RESEARCH ARTICLE

Multi factor optimization for mechanized formation of *khoa peda*

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Abstract Present investigation was carried out to optimize process parameters for mechanized formation of *khoa peda*. Mechanized *peda* forming system was designed on the principle of piston press technology. Experimental setup consisted of piston, cylinder, die, and knife cutter arrangement for extruding *khoa peda* mass into small discs. Process factors for the study were temperature (26 to 34°C), pressure (0.276 to 0.818 kg/cm^2) and die geometry ratio (1 to 2). Design Expert software (Ver. 8.0) was used for multi factor optimization. Textural properties of market samples were taken as target values for optimization. Optimized factors for the mechanized formation of *peda* were 34°C temperature of *peda* mass, 0.818 kg/cm^2 pressure and 1.913 die geometry ratio. At optimized parameters, the predicted values for hardness, adhesiveness, springiness, gumminess, chewiness, and thickness were 27.906 N,-0.315 N.s,0.089 mm, 3.005 N,0.302 N.mm and 1.89 cm respectively.

Keywords : *peda*, mechanization, formation, multi factor optimization

Introduction

Traditional Indian milk products have been an important part of the socio-cultural life of India. Inspite great number of traditional dairy product found in different part of India, each of these indigenous products has its unique flavor, texture, and appearance (Pal and Raju, 2010). In addition to increasing the shelf life, manufacture of traditional dairy products add value to milk and also provide considerable employment opportunity (Parekh, 2013). Some of the popular heat desiccated traditional dairy products are burfi, kalakand, *peda*, rabri, basundietc. *Peda* is one of the major khoa based sweets, which is very popular among Indians mainly because of its delicious taste and relative long shelf life. It has been reported that the quantity of *peda* produced in India is more than any other indigenous milk based sweet (Mahadevan 1991; Aneja et al, 2002; Jha et al., 2014).

Peda is prepared by heating a mixture of khoa and sugar until the desired granular, hard texture and flavour develops. Different varieties of *peda* have distinct characteristics and manufacturing process vary from region to region. The base for all these types of *peda* is khoa and cane sugar in different proportions. Other ingredients are also added for flavour. *Peda* is normally made into round balls of about 20-25 g size by rolling between the palms (Pal, 2000). Several types of *peda* are marketed in different regions of the country with modifications in the process i.e. Doodh *peda*/Mathura *peda* (Uttar Pradesh), Kunthalgiri*peda* (Karnataka), Dharwad *peda* (Karnataka), Lal*peda* (Eastern Uttar Pradesh), Plain *peda*, Kesar *peda*, Brown *peda*, etc. There is great potential for these region specific traditional Indian dairy products to become popular outside the region (Modha et al., 2014). It is only possible when mechanized process is developed for their large scale manufacture. At present manufacture of *peda* is mostly restricted to halwais (Gavhane et al., 2014). The process used by small scale sweet makers is usually energy inefficient and labour intensive. Commercial production of *peda* has been restricted to few dairy processing plants due to lack of appropriate processing equipments. And there is great opportunity for the organized dairy sector in the country to modernize and scale up their production (Bandyopadhyay and Khamrui, 2007).

Number of researchers have worked towards development of mechanized process for *peda*. NDDB method for making kesar *peda* involves heating khoa to 60°C and adding sugar, flavour and other ingredients in a planetary mixer. *Peda* mass after

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cooling to 5°C is fed to *peda* shaping machine followed by packaging (Banerjee, 1997). A *peda* sweet pressing machine integrated with the ball forming/multipurpose rounder machine has been developed by Aksar Food Machines (AFM, 2013). Cylindrical shaped piece is cut by cutter and die arrangement over a moving belt. Then cylindrical *peda*s are rounded by the rotating top plate. Number of studies has been carried out for mechanized production of *peda* mass. But substantial efforts have not been made for development of *peda* disc cutting and forming system. Therefore in this study a system was developed and multifactor optimization was carried out for formation and shaping of *peda*.

Materials and Methods

Experimental setup

Experimental set up consisted of a cylindrical barrel, cylindrical die, piston, water bath and pump (figure 1). The system was designed to handle 8 kg khoa mass per batch. Three dies were designed with different cone angle, taperness and die geometry (Table 1). Die geometry ratio was calculated as a/b, where a and b are the horizontal and vertical distance between the bottom edge and the top edge of the cone respectively. *Khoa peda* mass was filled in the barrel and was pressed by applying dead weight on the piston. Temperature of *peda* mass during extrusion was controlled by circulating hot water through the jacketed barrel. For each trial 4 kg *khoa peda* mass was used.

Table 1: Design specification of die geometry

Die geometry ratio (a/b)	Cone angle	Taper
1.0	90°	200%
1.5	67.38°	133.33%
2.0	53.13°	100%

Process parameter optimization

During preliminary trials it was observed that the factors affecting formation and shaping of *peda* were temperature of *peda* mass, total solids, force required for extrusion and die geometry. Effect of three process variables viz. temperature, pressure and die geometry were studied on mechanized

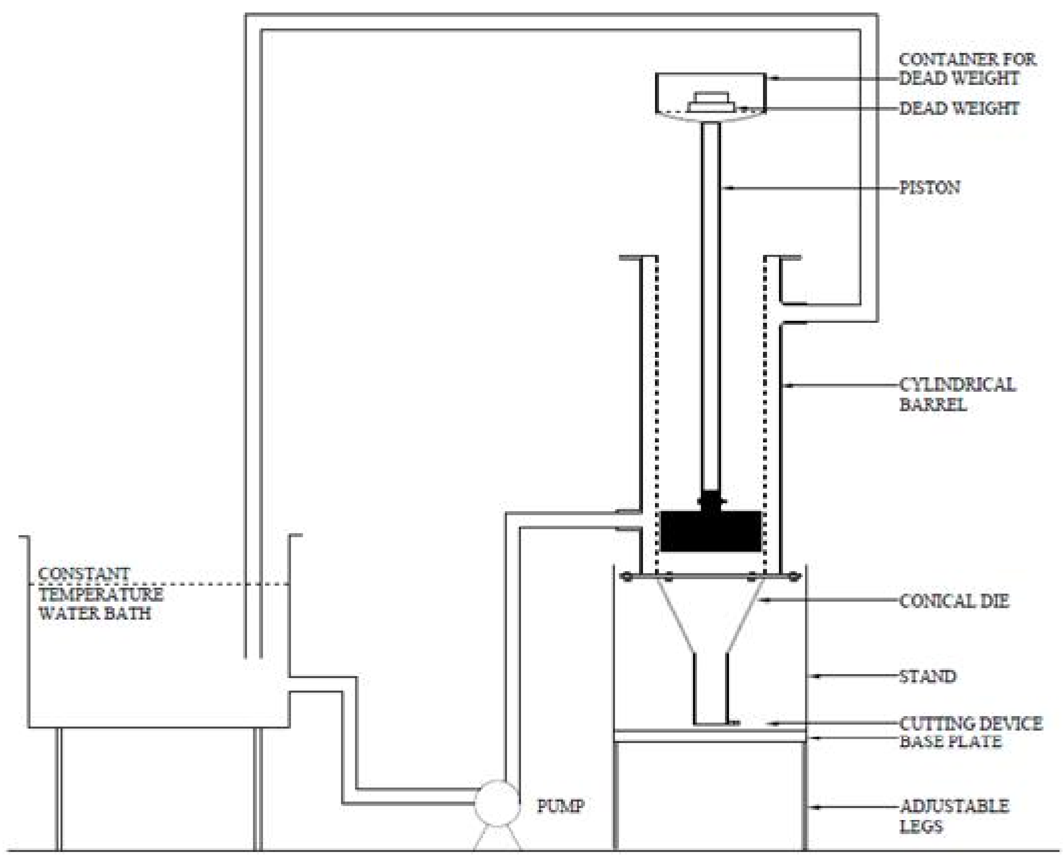


Figure 1 : Experimental set up for mechanized formation khoa peda

formation of *khoa peda*. During preliminary trials, low and high level of different variable parameters were selected (Table 2). On the basis of the geometrical dimension (thickness of *peda*) and texture characteristics, the process parameters were optimized. Thickness of each *peda* extruded from the developed system was measured using verniercalliper. Textural properties were measured using texture analyzer TA-XT2i (Stable Micro Systems, UK) fitted with a 25 kg load cell. Texture Expert software version 1.2 (Stable Micro Systems) was used to measure and analyze textural properties like hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience.

For multi factor optimization, Response Surface Methodology (RSM) was applied using Design Expert software (version 8.0). Central composite rotatable design was used to determine the effect of each factor (variable parameters) on the responses (thickness and textural parameters). Textural properties of market samples were taken as target values for optimization.

The three factors i.e. temperature of *peda* mass (°C), extrusion pressure (kg/cm^2) and die geometry were coded as A, B, and C. Their range and levels are presented in Table 2. A total of 20 trials were carried out in randomized order (Table 3). It was assumed that response (y) is a function of experimental factors (A, B, C) or y = f (A, B, C). Second order polynomial models were developed by multiple regression technique for each of the response using the software.

$$y = + \beta_0 + \beta_1*A + \beta_2*B + \beta_3*C + \beta_{12}*A*B + \beta_{13}*A*C + \beta_{23}*B*C - \beta_{11}*A^2 - \beta_{22}*B^2 - \beta_{33}*C^2 \quad \text{.............(equ. 1)}$$

Where β_0 is the intercept, β_1, β_2, β_3 are the first order cofficients, β_{12}, β_{13}, β_{23} are the cross product cofficients, and β_{11}, β_{22}, β_{33}, are the second order cofficients.

Results and Discussion

Effect of variable factors on thickness of the *peda*

The 3D plots showing effect of different variable factor on *peda* thickness are presented in figure 2. Considering die geometry at centre point (1.5), thickness of *peda* increased with increase in temperature as well as pressure. When the pressure was kept at the centre point 0.552 kg/cm^2, it was observed that increase in thickness was much more due to die geometry as compared to temperature. Considering temperature at the centre point 30°C, thickness was only affected by die geometry. Thickness of *peda* significantly depended on die geometry ($p<0.05$) whereas other parameters such as temperature and pressure were non-significant. Adequate Precision Value (APV) was found to be 7.650, which is a measure of signal to noise ratio. It was more than the minimum desirable (4.00) for high prediction ability. The response equation for thickness is as follows:

$$\text{Thickness} = +0.38+0.01A+4.09B-0.57C-0.11AB+0.045AC-0.67B \quad \text{.............(equ. 2)}$$

Effect of process variables on the textural properties of the *peda*

The body and textural attributes of *peda* will depend on the final total solids (TS), sugar content and working of *peda* mass during manufacturing. Process conditions during die extrusion were expected to affect of textural properties. Therefore, the effect of temperature, applied pressure and die geometry of *peda* was studied.

Hardness

During preliminary trials it was observed that temperature had major effect on extrusion process. The range of temperature selected for extrusion was 26 to 34°C. Temperature below this range resulted in very hard *khoa peda* mass. And the pressure required for extruding was very high. If the barrel temperature was too high (>34°C), shape of *peda* disc deformed and the pieces were not firm. Considering die geometry at centre point (1.5), with an increase in temperature as well as pressure hardness of *peda* increased (Fig. 3 a). When pressure was kept at the centre value (0.552 kg/cm^2), temperature had negligible effect on hardness. But increase in die geometry increased the hardness of final product (Fig. 3 b). Keeping temperature at the centre point 30°C, it was observed that increase in pressure resulted in more firm *peda* (Fig. 3 c). Results revealed that the effect on hardness was significant ($p<0.02$) with respect to die geometry while effect of temperature and pressure was non-significant. The regression model equation for hardness is given as:

$$\text{Hardness} = -167.32+5.92A+188.64B+65.43C-6.48AB-1.99AC+15.64BC \quad \text{..........(equ. 3)}$$

Table 2. Process temperatures and process pressures

Factors	Low level	High level	Levels
A - Temperature	26	34	26, 30, 34°C
B - Pressure	0.276	0.828	0.276, 0.552, 0.828 kg/cm^2
C - Die geometry	1.0	2.0	1:1, 1:1.5, 1:2

Table 3.The central composite rotatable design for three process variables

Std	Run	Factor 1 A: Temperature	Factor 2 B:Pressure	Factor 3 C:Die geometry
		℃	kg/cm^2	a/b
14	1	30	0.552	2.0
18	2	30	0.552	1.5
6	3	34	0.276	2.0
20	4	30	0.552	1.5
13	5	30	0.552	1.0
2	6	34	0.276	1.0
3	7	26	0.828	1.0
15	8	30	0.552	1.5
10	9	34	0.552	1.5
17	10	30	0.552	1.5
9	11	26	0.552	1.5
1	12	26	0.276	1.0
4	13	34	0.828	1.0
16	14	30	0.552	1.5
8	15	34	0.828	2.0
5	16	26	0.276	2.0
12	17	30	0.828	1.5
19	18	30	0.552	1.5
7	19	26	0.828	2.0
11	20	30	0.276	1.5

Adhesiveness

Adhesiveness is the work required to overcome the force between food and any surface in contact with the food product. Lower adhesion value is desirable to reduce extrusion pressure. And it will also enable easy removal of *peda* disc from any flat surface or belt conveyor over which it is formed. Adhesiveness is primarily affected by the composition of *peda* mass and the operating parameters during extrusion process. Considering die geometry at constant centre point (1.5) adhesiveness increased when any of the other two factors temperature or pressured were increased (fig. 4a). Adhesiveness was minimum when temperature and pressure were at lowest value. Keeping temperature constant (30°C), it was observed that adhesiveness decreased with increase in pressure as well as die geometry (Fig. 4c). Results revealed that effect of temperature, pressure and die geometry was non-significant. Adequate precision value (APV) for the model was 7.682, which was appreciably higher than the minimum desirable (4.00). Prediction equation for adhesiveness of *peda* in terms of actual parameters is given as:

Adhesiveness = -0.74+0.03A+3.32B-1.41C-0.14AB+0.03AC+0.70BC ....(equ. 4)

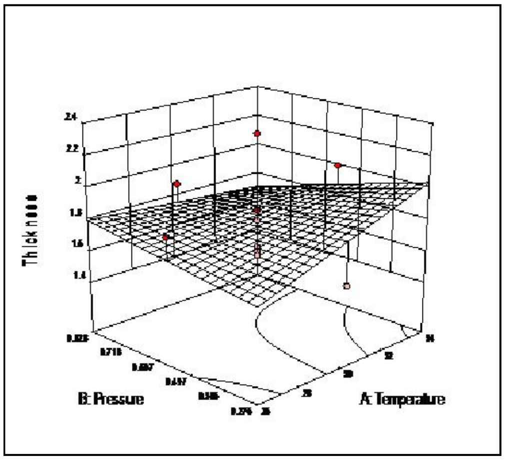
Springiness

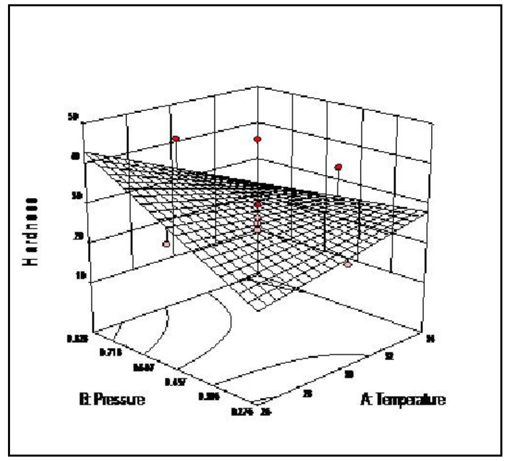
When die geometry was kept at centre point (1.5), with an increase in temperature or pressure springiness of *peda* decreased (Fig. 5a). Springiness was maximum for lower values of process variables (Pressure = 0.276 kg/cm^2 and Temperature = 26°C). Considering pressure at centre point (0.552 kg/cm^2), springiness increased with increase in temperature as well die geometry (Fig. 5b). When temperature was kept at the centre point (30°C), change in springiness was negligible with increase in pressure or die geometry. Effect of temperature, pressure and die geometry on springiness was non-significant. The response equation for springiness of *peda* in terms of actual parameters is given as:

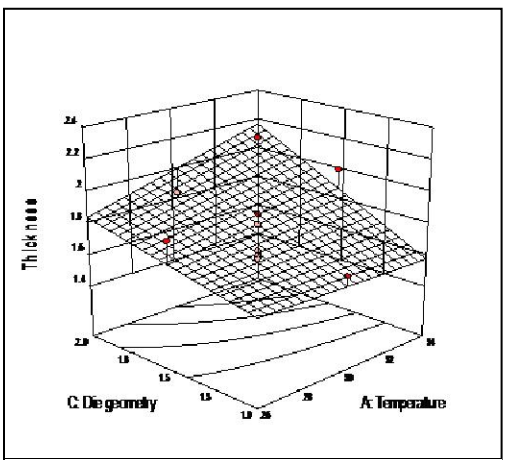
Springiness = -0.298+0.01A+0.02B+0.37C+9.06E-004AB-0.01AC-0.05BC ....(equ. 5)

Table 4. Product properties at optimized parameters

Hardness (N)	Adhesiveness (N.s)	Springiness (mm)	Gumminess (N)	Chewiness (N.mm)	Thickness (cm)	Desirability
27.906	-0.315	0.089	3.005	0.302	1.890	0.754







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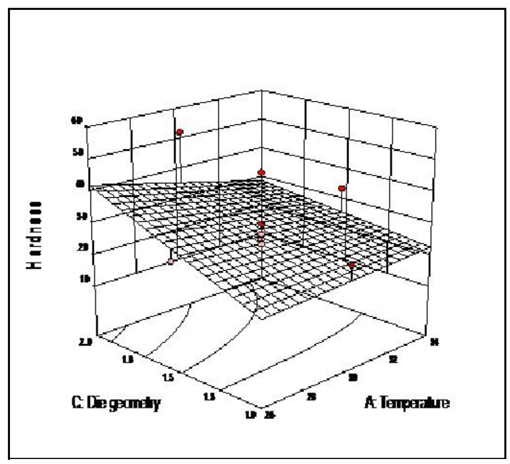

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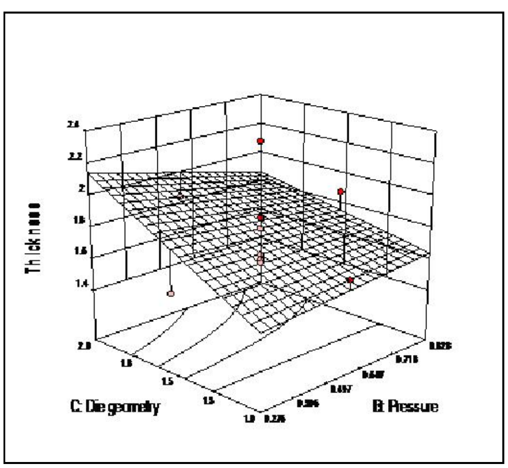

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Fig. 2 Response plot for thickness of peda disc

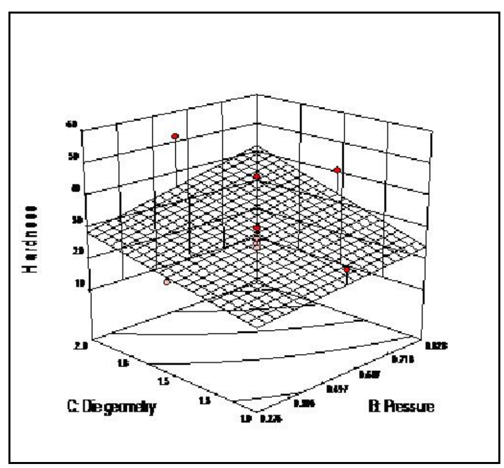

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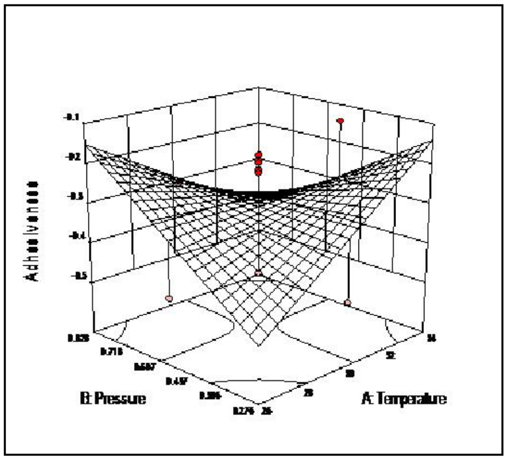
Fig. 3 Response plot for hardness



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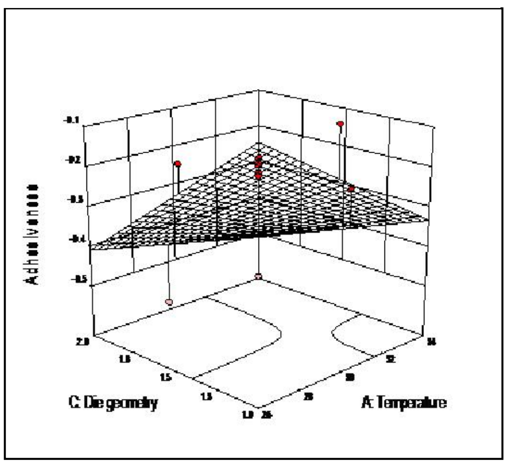

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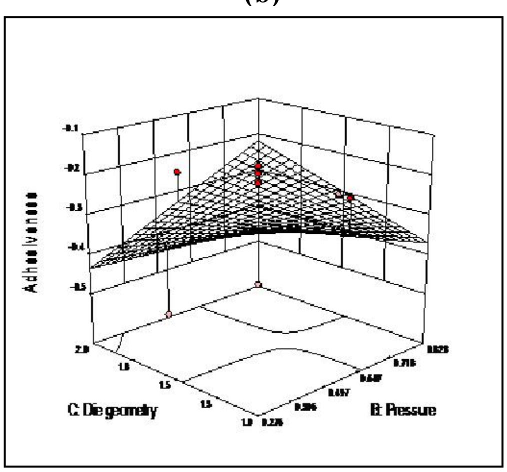

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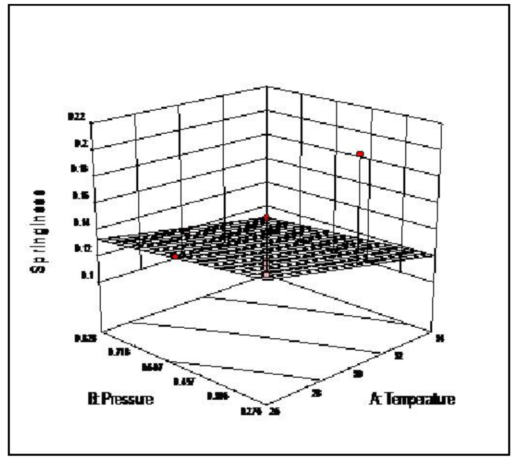
Fig. 4 Response plot for adhesiveness



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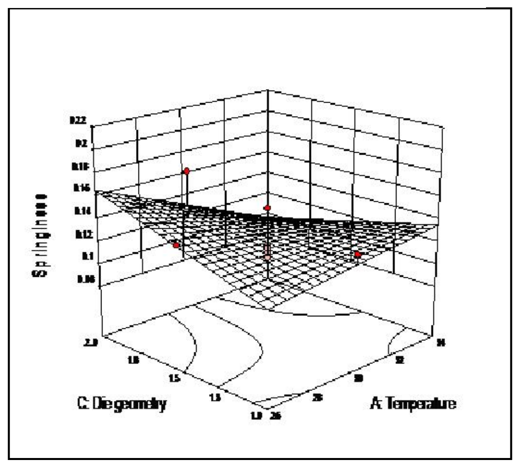

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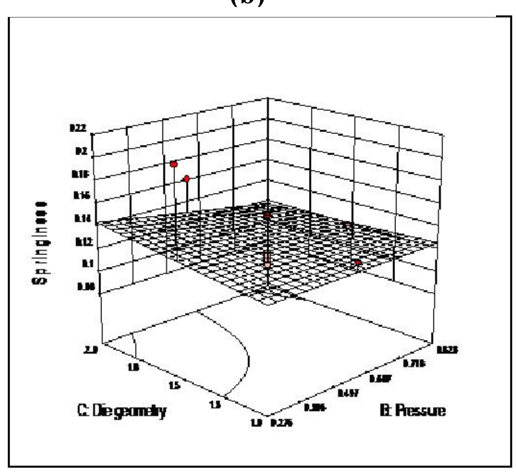

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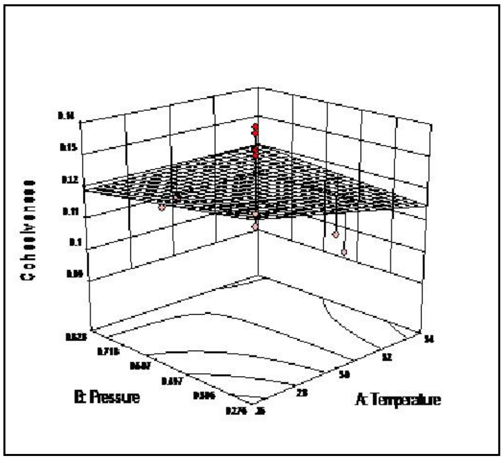
Fig. 5 Response plot for springiness



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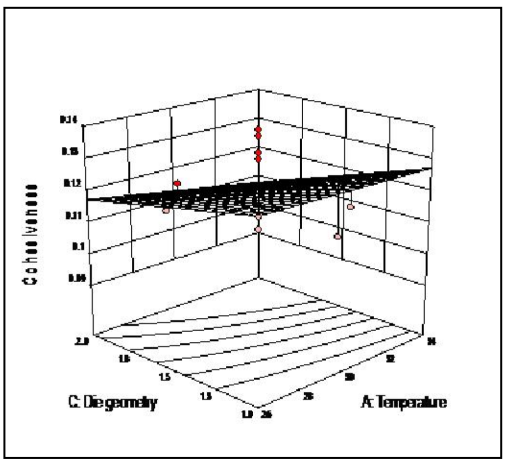

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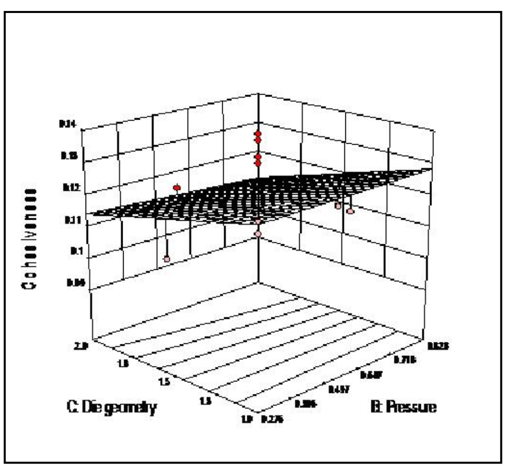

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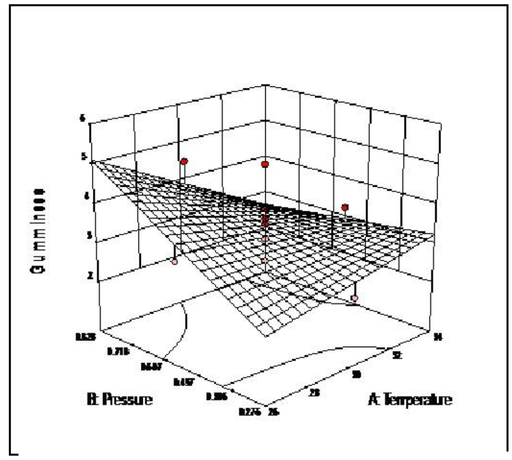
Fig. 6 Response plot for cohesiveness



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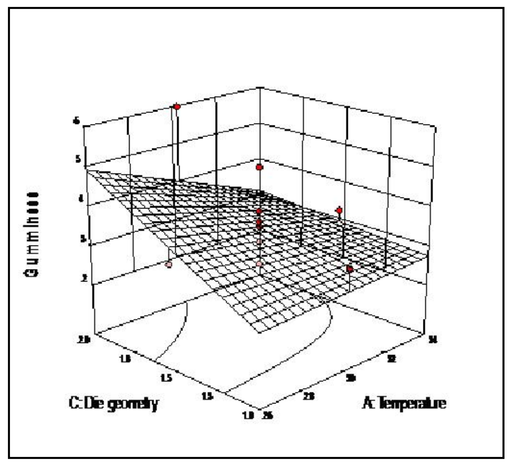

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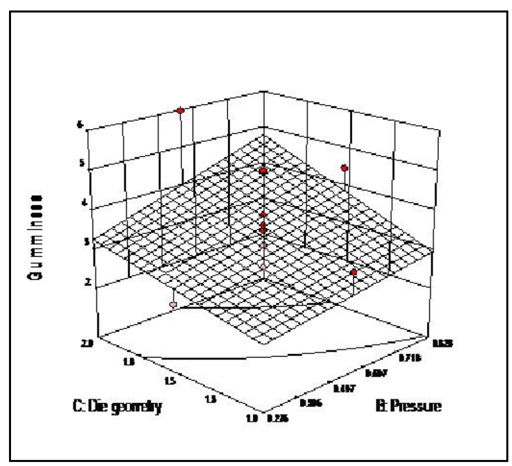

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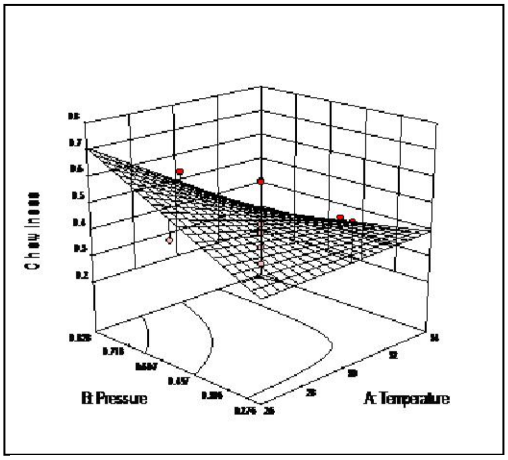
Fig. 7 Response plot for gumminess



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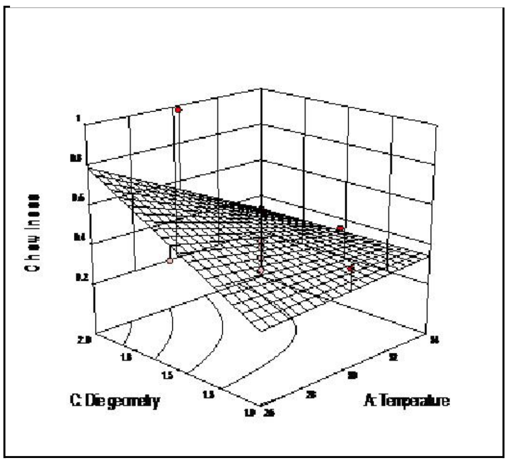

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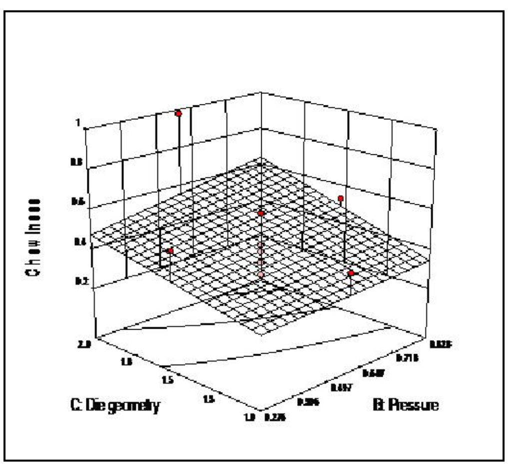

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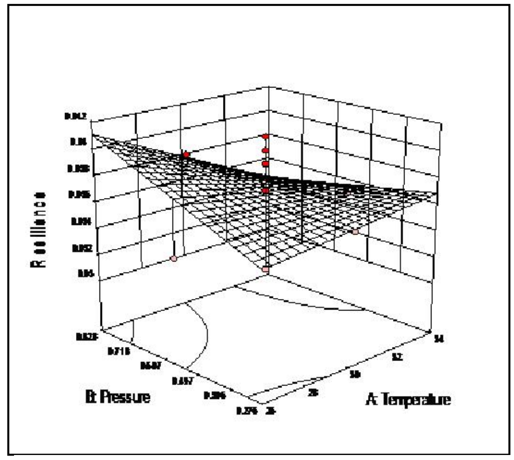
Fig. 8 Response plot for chewiness



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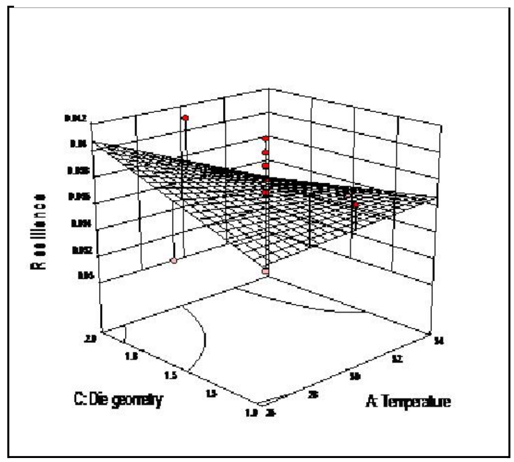

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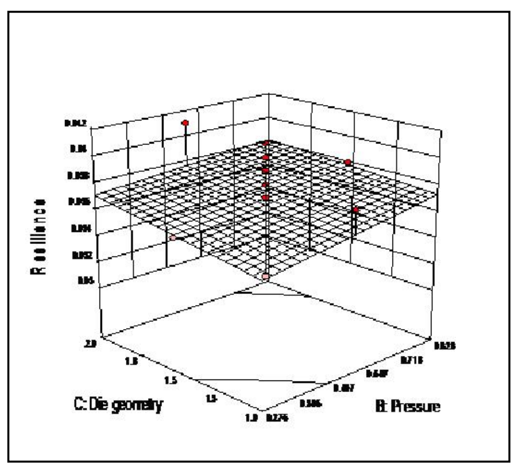

(c)

Fig. 9 Response plot for resilience

Cohesiveness

Cohesiveness was minimum (0.097) when extrusion was performed at 34°C barrel temperature, 0.552 kg/cm^2 pressure and 1.5 die geometry. While *peda* discs formed at 30°C, 0.552 kg/cm^2 pressure and 1.5 die geometry had maximum cohesiveness of 0.139. It was observed that variation in cohesiveness was non-significant with respect to all the three process factors temperature, pressure and die geometry (fig. 6). Following equation may be used to predict cohesiveness on the basis of actual parameters:

Cohesiveness =+0.16-8.00E-004A-0.08B+0.02C+2.94E-003AB-1.00E-003AC-7.25E-003BC ....(equ. 6)

Gumminess

The average gumminess of *peda* was in the range of 1.005 to 5.974N. Gumminess was minimum (1.005 N) for the sample with process parameters at 26°C, 0.276 kg/cm^2 pressure and 2.0 die geometry. While it was maximum (5.974 N) for *khoa peda* extruded at 30°C, 0.552 kg/cm^2 and 2.0 die geometry. From the response plot it was evident that gumminess primarily depended on pressure as well as die geometry and the effect of temperature was negligible (Fig. 7). Adequate precision value (APV) for the regression model was 9.220, which was appreciably higher than the minimum desirable (4.00) for prediction ability. It was found that the model can be used to navigate the design space and the prediction equation for gumminess is given as:

Gumminess = -19.59+0.70A+22.26B+8.15C-0.76AB-0.25AC+1.62BC ....(equ. 7)

Chewiness

The average chewiness of *khoa peda* varied from 0.103 to 0.978 N.mm. Chewiness increased with increase in extrusion pressure and die geometry. And it was not affected by temperature. Chewiness was minimum (0.103 N.mm) at 26°C, 0.276 kg/cm^2 extrusion pressure and 1.0 die geometry. While it was maximum (0.978N.mm) at 30°C, 0.552 kg/cm^2 applied pressure and 2.0 die geometry. When die geometry was kept at centre point (1.5), with an increase in temperature there was negligible change in chewiness, while with the increase in pressure increased the chewiness (Fig. 8a). Considering pressure at centre point (0.552 kg/cm^2), with an increase in die ratio there was increase in chewiness (Fig. 8b). Similar results were obtained by keeping temperature constant while increasing pressure and die ratio (Fig. 8c). Model was not significant with respect to temperature and pressure but it was significant with respect to die geometry ($p<0.04$). The regression equation for chewiness of *peda* in terms of actual parameters is as follows:

Chewiness = -3.66+0.13A+2.93B+2.04C-0.10AB-0.06AC+0.22BC..............(equ. 8)

Resilience

The average resilience of khoa *peda* varied from 0.031 to 0.041. The minimum resilience of 0.031 was obtained for the sample which had trial process parameters of temperature: 26^{0}C, pressure: 0.276 kg/cm^2 and die geometry: 1.0. While the *khoa peda* prepared at trial process parameters of temperature: 30^{0}C, pressure: 0.552 kg/cm^2 and die geometry: 2.0 had the maximum resilience of 0.041. As shown in figure 23, when die geometry was kept at centre point (1.5), with an increase in temperature and pressure resulted in increase in resilience. Similar results were observed when pressure was kept at centre point (0.552 kg/cm^2) and other process variables increased. The values of resilience were almost similar when pressure or die ratio was varied keeping temperature at the centre point (30^{0}C). ANOVA indicated that the effect of variable parameters on resilience of *peda* was non significant. Regression equation for resilience of *peda* in terms of actual parameters is given as:

Resilience = -0.028+1.99A+0.06B+0.03C-1.81E-003AB-8.75E-004AC-1.81E-003BC ....(equ 9)

Process optimization

For the optimization three process parameters i.e. temperature, pressure and die geometry had been taken in the range from low level to high level. The statistical significant responses viz., thickness, hardness, adhesiveness, springiness, gumminess and chewiness were considered for process optimization. The product properties of market samples were taken as target values for optimization (Table 4). Optimized factors for the mechanized formation of *peda* were 34°C temperature of *peda* mass, 0.818 kg/cm^2 pressure for pressing and 1.913 die geometry ratio. The predicted values of properties at optimized parameter are given in table 4.

Conclusions

It can be concluded that temperature of *peda* mass, extrusion pressure and die geometry affected the mechanized formation of *peda*. Piston press technology can be successfully used for mechanized formation and shaping of *peda* at commercial scale. The major advantage of piston cylinder system is simplicity in design and fabrication. For industrial production, experimental setup discussed in this study can be scaled up and pneumatic pressing system can be used instead of dead weight system.

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