The Pharma Innovation Journal 2021; SP-10(8): 934-941

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(8): 934-941

www.thepharmajournal.com
Received: 04-06-2021
Accepted: 06-07-2021

GS Saini
(1) Dairy Engineering Division, ICAR-National Dairy Research Institute, Karnal, Haryana, India
(2) College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Science University, Ludhiana, Punjab, India

IK Sawhney
Dairy Engineering Division, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Corresponding Author
GS Saini
(1) Dairy Engineering Division, ICAR-National Dairy Research Institute, Karnal, Haryana, India
(2) College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Science University, Ludhiana, Punjab, India

Effect of mechanized forming process variables on the rheological characteristic of khoa-peda

GS Saini and IK Sawhney

Abstract
In the present study rheological characteristics of *khoa-pedas* prepared using mechanized system based on the principle of piston press pressure technology consisting of a temperature controlled double jacketed hollow cylindrical barrel with piston system for applying pressure and conical die at the base for final compaction and shaping was done. Effect of three different process variables at different magnitude values, viz., temperature (26, 30, 34 °C), pressure (0.276, 0.552, 0.828 kg/cm^2) and conical die geometry (1:1, 1:1.5, 1:2) on the rheological characteristics of *khoa-pedas* was investigated. Statistically ($p<0.05$) meaningful effect was observed on some rheological parameters of final product at different values of process variables. Results revealed that in mechanized formed *khoa-peda* hardness varied from 7.62 N to 51.96 N, adhesiveness varied from -0.608N to -0.092N, springiness varied from 0.089mm to 0.214mm, cohesiveness varied from 0.097 to 0.139, gumminess varied from 1.005N-mm to 5.974N-mm, chewiness varied from 0.103N-mm to 0.978N-mm and resilience varied from 0.031 to 0.041 respectively. Adhesiveness, gumminess and chewiness of *khoa-peda samples,* were significantly affected by mechanized process variables.

Keywords: khoa-peda, temperature, pressure, die geometry, rheological parameters

1. Introduction
Since from the time immemorial when milch animals were domesticated Indigenous milk products have been an inseparable part of the socio-cultural and day to day routine life of Indian population. Whether it is childbirth, engagement, wedding ceremony, getting a job, inauguration of new house/car/shop, any feast/festival, social or religious occasion or any other significant task completion is followed by offering sweets. Public and mass appeal enjoyed by these Indigenous dairy products is endorsed by the fact that 50-55% of the India's milk production is utilized for making these products. The market demand for these products exceeds the western products (mainly – butter, cheese and milk powder).
Due to the following weaknesses of the Indian Dairy industry the organized dairy sector could not take up the production of these products on commercial scale:-
i. Absence of mechanized production lines for large scale production
ii. Labour intensive, energy inefficient methods of production
iii. Absence of physico-chemical, microbiological, and textural standards for most of the products lead to inconsistent product quality
iv. Poor shelf life due to absence of proper packaging system
v. Lack of proper storage, transportation, cold chain management and distribution network.

Great opportunity and vast potential lies in the production of the these Indigenous dairy products which could bring a remarkable value addition to the extent of 200% as compared to only 50 % obtained by western products. The consumption of Indigenous dairy products is likely to grow at an annual growth rate of more than 20% but for the western dairy products the growth rate is relatively much lower varying from 5-10% respectively (Bandopadhyay & Khamrui, 2007) [2]. In addition Indigenous dairy product can provide considerable employment opportunity (Parekh, 2013) [8].
Generally the word *Peda* means a blob of any doughy substance. *Khoa-peda* is milk based sweet meat prepared from *khoa*. Its recipe originated from the town of Mathura in Uttar Pradesh. Mathura till date is associated with this amazing mouth watering sweet. The *peda* recipe followed by the sweet makers of Mathura has *khoa* as the main ingredient. Sugar, cardamom powder and nuts like pistachios and almonds are the other ingredients added to *peda*. Traditionally *khoa-peda* is prepared by mixing *khoa* and sugar in the ratio of 3:1 (w/w).

The *khoa* sugar mixture is heated on the gentle low fire till the mixture turns firm. It is then removed from fire and if needed nuts and flavourings are added. The heating process dries out the moisture and sugar provides the preservative effect giving *khoa-peda* a long shelf life. After this the mixture is formed/shaped into *pedas* by rolling between the hand palms after applying little ghee to avoid sticking. *Peda* is characterized by light to dark brown in colour, spherical to disc round in shape being pressed at both the ends, firm in texture and 10-25g in weight (Aneja *et al*., 2002, Banjare *et al*., 2015) [1, 4].

There are several types/variants of *khoa-peda* available in Indian market. Some of them are- *plain peda, kesar peda, brown peda, lal peda, yellow peda, malai peda, white peda, kheer peda, mini peda, elaichi peda* etc. Some *pedas* are famous based upon their area or place of origin for e.g., *peda* from Mathura (U.P.) is famous as *Mathura peda*, *peda* from Dharwad (Karnataka) is famous as *Dharwad peda* and *peda* from Rajkot (Gujarat) is famous as *Rajkot peda* (Modha HM *et al* 2015, Sharma HK *et al* 2003, Londhe G *et al* 2012) [7, 6].

Khoa-peda processing involves two distinctly different categories of operations. The first category includes the operations for preparation of *khoa*, blending of sugar and other ingredients to prepare *khoa-peda* mass, which is a base material for preparation of *khoa-peda*. The second category of operation involves shaping/forming the *khoa-peda* mass into disc shaped *pedas* (Singh G *et al* 2015, Singh G *et al* 2018) [9, 11]

Designed mechanized forming set up was used for shaping the *khoa peda* mass to *khoa-pedas*. In the present study effect of different mechanized operating forming/shaping process variables were studied for their effect on the rheological characteristics of *khoa-pedas* manufactured with it.

2. Methodology

2.1 Preparation of *khoa-peda* mass

Khoa used in this study was taken from the Experimental Dairy Plant of NDRI, Karnal. About 3.0 kg *khoa* was taken for each trial. *Khoa* was heated in a steam heated double jacketed kettle till the desired consistency of *khoa* was reached. Sugar in the powdered form was then added to *khoa* at the rate of 33% w/w. The mixture of *khoa* and sugar was heated and the contents were mixed thoroughly so that sugar gets properly mixed in the mass. The *khoa*-sugar mixture was further heated till the desired colour (slightly brown due) and desired consistency of the mixture was reached.

2.2 Mechanized forming set up

Mechanized forming set up was fabricated out of SS-304 as shown in (Fig. 1). It consisted of following components:-

a. Double jacketed hollow cylindrical barrel, with a flange at bottom as shown in Fig.1
b. Temperature controlled water bath and its circulation in the above cylindrical barrel (a)
c. Inter-changeable conical dies to be attached below the cylindrical barrel (a) as shown in Fig.2. This die consisted of two sections (i) top conical section and (ii) bottom cylindrical section. Top conical section for compaction of *khoa* mass and bottom cylindrical section for forming and shaping *khoa* mass into cylindrical roll. The cylindrical barrel and the bottom conical discs were joined via flanged joint. Nuts and bolts were used and gasket was placed between the flanges to prevent any leakage of *khoa* mass and to make a tight joint and slip free joint.
d. Cutting mechanism was attached at the exit of inter-changeable die (c) for cutting the compacted cylindrical mass roll into *khoa-pedas* which were disc shaped.
e. Piston pressure mechanism for forcing out the *khoa-peda* mass through the set up.

2.3 Different process variables selected for trials

After the fabrication of mechanized forming set up, a few preliminary trials were conducted and available literature was reviewed to finalize three process variables i.e. temperature, pressure and die geometry at different level of magnitudes.

2.4 Experimental procedure

Khoa- peda mass was taken in the temperature controlled double jacketed cylindrical barrel. Water from temperature controlled water bath was circulated in the barrel to get and maintain the desired temperature of the *khoa* mass present inside the barrel for the conduct of different trials. Then pressure of different magnitude was applied via a piston on the *khoa* mass in the barrel to force it out of the conical die attached below it. As shown in section (2.3) temperature was varied and maintained at 3 different levels (viz. 26 ^{0}C, 30 ^{0}C, and 34 ^{0}C), pressure was varied at 3 different levels (viz. 0.276 kg/cm^2, 0.552 kg/cm^2, and 0.828 kg/cm^2) and 3 different conical dies with different geometry (viz. 1: 1, 1: 1.5 and 1:2) were attached for conducting the trails. *Khoa-pedas* thus formed were individually wrapped in parchment paper and packed in the cardboard boxes for further rheological analysis.

2.5 Rheological analysis of *khoa-peda* samples

The samples prepared under different combinations of process variables were subjected to textural analysis, using texture analyzer TA-XT2i (Stable Micro Systems, Godalming, Surrey, UK) fitted with a 25 kg load cell. All the measurements were carried out at 25±1°C temperature.

3. Results and Discussion

Number of trials and combination of different process parameters for each trial were calculated using Response Surface Methodology (RSM). The details of the combination of parameters for different trial runs are presented in Table -1. The rheological results were analyzed by using Software Design Expert-8.

Effect of process parameters on the textural properties of *khoa-peda*

Texture profile is a result of physical interaction in *khoa-peda* mass during manufacturing. So, variations in the mechanized process variables were expected to affect the texture profile. The effect of temperature, pressure and die geometry was observed on the textural properties. The detailed analysis of texture profile analysis as affected by process parameters is presented by RSM as follows:

3.1 Effect on Hardness

The average hardness varied from 7.62 to 51.96 N. The minimum hardness of 7.62N was obtained for the sample which had mechanized forming trial process variables as temperature: 26 ^{0}C, pressure: 0.276 kg/cm^2 and die geometry: 1.0. While the *khoa-peda* prepared at trial process variables of temperature: 26 ^{0}C, pressure: 0.276 kg/cm^2 and die geometry: 1.0 had the maximum hardness of 51.96N. Effect of different variables and their interaction effect on the diameter were analyzed and are presented in (Fig. 3). Effect of temperature, pressure and die geometry was found non-significant on hardness. As shown in (Fig. 3a), considering die geometry at centre point (1.5), with an increase in temperature there is gradual increase in hardness, while with increase in pressure also resulted in increase hardness. (Fig 3b) reveals that when the pressure was kept at the centre point (0.552 kg/cm^2), increase in temperature has no effect on hardness while increase in die geometry increased hardness to a large extent. (Fig 3c) shows that effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is not significant with respect to temperature (p=0.37), pressure (p=0.10) and die geometry (p=0.02). Interaction effect of temperature and pressure (p=0.04), temperature and die geometry (p=0.22) and pressure and die geometry (p=0.50) is not significant. The prediction equation for the determination of diameter at any given values of process variables is give below.

Hardness = -167.32+5.92T+188.64P+65.43D-6.48TP-1.99TD+15.64PD..........(2)

3.2 Effect on Adhesiveness

The average adhesiveness varied from -0.608 to-0.092N. Effect of different variables and their interaction effect on adhesiveness were analyzed and are presented in (Fig. 4). As shown in (Fig. 4a), considering die geometry at centre point (1.5), with an increase in temperature and pressure increased the adhesiveness to a large extent. (Fig 4b) reveals that when the pressure was kept at the centre point (0.552 kg/cm^2), increase in temperature and die geometry resulted in decrease in adhesiveness. (Fig 4c) shows effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is significant with respect to temperature (0.67), pressure (0.77) and die geometry (0.61). Interaction effect of temperature and pressure (0.004), temperature and die geometry (0.17) and pressure and die geometry (0.05) is significant. The prediction equation for the determination of adhesiveness at any given values of process variables is given below.

Adhesiveness = -0.74+0.03T+3.32P-1.41D-0.14TP+0.03TD+0.70PD..............(3)

3.3 Effect on Springiness

The average springiness varied from 0.089 to 0.214mm. Effect of different variables and their interaction effect on springiness were analyzed and are presented in (Fig. 5). As shown in (Fig. 5a), considering die geometry at centre point (1.5), with an increase in temperature springiness was decreased, while with the increase in pressure slightly decreased the springiness. (Fig. 5b) reveals that when the pressure was kept at centre point (0.552 kg/cm^2), with an increase in temperature springiness was increased, while with the increase in die geometry increased the springiness to large extent. (Fig. 5c) shows the effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is not significant with respect to temperature (0.18), pressure (0.49) and die geometry (0.77). Interaction effect of various process variables is also not significant. The prediction equation for the determination of springiness at any given values of process variables is given below.

Springiness = -0.298+0.01T+0.02P+0.37D+9.06E-004TP-0.01TD-0.05PD.............(4)

3.4 Effect on Cohesiveness

The average cohesiveness varied from 0.097 to 0.139. Effect of different variables and their interaction effect on cohesiveness were analyzed and are presented in (Fig. 6). As shown in (Fig. 6a), considering die geometry at centre point (1.5), with an increase in temperature cohesiveness was decreased, while with the increase in pressure decreased the cohesiveness. (Fig. 6b) reveals that when the pressure was kept at centre point (0.552 kg/cm^2), with an increase in temperature resulted in negligible change in cohesiveness, and with the increase in die geometry decreased the cohesiveness. (Fig. 6c) shows the effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is not significant with respect to temperature (0.49), pressure (0.88) and die geometry (0.07). Interaction effect of various process variables is also not significant. The prediction equation for the determination of cohesiveness at any given values of process variables is given below.

Cohesiveness =+0.16-8.00E-004T-0.08P+0.02D+2.94E-003TP-1.00E-003TD-7.25E-003PD..............(5)

3.5 Effect on Gumminess

The average gumminess varied from 1.005 to 5.974N.mm. Effect of different variables and their interaction effect on gumminess were analyzed and are presented in (Fig. 7). As shown in (Fig. 7a), considering die geometry at centre point (1.5), with an increase in temperature gumminess was increased, while with the increase in pressure increased the gumminess to a larger extent. (Fig. 7b) reveals that when the pressure was kept at centre point (0.552 kg/cm^2), with an increase in temperature resulted in negligible change in gumminess, while with the increase in die geometry increased the gumminess to a large extent. (Fig. 7 c) shows the effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is significant with respect to temperature (0.21), pressure (0.09) and die geometry (0.04). Interaction effect of temperature and pressure (0.03), temperature and die geometry (0.15) and pressure and die geometry (0.52) is significant. The prediction equation for the determination of gumminess at any given values of process variables is given below.

Gumminess=-9.59+0.70T+22.26P+8.15D-0.76TP-0.25TD+1.62PD..............(6)

3.6 Effect on Chewiness

The average chewiness varied from 0.103 to 0.978N.mm. Effect of different variables and their interaction effect on chewiness were analyzed and are presented in (Fig. 8). As shown in (Fig. 8a), considering die geometry at centre point (1.5), with an increase in temperature resulted in negligible change in chewiness, while with the increase in pressure increased the chewiness to a large extent. (Fig. 8b) reveals that when the pressure was kept at centre point (0.552 kg/cm^2), with an increase in temperature chewiness was increased slightly, while with the increase in die geometry increased the chewiness to a large extent. (Fig. 8c) shows the effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is significant with respect to temperature (0.04), pressure (0.32) and die geometry (0.04). Interaction effect of temperature and pressure (0.08), temperature and die geometry (0.05) and pressure and die geometry (0.61) is significant. The prediction equation for the determination of chewiness at any given values of process variables is given below.

Chewiness = -3.66+0.13T+2.93P+2.04D-0.10TP-0.06TD+0.22PD…………………….................(7)

3.7 Effect on Resilience

The average resilience varied from 0.031 to 0.041. Effect of different variables and their interaction effect on resilience were analyzed and are presented in (Fig. 9). As shown in (Fig. 9a), considering die geometry at centre point (1.5), with an increase in temperature resilience was increased, while with increase in pressure increased the resilience to a large extent. (Fig. 8b) reveals that when the pressure was kept at centre point (0.552 kg/cm^2), with an increase in temperature resilience was increased, while with the increase in die geometry increased the resilience to a large extent. (Fig. 8c) shows the effect of pressure and die geometry when the temperature was kept at the centre point (30 °C). Model is not significant with respect to each process variable as wells as interaction effect of various process variables is also not significant. The prediction equation for the determination of resilience at any given values of process variables is given below.

Resilience = -0.028+1.99T+0.06P+0.03D-1.81E-003TP-8.75E-004TD-1.81E-003PD.............. (8)

Table 1: Parameters combinations for different trial runs as per RSM

		Factor 1	Factor 2	Factor 3
Std	**Run**	**A: Temperature (^{0}C)**	**B: Pressure (kg/cm^2)**	**C: Die geometry (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

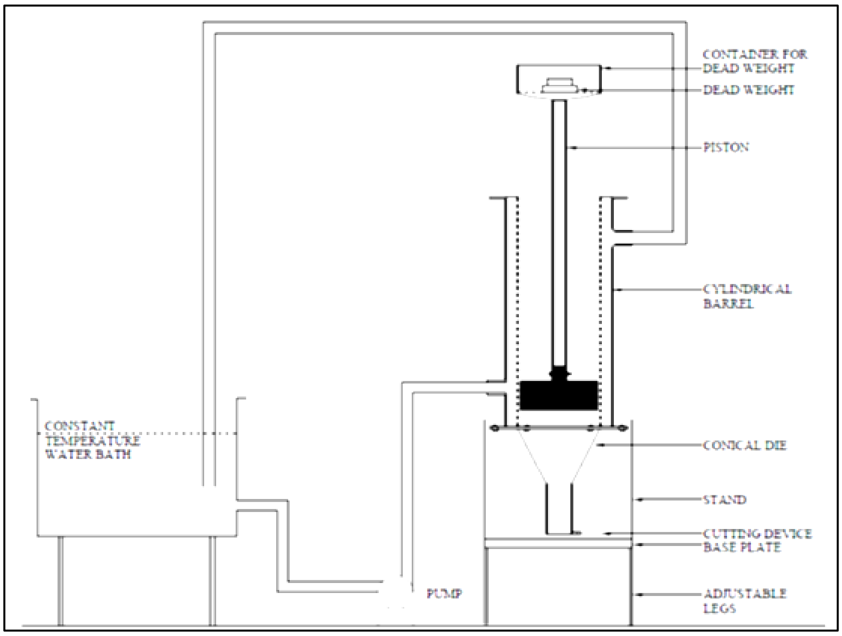
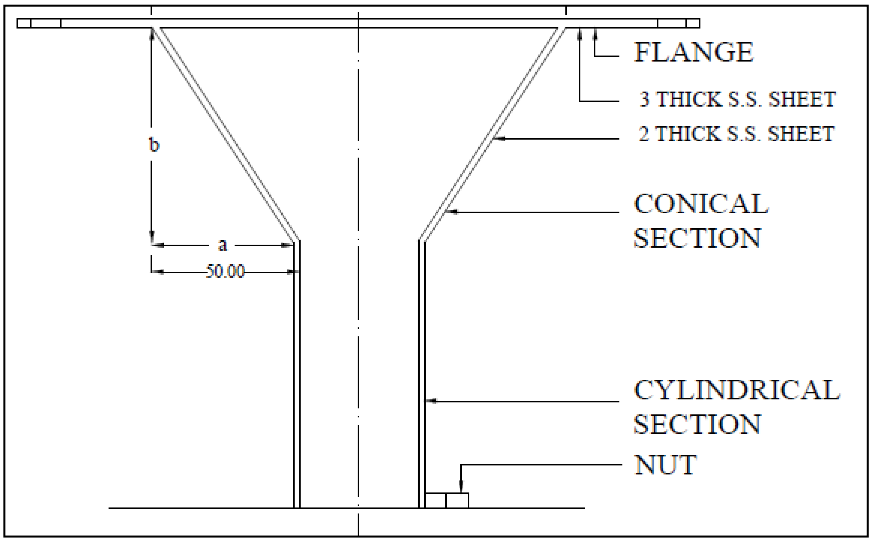


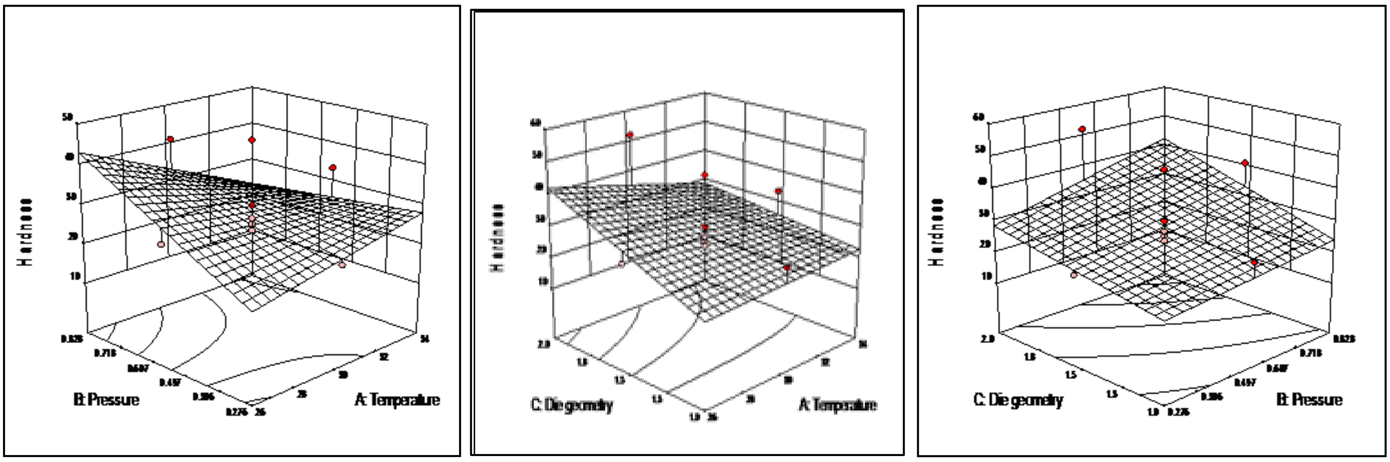
Fig 1: Experimental set up



$$* \text{ Die geometry of conical die } = \frac{b}{a}$$

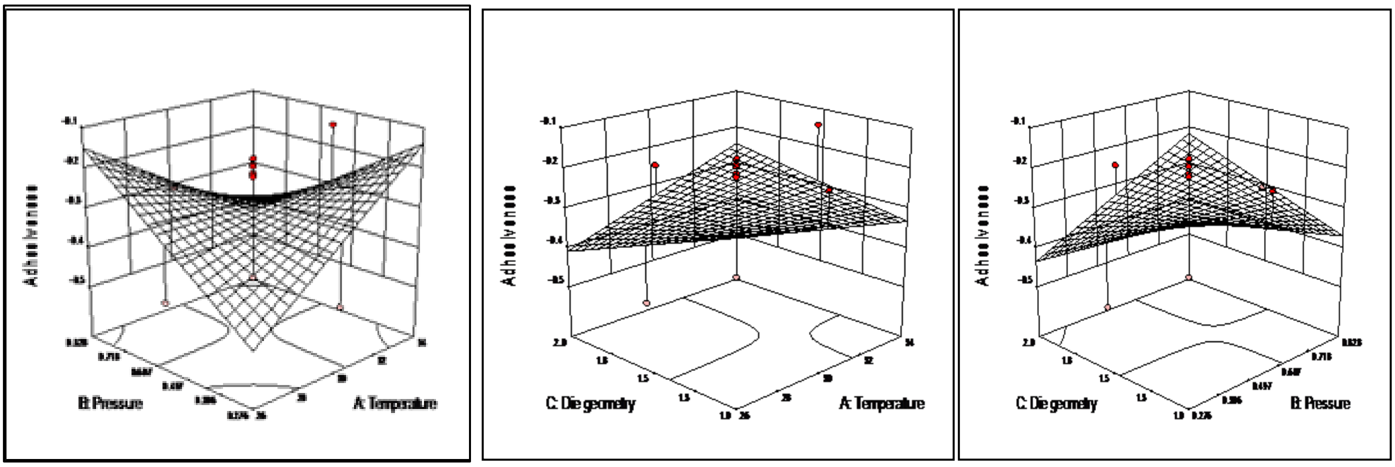
Where, a and b are the geometric measurement of bottom conical dies a is (cone base diameter – cone tip hole diameter) b is height of right angled cone

Fig 2: Geometrical details of conical die



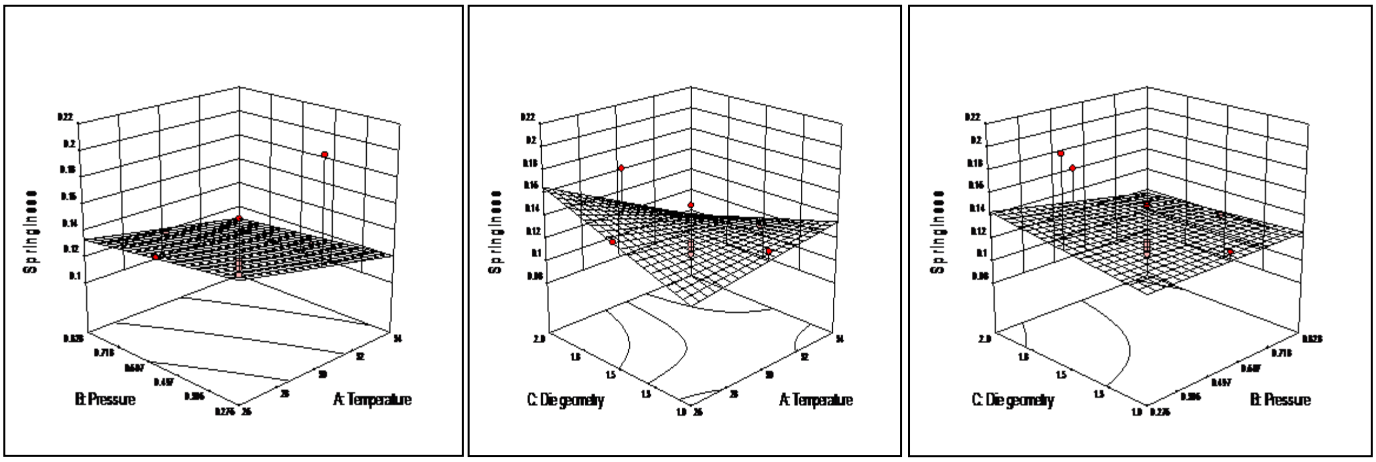
A. B. C.

Fig 3: Effect on hardness



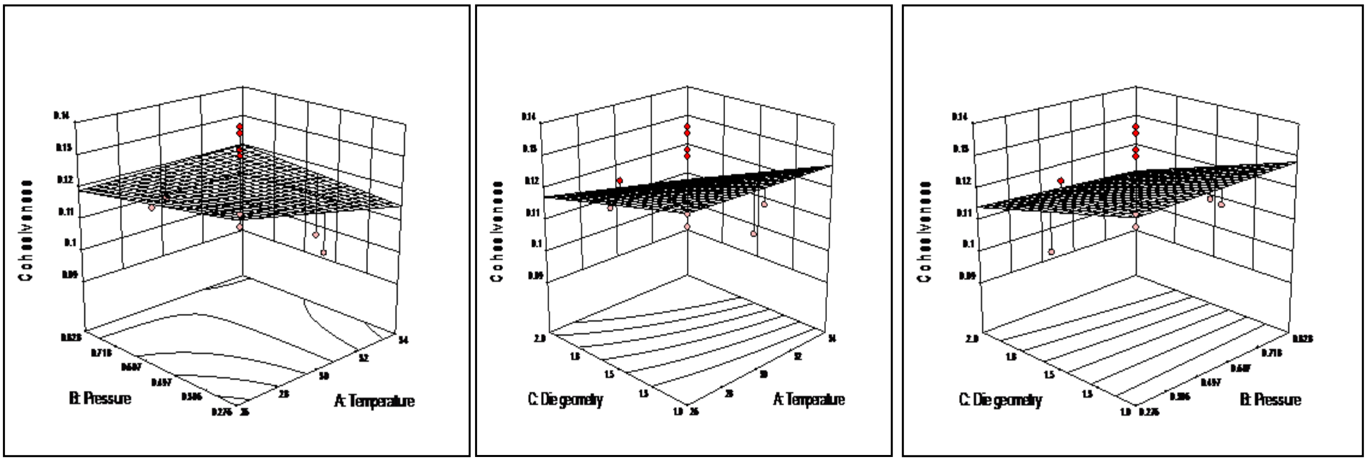
A. B. C.

Fig 4: Effect on adhesiveness



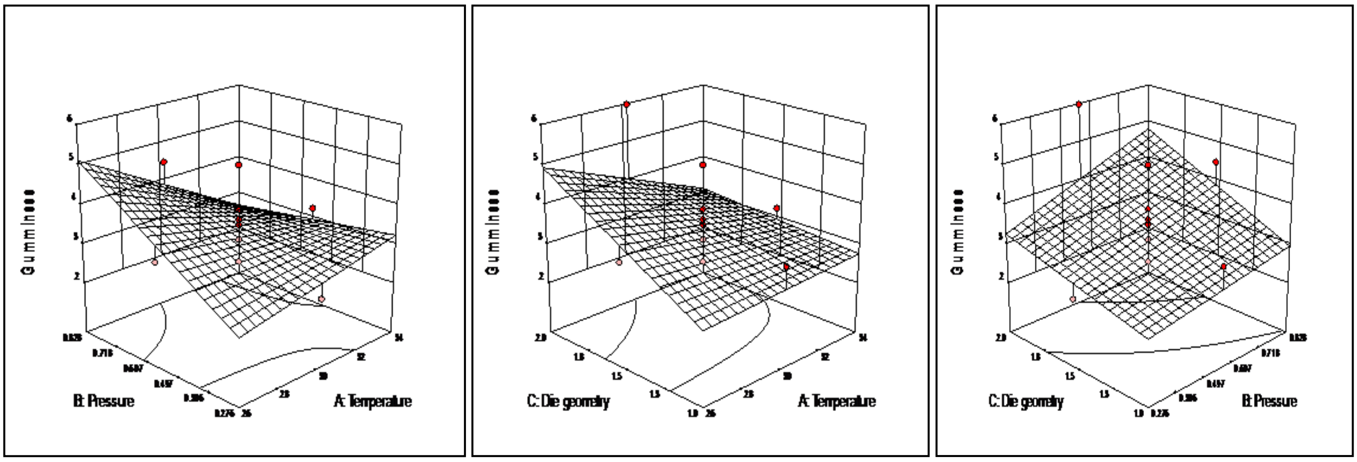
A. B. C.

Fig 5: Effect on springiness



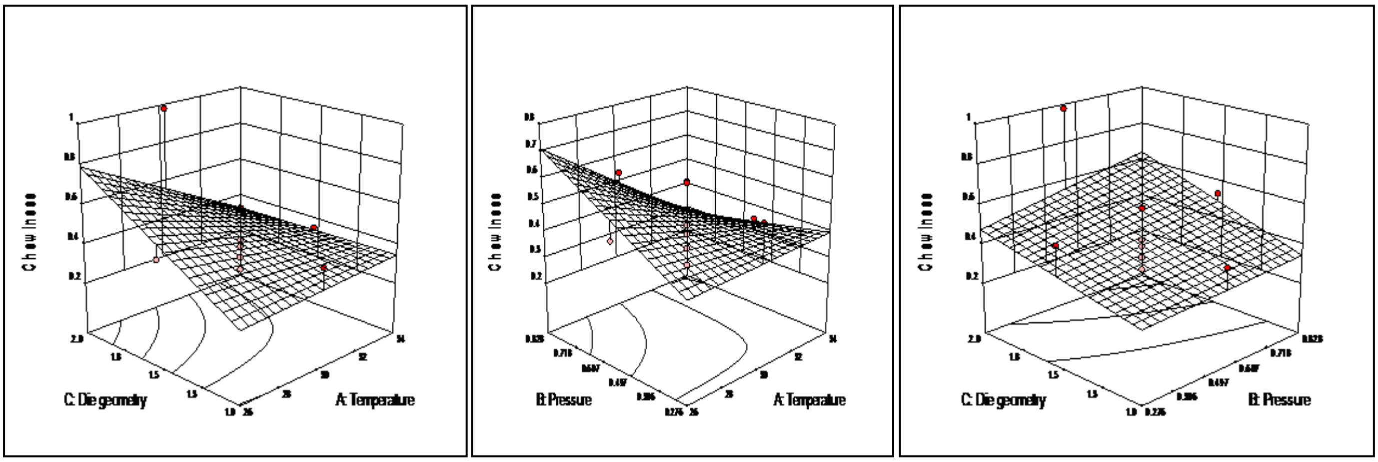
A. B. C.

Fig 6: Effect on cohesiveness



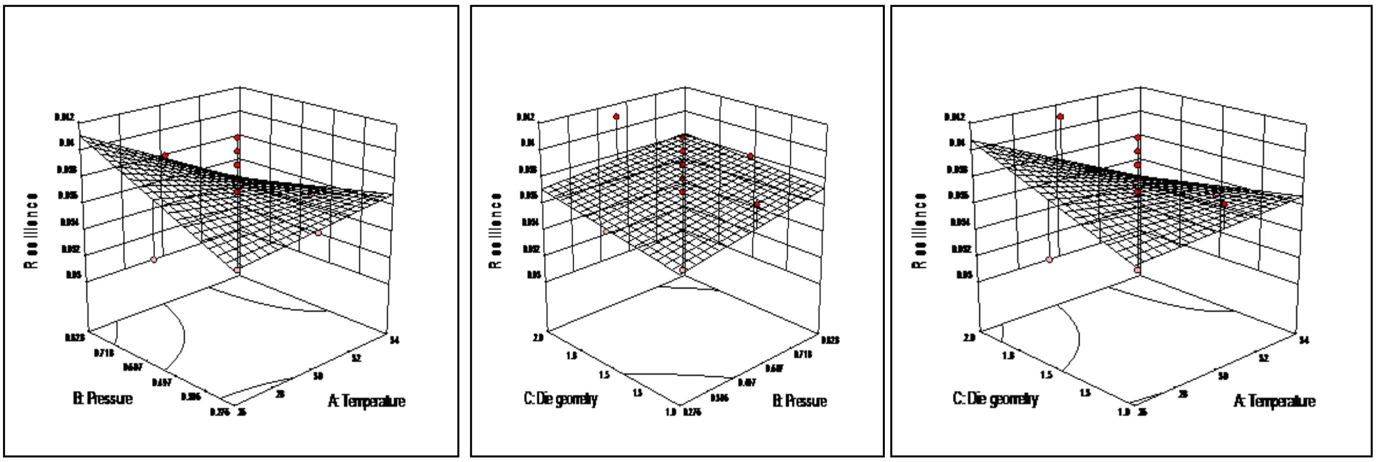
A. B. C.

Fig 7: Effect on gumminess



A. B. C.

Fig 8: Effect on chewiness



A. B. C.

Fig 9: Effect on resilience

4. Conclusion

Software Design Expert-8, 2fi model, which was used for analysis, revealed that mechanized process variables significantly affected adhesiveness, gumminess and chewiness of *khoa-peda samples*, while hardness, springiness, cohesiveness and resilience were not significantly affected. It is concluded that mechanized forming process variables used in above method affected the rheological characteristics of final product.

5. Acknowledgement

Author acknowledges the facilities and support provided by National Dairy Research Institute Karnal and Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana for smooth conduct and analysis of the above work.

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