is made from *Chhana*, *Maida* and water (Pagote & Jayaraj, 2012). *Channa Jalebi* has a firmer texture than *Maida* and *Khoa Jalebi* (Nawale, 2010; Singhariya & Pagote, 2012; Rathod & Pagote, 2013). *Khoa Jalebi* is prepared by frying the extruded batter made of *Khoa*, arrowroot powder, toukir, and water (Chaudhary, 2015).

The amino acids make up of a protein source determines its quality and legume protein is rich in essential amino acids such as lysine, leucine and arginine (Boye, Zare, & Pletch, 2010a; Boye et al., 2010b). They are also rich sources of complex carbohydrates, vitamins, and minerals (Borsuk, 2011). Lentil is believed to be a functional food because of its high protein and fiber content. It contains 28.2 % protein, 1.8 % oil, 41-51.8 % carbohydrate, 21.4

% fiber, and also contains other mineral nutrients and unsaturated linoleic and oleic acid for human consumption (Bhatty, 1988; Man & Paucean, 2013).

Although the protein content of cereals is about 8-12 %, they often lack in some essential amino acids making them an incomplete protein. The present study was focused on studying the effect of lentil flour incorporation in *Jalebi* batter, % inoculum and fermentation time on the various physico-chemical and rheological parameters, which would map the road for the mechanization of *Jalebi*.

2 | MATERIALS AND METHODS

2.1 | Materials

Refined wheat flour (*Maida*), lentil flour, and *Dahi* culture were purchased from a local market of Jalandhar, Punjab, India.

2.2 | Methods

Lentil flour and *Maida* were mixed in different proportions. The blend (45 g) was inoculated with the *Dahi* culture and made up to batch size 100 g using water and fermented for the derived experimental time (Table 1).

2.3 | Design of Experiment

Response surface methodology was used for the design and analysis of all the experiments (Kaur, Sarkar, Sharma, & Singh, 2009). Central composite rotatable design were employed and the effect of variables, i.e. pulse flour (8-92%), inoculum (1.6-18.4%), and fermentation time (0-32 hour) on the responses pH, acidity (% LA), viscosity (Pa), flowability (sec^{-1}), pourability (mm sec^{-1}) was studied. The process variables in coded and actual levels is shown in Table 1.

2.4 | Flowability

The flowability of the batter was determined using the instrument as designed by Chakkaravarthi, Kumar, and Bhattacharya (2013). The instrument functioned on the principle of gravity, simulating the movement of *Jalebi* batter with 45° angle of inclination. The gadget is made of acrylic sheets of 3 mm thickness. The batter was poured manually on the V-shaped slanted surface in a fixed amount and the time taken by the *jalebi* batter to travel 30 cm was expressed for the measurement of flowability. Flowability is calculated as per Equation (1).

$$\text{Flowability} = 1 / \text{time taken to run on 30 cm on the slant surface} \quad \text{Eq. (1)}$$

Flowability was represented in sec^{-1} , and equation designates that an easily flowable material will take a less time to run on slant surface.

2.5 | Pourability

The pourability of the batter was performed as described by Chakkaravarthi et al. (2013). An instrument based on principle of gravity was designed to check the movement of *Jalebi* batter. The batter was allowed to flow through the orifice of a container. The container had a diameter of 80mm with an orifice of 7.0 mm diameter.

The batter was allowed to fall freely through 7.0 mm diameter port opening and further passed between the graduated marks of the equipment. The time taken was noted and calculated by Equation (2)

$$\text{Pourability} = \text{Distance of the graduated marks} / \text{Time required to flow between two graduated marks} \quad \text{Eq. (2)}$$

Pourability is represented in mms^{-1} which shows that the easily pourable material will take less time so that the value of pourability turn out to be high.

2.6 | Viscosity

The viscosity of the batter was assessed as described by Nisha, Ananthanarayan, and Singhal (2005) using a Brookfield viscometer. Brookfield viscometers have the principle of rotational viscometer, in which the torque requires to turn an object, such as a spindle, in a fluid indicates the viscosity of the fluid.

2.7 | pH and acidity

The pH of the batter was determined by a portable electronic pH meter (Model EZDO PL-600, HTA Instrumentation, Bangalore, India) (AOAC, 1984). The acidity of the batter was determined as described by Balasubramanian, Jincy, Ramanathan, Chandra, and Deshpande (2015).

2.8 | Data Analysis

The responses (pH, acidity, flowability, pourability, viscosity) for different combinations designed by software were associated to the variables by a second degree polynomial (Equation 3) as shown in Eq 3:

$$y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12} X_1X_2 + b_{13} X_1X_3 + b_{23} X_2X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + \epsilon$$

Eq. (3)

Where, b_i , ($i = 0, 1, 2, 3, 12, 13, 23, 11, 22, \text{and } 23$) are the coefficients of the polynomials, b_0 (constant), b_1, b_2, b_3 indicates linear effect; b_{12}, b_{13}, b_{23} indicates interactive effects; b_{11}, b_{22}, b_{33} shows quadratic effects; and ϵ is error. Data were analyzed multiple regression analysis and the terms were evaluated by analysis of variance (ANOVA) for each response. Design

Expert Software version 7.0 (Stat-Ease Inc., Dulles, Washington, USA) was used for the statistical analysis of data and three dimensional plotting were performed. The appropriateness of model was analyzed by using different parameters such as F -test, R^2 , Adj R^2 and Pred R^2 (Montgomery, 2001). 3-D plots were created using design expert software from the predicted model.

3 | RESULTS AND DISCUSSION

3.1 | Effect on pH

The pH of the *Jalebi* batter ranged from 4.39 (Experiment No. 6) to 6.22 (Experiment No. 20) depending on the treatment conditions (Table 1). Table 2 shows that the inoculum size and fermentation time affected the pH of the *Jalebi* batter significantly ($p < 0.05$) at linear and interactive level (Figure 1a) while, the pulse flour percent is significant only at the quadratic terms. The variation in the pH value may be due to the lactic acid production during fermentation. The lactic acid plays a major role in reducing the pH of batter to an optimum level of 4.4-4.5 (Soni & Sandhu, 1990). With the increase in the inoculum size, there was a significant decrease in pH, which may be due to lactic acid production by increased number of lactic acid bacteria present in the inoculum (Chakkaravarthi et al., 2013). Balasubramanian et al. (2015) reported that lowering of pH value is linked with the growth of *S. faecalis* producing lactic acid. The hetero-fermentative lactic acid bacterium are responsible for the reduction in pH and the fermentation time. Kaur, Singh, and Singh (2000) reported the activity of lactic acid bacteria and subsequent decrease in pH (6.5-4) of idli batter during fermentation. A complete second-order model (Eq. 3) was evaluated for its appropriateness to explain the variation of pH with parameters under study (pulse flour, inoculum size and fermentation time). Table 2 and 3 depicts the coefficients of the model and other statistical parameters. The F value of 51.95 is significant at $P < 0.01$. The analysis of variance

(ANOVA), Table 3, shows that the coefficient of determination, R^2 value, is 0.98, which means that 98% variation in the data is explained by the model. Adj R^2 value is 0.96, which indicates that the terms kept in the model contributed in the variation. Predicted R^2 0.91 shows the model predicts a response value well in the experimental regions. The following response model was generated to represent the variation in pH for further analysis:

$$Y_1 = 5.42 + 0.02X_1 - 0.28X_2 - 0.42X_3 + 0.02 X_1X_2 - 0.02X_1X_3 - 0.18 X_2X_3 - 0.12X_1^2 + 0.01X_2^2 + 0.02X_3^2 \tag{Eq. (4)}$$

Where, Y_1 is the pH of the batter and X_1 , X_2 and X_3 are coded independent variables.

TABLE 1 Effect of pulse flour, inoculum size, and fermentation time on pH, acidity, viscosity, flowability, pourability

Sl. No.	Independent variables			Dependent variables				
	pulse flour %	Inoculum size %	Fermentation time hour	pH	Acidity %LA	Viscosity Pa	Flowability sec^{-1}	Pourability mm sec^{-1}
1	75	5	24	5.39	0.49	18.65	0.12	0.82
2	25	15	1	5.51	0.45	39.28	0.13	0.53
3	75	15	1	5.72	0.44	15.76	0.15	0.63
4	50	10	12.5	5.34	0.45	26.60	0.11	0.42
5	75	5	1	5.81	0.43	14.98	0.11	0.49
6	75	15	24	4.39	0.63	20.46	0.10	0.43
7	50	1.6	12.5	5.94	0.44	21.91	0.08	0.42
8	50	10	12.5	5.42	0.43	24.48	0.11	0.45
9	50	10	32	4.84	0.54	28.92	0.08	0.38
10	92	10	12.5	5.16	0.53	11.40	0.14	0.55
11	25	5	24	5.31	0.51	40.91	0.05	0.25
12	8.0	10	12.5	5.09	0.54	56.40	0.03	0.09

13	50	10	12.5	5.32	0.47	28.79	0.11	0.41
14	50	10	12.5	5.57	0.43	25.92	0.11	0.43
15	25	15	24	4.43	0.58	50.64	0.03	0.05
16	50	10	12.5	5.36	0.45	25.61	0.11	0.47
17	50	10	12.5	5.48	0.43	24.12	0.12	0.48
18	50	18.4	12.5	5.04	0.50	25.24	0.12	0.49
19	25	5	1	5.84	0.44	45.87	0.05	0.12
20	50	10	0	6.22	0.31	22.50	0.12	0.49

TABLE 2 Regression coefficient of full second order model for different responses (pH, acidity, viscosity, flowability and pourability)

Predictor	pH	Acidity	Viscosity	Flowability	Pourability
Constant	+5.42	+0.44	+25.82	+0.11	+0.44
X ₁	+0.02	-0.0006	-13.37**	+0.031**	+0.16**
X ₂	-0.28**	+0.026*	+0.83	-0.011*	+0.006
X ₃	-0.42**	+0.062**	+1.87*	-0.015**	-0.029**
X ₁ X ₂	+0.02	+0.007	-0.07	-0.005*	-0.057**
X ₁ X ₃	-0.02	+0.005	+0.25	+0.007*	+0.060**
X ₂ X ₃	-0.18*	+0.024*	+2.17*	-0.020**	-0.14**
X ₁ ²	-0.12*	+0.037**	+3.45*	-0.008*	-0.041*
X ₂ ²	+0.01	+0.013*	-0.20	-0.003	+0.007
X ₃ ²	+0.02	-0.004	+0.55	-0.005*	-0.0005

Where ** = significant at P<0.01 and * = significant at P<0.05

3.2 | Effect on Acidity

The acidity of the *Jalebi* batter ranged from 0.306 to 0.630 (Table 1). Table 3 showed that the model stands significant and also lack of fit was found to be non-significant. The analysis of variance (ANOVA), Table 3, showed that the F value is 25.89 which is significant at $P < 0.01$ (Table 3). The values of R^2 , Adj R^2 and Predicted R^2 in Table 3 indicates that the model predicts a response value well in the experimental regions.

The result of the complete second order model is given in Table 2. The results show that, both inoculum size ($P < 0.05$) and fermentation time linearly affected the acidity positively, whereas, pulse flour ($P < 0.01$) (Table 2) affected the acidity negatively. The effect of fermentation size was more when compared to inoculum size since fermentation aids the development of lactic acid bacteria. Balasubramanian et al. (2015) reported the acidity of idli batter from 0.443-0.910%.

Both the variables viz fermentation time and inoculum size positively affected the acidity of the batter ($P < 0.05$), where, fermentation time had a higher effect than the inoculum size; however, there interaction had greater effect than the individual variable (Figure 1b). The increase in the inoculum during fermentation provided rapid acidification by secretion of organic acids, mainly by lactic acid bacteria and thus leading to a faster fermentation (Soni & Sandhu, 1990). Balasubramanian and Viswanathan (2007) reported that the inoculum serves a source of microorganisms for fermentation and hence it increase the acidity of the batter. A similar observation was reported by Rekha and Vijayalakshmi (2011) for idli. During fermentation the two most important changes occurring are acidification and leavening (Soni & Sandhu, 1990). The effect of the inoculum size on the acidity of the batter depends on the fermentation time (Chakkaravarthi et al., 2013). The air pocket formation and leavening action during fermentation is also responsible for the increase in acidity (Shrivastava &

Ananthanarayan, 2015) whereas, the inoculum provided the culture for fermentation. The acidity increases with decrease in the pH value (Soni & Sandhu, 1990). When compared to inoculum size and pulse flour, fermentation time had more effect on acidity.

Equation (5) represented the statistically significant model to analyse variation in acidity of the batter

$$Y_2 = 0.44 - 0.0006X_1 + 0.026X_2 + 0.062X_3 + 0.007 X_1X_2 + 0.005X_1X_3 + 0.024 X_2X_3 + 0.037X_1^2 + 0.013X_2^2 - 0.004X_3^2 \quad \text{Eq. (5)}$$

Where, Y_2 is the acidity of the batter and X_1 , X_2 and X_3 are coded independent variables.

TABLE 3 Analysis of variance of fitted models of the response functions

Response	Sources of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
pH	Regression	9	3.94	0.44	51.95**
	Error	5	0.046	9.19×10 ⁻³	
	Total	19	4.02		
	Lack of fit	5	0.038	7.647×10 ⁻³	0.083NS
	R2 =0.98;				
	R2(adj.)=0.96;				
	R2(pre)=0.91				
Acidity	Regression	9	0.088	9.814×10 ⁻³	25.89**
	Error	5	1.131×10 ⁻³	39.67	
	Total	19	0.092		

	Lack of fit	5	2.660×10^{-3}	5.319×10^{-3}	2.35NS
	R2		=0.96;		
	R2(adj.)		=0.92;		
	R2(pre)		=0.75		
Viscosity	Regression	9	2711.82	301.31	41.88**
	Error	5	14.11	2.82	
	Total	19	2783.77		
	Lack of fit	5	57.84	11.57	4.10NS
	R2		=0.97;		
	R2(adj.)		=0.95;		
	R2(pre)		=0.81		
Flowability	Regression	9	0.023	2.520×10^{-3}	58.31**
	Error	5	9.733×10^{-3}	1.947×10^{-3}	
	Total	19	0.023		
	Lack of fit	5	3.349×10^{-4}	6.697×10^{-5}	3.44NS
	R2		=0.98;		
	R2(adj.)		=0.96;		
	R2(pre)		=0.87		

3.3 | Effect on viscosity

The viscosity of the *Jalebi* batter ranged from 11.4 to 56.4 Pa (Table 1). Minimum viscosity was observed in the experimental run number 9 with experimental conditions 92% pulse flour, 10% inoculum and 12.5 hour fermentation, whereas, the corresponding conditions for

maximum viscosity was observed in the experimental run number 12 with experimental conditions 8% pulse flour, 10% inoculum, and 12.5 hours fermentation. Viscosity and other rheological properties of batter depend upon the particle size of the flour and the solid concentration in the batter (Rekha & Vijayalakshmi, 2011).

From the ANOVA Table 3, lack of fit with F value 4.10 is non-significant and therefore, the model is significant. Viscosity model with F value 41.88 was significant at $P < 0.01$. The linear effect of pulse flour percent and fermentation time was significant ($P < 0.05$) dominated the inoculum size, while, the interactive effect of the inoculum size and fermentation time (significant at $P < 0.05$) dominated the other interactions (Table 2). At the quadratic level the change in pulse flour showed a significant effect ($P < 0.05$).

As observed from the Figure 1c, it is observed that an increase in pulse flour from 25-75% decreased viscosity from 45-15 Pa. Batter is a complex system having three phases such as solid, liquid, and gas. Hence the viscosity of such complexes will depend on different factors such as nature of substances in the liquid phase and their effect on interfacial tension. The negative effect of pulse flour on viscosity can be due to their surface active properties, since the pulse flour made the batter smoother (Nisha et al., 2005). Kaur et al. (2000) reported the decrease in viscosity of *Idli* batter due to its pseudoplastic shear thinning behaviour. The enhanced aeration of batter and activity of microbial enzymes like amylase and proteases are the suggested factor for change in the viscosity of batter. Asha, Susheelamma, and Guha (2007) reported that pulse flour batters mainly black gram flour have the higher water imbibition capacity and increased viscosity rates to increase in pulse flour in the batter. The increase in fermentation time slightly increased the viscosity from 25-30 Pa. The change in flow behaviour of the batter namely viscosity was reported by Chakkaravarthi, Kumar, and Suvendu (2009).

Equation (6) was chosen to represent the changes in viscosity with the independent variables

$$Y_3 = 25.82 - 13.37X_1 + 0.83X_2 + 1.87X_3 - 0.07 X_1X_2 + 0.25X_1X_3 + 2.17 X_2X_3 + 3.45X_1^2 - 0.2X_2^2 + 0.55X_3^2 \quad \text{Eq. (6)}$$

Where Y_3 is the acidity of the batter and X_1 , X_2 and X_3 are coded independent variables.

3.4 | Effect on Flowability

The flowability of the batter ranged from 0.03 to 015 sec⁻¹ (Table 1). Chakkaravarthi et al. (2013) reported the flowability of *Maida Jalebi* batter from 0.0027 to 0.0638 sec⁻¹.

From the ANOVA (Table 3), F value of lack of fit is 3.44 which is non-significant and hence the model is fit. The F value of model is 58.31, which shows that the model is significant (P<0.01). From the Table 3, R² value, is 0.98, which means that 98% variation in data was explained by the model. Adj R² value is 0.96 which indicates that the terms kept in the model contributed in variation.

The results of the complete second order model are given in Table 3. From the Table 2 it can be observed that both pulse flour and inoculum size has a significant positive effect (P<0.01) on the flowability of the batter, whereas, the fermentation time has a negative effect on the flowability. The effect of pulse flour on flowability of the batter was more when compared to inoculum size and fermentation time.

The addition of pulse flour, increased the flowability of the batter significantly (P<0.01) (Table 2). With an increase in pulse flour from 25-75% the flowability varied from 0.06-0.14 sec⁻¹. The increase in flowability of the batter may be due to the high water holding capacity of pulse flour than that of normal *Maida* (Nisha et al., 2005). Asha et al. (2007) reported that pulse flour batters have higher water imbibition capacity. Chakkaravarthi et al. (2013)

reported that the increase in moisture content increases the flowability of *Maida* batter. Similar, positive and significant effect was shown by inoculum size at linear level ($P < 0.01$) (Table 2). An increase in inoculum size from 5-15%, flowability varied from 0.09-0.14 sec^{-1} . A strong interactive effect of curd and fermentation time on flowability was reported by Chakkaravarthi et al. (2013) and concluded that the effect of curd on the flowability will depends on the fermentation time. The increase in the flowability may be due to the action of inoculum as a source of moisture. The enhanced aeration of the batter due to the effect of inoculum, fermentation time and subsequent decrease in viscosity was reported by Kaur et al. (2000). Increase in fermentation time decreased the flowability of the batter significantly ($P < 0.01$) at linear level (Table 2). The increase in fermentation time from 1-24 hours, decreased the flowability from 0.14-0.08 sec^{-1} . A decrease in flowability of *Maida Jalebi* batter with increase in fermentation time was reported by Chakkaravarthi et al. (2013). The decrease in flowability may be due to the result that, the acids produced during fermentation attains saturation and further increase in fermentation time or inoculum does not contribute to pH (Asha et al., 2007), and affects the flow behaviour of the batter. Time dependent change in viscosity will occur while pouring of batter that is seen in shear-thinning thixotropic fluids (Chakkaravarthi et al., 2013). The interaction between both inoculum size and fermentation time negatively affected the flowability since the effect of fermentation time was more dominant (Figure 1d). In quadratic level pulse flour ($P < 0.05$), and fermentation time ($P < 0.05$) positively affected, whereas, the inoculum size negatively affected the flowability.

The response model generated is represented by Equation (7)

$$Y_4 = 0.11 + 0.031X_1 - 0.011X_2 - 0.015X_3 - 0.005 X_1X_2 + 0.007X_1X_3 - 0.020X_2X_3 - 0.008X_1^2 - 0.003X_2^2 - 0.005X_3^2 \quad \text{Eq. (7)}$$

Where, Y_5 is the flowability of the batter and X_1 , X_2 and X_3 are coded independent variables.

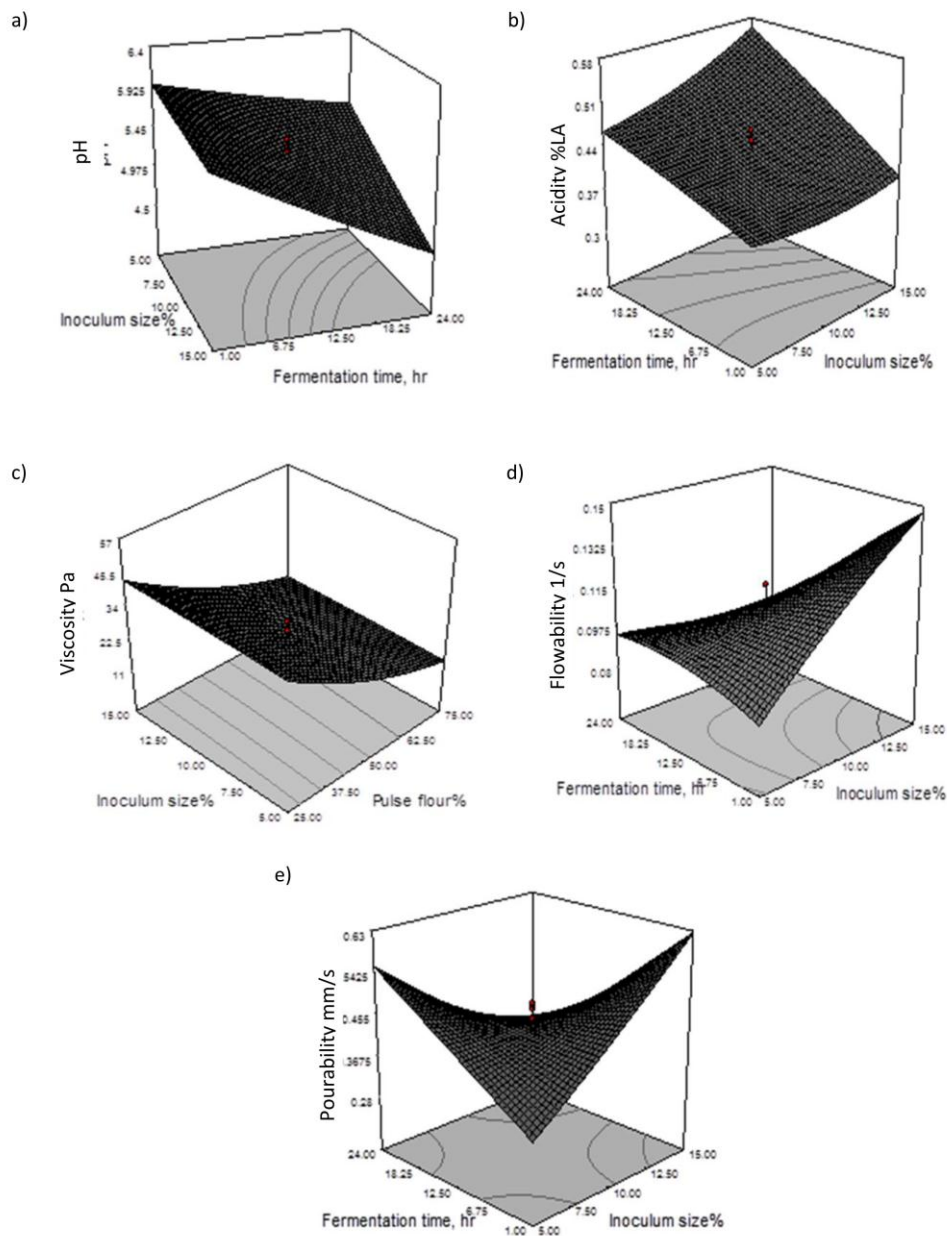


Figure 1: Effect of independent variables on different responses.

3.5 | Effect on pourability

Pourability of the batter ranged from 0.05 to 0.82 mm sec⁻¹ (Table 1) under different treatment conditions. The pourability of *Maida Jalebi* batter ranged from 0.0067-0.2740 mm sec⁻¹ as reported by Chakkaravarthi et al. (2013). Change in rheological properties will depend upon the particle size of flour and solid concentration of batter (Swami, Das, & Maiti, 2004).

The analysis of variance (Table 3) shows that the lack of fit 2.24 was non-significant and hence the model is fit. The F value is 52.15, which indicates that the model is significant (P<0.01). The results of the complete second order model are given in Table 2. From the table the addition of the pulse flour has a positive effect on pourability of the batter, whereas, fermentation time have a negative effect on its pourability. The effect of pulse flour on pourability of the batter was more dominant when compared to fermentation time. The inoculum size had a positive significant effect (P<0.05) on the pourability of the batter. However, the pourability was most effectively affected by the interaction of fermentation time and the inoculum size (Figure 1e).

The response model generated is represented by Equation (8)

$$Y_5 = 0.44 + 0.16X_1 + 0.006X_2 - 0.029X_3 - 0.057 X_1X_2 + 0.060X_1X_3 - 0.14X_2X_3 - 0.041X_1^2 + 0.007X_2^2 - 0.0005X_3^2 \quad \text{Eq. (8)}$$

Where, Y₅ is the pourability of the batter and X₁, X₂ and X₃ are coded independent variables.

3.6 | Optimization

The compromised optimum condition was obtained using the Design Expert Software Package (version 7.0). Optimization of the final product was based on the fact that viscosity and flowability is similar to the market sample of *Maida Jalebi* batter. Hence, the conditions

applied to numerical optimization were pulse flour incorporation maximum, inoculum minimum and fermentation time minimum for the independent variables and in responses viscosity target as 43.6 Pa (market sample), flowability as 0.06 sec^{-1} and pourability $0.2564 \text{ mm sec}^{-1}$. The compromised optimum condition obtained were: Pulse flour 26%, inoculum size 8%, and fermentation time 10 hr with pH 5.47, acidity 0.46 %LA, viscosity 41.5 Pa, flowability 0.067 sec^{-1} , pourability 0.23 mm sec^{-1} . While the model predicted values were, pH 5.6, acidity 0.44 %LA, viscosity 43.0 Pa, flowability 0.07 sec^{-1} and portability 0.28 mm sec^{-1} . Thus, there was no significant difference ($P < 0.05$) between predicted and experimental values.

4 | CONCLUSION

RSM was employed to investigate the effect of pulse flour incorporation, inoculum size and fermentation time on *Jalebi* batter properties. It was concluded that pulse flour and the fermentation time significantly affected the flow behaviour property of *Jalebi* batter, while inoculum and fermentation time influenced the pH and acidity of the batter. Mathematical models were developed for individual response functions and finally optimized conditions generated experiment were pulse flour 26%, inoculum size 8%, and fermentation time 10 hr showed response values of pH 5.6, acidity 0.44 %LA, viscosity 43 Pa, flowability 0.07 sec^{-1} , pourability 0.28 mm sec^{-1} .