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Effect of processing parameters of twin screw extruder and product mix on sensory quality of fresh extruded Peda

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Abstract
Peda is one of the most popular khoa based traditional dairy sweets enjoyed by everyone due to its taste and health aspects. Traditionally, it is prepared by heating a mixture of *khoa* and sugar in a *karahi* (iron pan) with the help of *khunti* until the desired granular, hard texture and flavour develops. The manufacture of *peda* is mostly restricted to *halwais*. The demand for this product is constant throughout the year. During festival season, the demand of *peda* increases many folds and the manufacturers find it difficult to meet the same. Present study was undertaken to investigate the possibilities of applying twin screw extruder machine for production of acceptable quality *peda* consistently. The extruded *peda* were prepared by introducing product mixes namely C_1 (containing 0% skim milk powder, 70% *khoa*, 0% ghee & 30% sugar); C_2 (containing 05% skim milk powder, 60% *khoa*, 05% *ghee* & 30% sugar); C_3 (containing 10% skim milk powder, 55% *khoa*, 05% *ghee* & 30% sugar) and C_4 (containing 15% skim milk powder, 50% *khoa*, 05% *ghee* & 30% sugar) into the twin screw extrusion machine and processed at three level of barrel temperatures i.e. 60 ^{0}C (T_1), 70 ^{0}C (T_2) & 80 ^{0}C (T_3) and three level of screw speed i.e. 14 rpm (R_1), 21 rpm (R_2) & 28 rpm (R_3). Among the different set of treatments, the combinations $C_3T_3R_1$, $C_3T_3R_2$ and $C_4T_2R_3$ resulted in most acceptable extruded *peda* in terms of sensory characteristics.

Keywords: *Khoa, peda*, extruded *peda*, extrusion technology, dairy product

Introduction
Peda is heat desiccated indigenous milk sweet commonly prepared by heating a mixture of *khoa* and sugar until the desired granular and firm texture and flavour develops. It is highly nutritious product as it contains almost all milk solids plus sugar and other additives. Several varieties of *peda*, *viz*. plain, *kesar*, brown (*lal*) *etc*. are available in the market. The dairy ingredients *viz*. skim milk powder and ghee is also employed for manufacturing of *peda* as an alternative source of milk solid in situations where availability of milk or *khoa* is a problem. The manufacture of *peda* is mostly restricted to *halwais*. The demand for this product is constant throughout the year. During festival season, the demand of *peda* increases many folds and the manufacturers find it difficult to meet the same. Traditionally, *peda* is mostly prepared by heating a mixture of *khoa* and sugar in a *karahi* (iron pan) with the help of *khunti* until the desired granular, hard texture and flavour develops. Its mechanized process involves heating *khoa* to 60^{0}C and adding sugar, flavour and other ingredients in a planetary mixer. The dough after cooling to 5^{0}C is fed to *peda* shaping machine followed by packaging (Banerjee, 1997) [2]. Extrusion technology has become very popular and is being increasingly used for the manufacture of various food products. In the extrusion technology, single or twin screw food extruder are used to transport, mix, knead, shear and/or cook multiple ingredients into a uniform food product by forcing the ingredient mix through die to produce specific shapes and lengths (Riaz, 2000) [14]. Extrusion is currently utilized to produce textured protein products, snack foods, toast and confectionary products. In spite of its immense potential, in the dairy industry extrusion technology is rarely utilized. Some research work has been done, on only very few products examples is casein/caseinate production (Fichtali, 1990) [5], production of processed cheese (Zuber *et al.*, 1987; Kazuo *et al.*, 1993; Adhikari *et al.*, 2009) [18, 9, 1], mozzarella cheese (Ferrari *et al.*, 2003) [4], *sandesh* (Kumar and Das, 2007) [10] etc. Extrusion is a very useful technology for dairy processing operations involving conveying, mixing, kneading, cooking, shearing and shaping which is yet to be exploited by the dairy industry. Present study was undertaken to investigate the possibilities of applying extrusion technology for production of acceptable quality extruded *peda*.

Materials and Methods

Good quality fresh *khoa* and *ghee* (brand *Devbhog*) were obtained from Chhattisgarh State Cooperation Dairy Federation Ltd., Urla, Raipur. Skim Milk Powder, (brand SAGAR, AmulFed Dairy, Bhat) and sugar of commercial grade were procured from local market of Raipur city.

Details of product mix

Trials were conducted using *khoa* as a base materail for making extruded *peda*. *Khoa* was partially replaced with skim milk powder and its proportions were varied from 0, 5, 10 & 15% in product mix C_1, C_2, C_3 & C_4 respectively. Its level were restricted up to 15% as higher concentration resulted in powdry taste and under cooked finished products (Londhe, 2006 and Suryawanshi *et al.*, 2014) [11, 17]. The requirement of *khoa* was also partially replaced with ghee to compensate the fat percentage and its level was kept constant (5%) in product mix C_2, C_3 & C_4. To make the product sweet, level of sugar was kept constant (30%) in all product mix. The details of product mix/ formulations used for preparation of extruded *peda* were as under:

- **C_1:** 0% skim milk powder, 70% *khoa*, 0% ghee & 30% sugar
- **C_2:** 05% skim milk powder, 60% *khoa*, 05% *ghee* & 30% sugar
- **C_3:** 10% skim milk powder, 55% *khoa*, 05% *ghee* & 30% sugar
- **C_4:** 15% skim milk powder, 50% *khoa*, 05% *ghee* & 30% sugar

Twin screw extruder machine

In this study, a twin screw co-rotating extruder (Model: SY 30-IV, Jinan Saibainuo Technology Development Co. Ltd., China) was used to evaluate its applicability for manufacturing extruded *peda*. The complete specification of the twin screw extruder used in the study is presented in Table 1. Twin screw extruder had four temperature control zones along the barrel where heating was performed by the induction heaters integrated with the system. The operating temperature of the barrel was same in all heating zones during each run. Every heating zone also had water jacket for cooling function. The speed of the twin screw was controlled by variable frequency drive (VFD) motor (3 phase, 7.5 HP) with gear box. All the operating parameters of the extruder were controlled through the touch screen control system.

Table 1: Specifications of the twin screw extruder (TSE) for production of extruded *peda*

Particulars	Specifications
Diameter of screw	2.6 cm
Root diameter	1.9 cm
No. of flight	33
Flight clearance	0.5 mm
Pitch	3.4 to 1.8 cm
Channel width	2.6 to 1.2 cm
Axial Flight width	4 to 2 mm
Flight depth	3 to 4 mm
Total axial length of flighted section of screw	65 cm
Helix angle	17^0
Diameter of barrel	5.7 cm
Barrel length	65 cm
Length of feeding zone	7 cm
Length of heating zone	58 cm
Diameter of mould plate die	2 cm

Processing parameters

Preliminary trials have been conducted to optimize the operational parameters of twin screw extruder in which three levels of barrel temperature i.e. 60^0C (T_1), 70^0C (T_2) & 80^0C (T_3) and three levels of screw speed i.e. 14 rpm (R_1), 21 rpm (R_2) & 28 rpm (R_3) were selected. The product mixes C_1, C_2, C_3 & C_4 were subjected to above process parameters to produce extruded *peda*.

Manufacture of extruded *peda*

The flow diagram for manufacture of extruded *peda* is shown in Fig. 1. The twin screw extruder machine was put into the operation after setting of processing parameters and stabilization of barrel temperatures. The product mix C_1, C_2, C_3 & C_4 was introduced into the feeding section of twin screw co-rotating extruder. These product mixes were extruded at each of the three different barrel temperatures (i.e. T_1, T_2 & T_3) and screw speeds (i.e. R_1, R_2 & R_3). The extruder was emptied and cleaned between each run. During extrusion, the product mixes were handled by the screw flight while moving and conveyed forward through a mixing/kneading section, evaporation/cooking section and finally extruded through the mould plate fitted at the exit. *Peda* mass was collected in a clean tray and cooled to room temperature. It was then manually formed into round balls by rolling in palm of about 20-25 g each. Fresh product was then packed in serving cup (low density polyethylene material of thickness 130µm, rectangle shape and had dimensions of 5x4x2.5cm) and subjected to sensory evaluation.

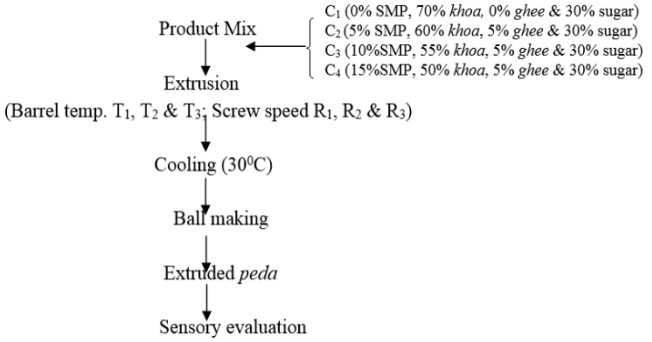

Fig 1: Process chart for manufacture of extruded *peda*

Sensory evaluation

In order to check the consumer acceptance and opinion sensory evaluation was carried out for fresh extruded *peda* samples by using 9 point Hedonic scale (ranging from 1 = disliked extremly to 9 = liked extremly) as developed by Gupta (1976) [6]. The product was made in replicates of three and served to a panel of five judges for sensory properties such as colour and appearance, flavour, sweetness, body & texture and overall acceptability. The results obtained were statistically analysed using by three factor factorial experiment design as described by Steel and Torrie (1980) [16].

Result and Discussion

Effect of product mix on sensory properties of fresh extruded *peda*

The effect of product mix on sensory quality of fresh extruded *peda* has been shown in Table 2. The maximum score for colour and appearance (7.40), sweetness (7.43) and overall acceptability (7.40) were recorded for the combinations code C_3. The highest score for body and texture (7.17) were

recorded for product mix/combinations code C_4 while flavour (7.44) for product mix/combinations code C_2. However, product mix C_4 was at par with product mix C_3 in body & texture attributes and product mix C_2 was at par with product mix C_3 in flavour attributes. During the experiment it was observed that, product prepared from C_1 combination resulted in weak bodied having slight blackish tint whereas the product prepared from C_4 combinations resulted in coarse texture, firm body and powdery flavor. It may be due to the higher concentration of solid not fat and lesser amount of fatty material content. This observation is consistent with studies done by Londhe (2006) [11] and Suryawanshi *et al.* (2014) [17].

Table 2: Effect of product mix on sensory properties of fresh extruded *peda*

Product mix/ Combinations (C), SMP: *Khoa*	Sensory properties				
	Colour and Appearance	Body & Texture	Flavour	Sweetness	Overall Acceptability
C_1 (00:70)	6.95^{c}	6.54^{b}	7.20^{bc}	7.24^{b}	6.66^{c}
C_2 (05:60)	7.26^{ab}	6.58^{b}	7.44^{a}	7.39^{ab}	7.00^{b}
C_3 (10:55)	7.40^{a}	7.11^{a}	7.30^{ab}	7.43^{a}	7.40^{a}
C_4 (15:50)	7.13^{bc}	7.17^{a}	7.11^{c}	7.34^{ab}	7.25^{ab}
F- value	4.93	16.65	5.06	1.84	15.91
SE(m)	0.99	3.02	0.55	0.16	2.78
CD (5 %)	0.24	0.23	0.17	0.16	0.22

Effect of barrel temperature on sensory properties of fresh extruded *peda*

Three barrel temperatures i.e. 60^0C (T_1), 70^0C (T_2) and 80^0C (T_3) were selected for the study. During the experiment it was observed that, barrel temperature of 60^0C resulted in under-cooked product. The lowest sensory score recorded were 7.02, 6.54, 7.06, 7.26 and 6.90 for colour and appearance, body and texture, flavour, sweetness and overall acceptability, respectively. It was observed from Table 3 that the sensory characteristics of extruded *peda* increased significantly ($P \leq 0.05$) with increasing barrel temperature.

The sensory quality of *peda* with respect to flavour (sweet pleasant), body and texture (smooth and soft texture) and colour and appearance (slight yellow brown) was found to be good (acceptable) at barrel temperature of 80^0C (T_3). It was noticed that, beyond the highest selected temperature of 80^0C, the flavour, body & texture and colour & appearance of extruded *peda* resulted in slightly nutty and cooked flavour, firm body and pronounced brown colour. At very high temperature, squeezing of free fat was observed which might be due to the rupturing of fat globule membrane which ultimate resulted in firm body & texture. The results are in agreement with Boghra and Mathur (1996) [3] reported release of free fat owing to rupturing of fat during high heat treatment processing of *khoa* and *peda*. It was observed that the exit temperature of melt of extruded *peda* mass was somewhat higher than the operating temperature of barrel. This could be due to the frictional heat generated between the screw and barrel surfaces. This observation is in consistent with studies done by Riaz (2000) [14] and Guy (2001) [7]. The desirable brown colour at a barrel temperature of 80^0C could be attributed to the maillard browning when the product was exposed to high temperature.

Table 3: Effect of barrel temperature on sensory properties of fresh extruded *peda*

Barrel temperature (T), ^{0}C	Sensory properties				
	Colour and Appearance	Body & Texture	Flavour	Sweetness	Overall Acceptability
T_1 (60)	7.02^{a}	6.54^{a}	7.06^{a}	7.26^{a}	6.90^{a}
T_2 (70)	7.17^{ab}	6.87^{b}	7.35^{b}	7.38^{ab}	7.10^{b}
T_3 (80)	7.27^{b}	7.15^{c}	7.37^{b}	7.40^{b}	7.23^{b}
F-value	1.13	18.71	9.58	2.53	5.78
SE(m)	0.22	3.40	1.04	0.22	1.01
CD (5 %)	0.21	0.20	0.15	0.14	0.19

Effect of screw speed on sensory properties of extruded *peda*

In order to avoid burning of milk solids due to sticking over the inner surface of extruder barrel and uniform distribution of product mix during processing, it is required to be scraped continuously. Three screw speeds i.e. 14 (R_1), 21 (R_2) and 28 rpm (R_3) were selected for the study. In *peda* making, the speed of screw plays an important role in deciding the quality of product in general and body and texture in particular. It was observed from Table 4 that the increased screw speed improved the overall quality of extruded *peda*. Generally, shorter residence time is desirable for better product characteristics, which is achieved at higher screw speeds. The maximum score for colour and appearance (7.30), body and texture (7.37), sweetness (7.40) and overall acceptability (7.15) were recorded for the *peda* processed at the higher screw speed of 28 rpm, while highest flavor score (7.41) was obtained at lower screw speed of 14 rpm (R_1). In general, higher screw speeds promote shorter residence time, efficient mixing, better dispersion of the product and higher throughput as well. Karunanithy *et al.* (2007) [8] obtained higher score for majority of sensory parameters of *rasogolla*, made from the mechanically kneaded *chhana* at higher peripheral speed of 93.46 cm/s (171.7 rpm). Narwade *et al.* (2007) [12] obtained higher sensory score for *peda* samples made traditionally at higher speed of stirrer. Similarly, Reddy (1985) [13] also recorded higher sensory score and recommended high speed of stirrer for the manufacture of *peda*. However, for the development of aroma and flavor characteristics sufficient cooking of the mix is essential. The result of flavor score highlights the significance of cooking time which is related with screw speed. The lower will be screw speed high will be the cooking time and vice versa.

Table 4: Effect of screw speed on sensory properties of fresh extruded *peda*

Screw speed (R), rpm	Sensory properties				
	Colour and Appearance	Body & Texture	Flavour	Sweetness	Overall Acceptability
R_1 (14)	7.05^{a}	6.83^{a}	7.41^{b}	7.21^{a}	6.95^{a}
R_2 (21)	7.16^{ab}	6.86^{a}	7.28^{b}	7.33^{ab}	7.13^{ab}
R_3 (28)	7.30^{b}	7.37^{b}	7.09^{a}	7.40^{b}	7.15^{b}
F-value	0.07	0.05	8.24	0.80	2.61
SE (m)	0.01	0.01	0.90	0.07	0.45
CD (5 %)	0.21	0.20	0.15	0.14	0.19

Combined effect of product mix (C), barrel temperature (T) and screw speeds (R) on sensory properties of fresh extruded *peda*

The combined effect of product mix, a barrel temperature and screw speed on the sensory properties of fresh extruded *peda* is presented in Table 5. The analysis of variance indicated that there was significant difference in the score of colour and appearance of the product between different product mix, barrel temperature and within different screw speeds used for preparation of extruded *peda*. Table 5 revealed that the colour and appearance score of the product was poor for product mix C_1 at low barrel temperature of 60^0C at all screw speeds. However, significant ($P \leq 0.05$) improvement on colour and appearance attributes was noticed at higher barrel temperature irrespective of screw speed. The colour and appearance scores increased when the level of skim milk powder incorporation increased and also with increase in level of barrel temperature and screw speeds. Highest colour and appearance score (7.67) was obtained for treatment combination $C_3T_2R_2$. However, the treatment combinations of $C_3T_2R_2$ were found significantly ($P \leq 0.05$) at par with treatments $C_3T_3R_1$ and $C_3T_3R_2$ on colour and appearance characteristics.

Highest sensory score obtained for body & texture and flavor characteristics were 7.90 and 7.73 respectively for the treatment combination code $C_3T_3R_1$ and $C_3T_3R_2$. This revealed that product mix C_3 containing 10% skim milk powder developed desired body & texture and flavor characteristics in the product at higher temperature coupled with low screw rpm. This may be due to the fact that, at the lower screw speed, the residence time of the product in the twin screw extruder is increased which lead to more release of flavouring compounds at lower speeds. In general, higher screw speeds causes more break up of grains formed, which resulted in poor body and texture of the final product. This result is consistent with findings of Sharma (2007) [15] reported significant decrease in body and texture score of *khoa* made by thin film scraped surface heat exchanger for all levels of fat in milk with increase in rotor speed from 20 to 40 rpm at 1.0-1.5 kg/cm^2 steam pressure. He further reported decease in flavour score of machine made *khoa* samples from 7.0 at 20 rpm to 6.3 at 40 rpm.

The constant level of sugar (30%) was utilized in all product mixes. Best three sweetness scores recorded were 7.90, 7.73 and 7.70 for the treatments combination $C_2T_2R_3$, $C_4T_2R_3$ and $C_2T_3R_2$, respectively. These results revealed that, sweetness scores increases with increase of screw speeds. The generation of shearing effect at higher screw speed might be the reason for rapid and uniform mixing of sugar which ultimately resulted in increased sweetness.The lowest sweetness score was 6.73 for treatment $C_1T_3R_2$ (representing product mix C_1 containing of 00:70 feed composition for skim milk powder and *khoa* respectively, 80^0C barrel temp. and 21 rpm screw speed).

Overall acceptability of any product is an important parameter in addition to other sensory parameters like colour, body and texture, flavour, and/or physico- chemical qualities and packaging of product which represent the total performance of the product in the mind of consumers. Overall acceptability score of fresh sample of extruded *peda* ranged from 5.53 to 7.70. The minimum score (5.53) was obtained for the samples prepared from *khoa* –sugar mix (C_1) at combined processing conditions of 60^0C barrel temperature and 28 rpm screw speeds (i.e. treatment code $C_1T_1R_3$) while maximum score (7.70) was recorded for the product obtained from combination of product mix C_4 and processing conditions of 70^0C barrel temperature and 28 rpm screw speeds (i.e. treatment code C_4T_2 R_3). Second best overall acceptability score of 7.67 was obtained for treatment combinations $C_3T_3R_1$ and $C_3T_3R_2$.

Table 5: Effect of product mix, barrel temperature and screw speed on sensory properties of fresh extruded *peda*

Product mix, barrel temp. (^{0}C) and screw speed (rpm)	Sensory properties				
	Colour and Appearance	Body &Texture	Flavour	Sweetness	Overall Acceptability
C_1T_1 R_1	6.77^{a}	6.30^{b}	7.33^{b}	7.40^{b}	6.83^{b}
C_1T_1 R_2	6.70^{a}	5.50^{a}	7.03^{b}	7.10^{a}	6.57^{b}
C_1T_1 R_3	6.37^{a}	5.77^{a}	6.50^{a}	6.93^{a}	5.53^{a}
C_1T_2 R_1	6.40^{a}	6.70^{bc}	7.47^{bc}	7.47^{b}	5.63^{a}
C_1T_2 R_2	7.13^{b}	6.53^{bc}	7.53^{bc}	7.53^{b}	7.37^{c}
C_1T_2 R_3	7.47^{b}	6.80^{bc}	7.67^{c}	7.40^{b}	7.43^{c}
C_1T_3 R_1	7.53^{b}	6.40^{b}	7.47^{bc}	7.13^{a}	6.77^{b}
C_1T_3 R_2	6.80^{a}	7.60^{cd}	6.40^{a}	6.73^{a}	6.63^{b}
C_1T_3 R_3	7.47^{b}	7.33^{cd}	7.40^{bc}	7.53^{bc}	7.23^{bc}
C_2T_1 R_1	7.53^{b}	6.80^{bc}	7.73^{c}	7.40^{b}	7.03^{bc}
C_2T_1 R_2	7.13^{b}	6.67^{bc}	7.50^{bc}	7.17^{a}	6.80^{b}
C_2T_1 R_3	7.20^{b}	6.00^{a}	6.67^{a}	7.20^{a}	6.60^{b}
C_2T_2 R_1	7.17^{b}	6.40^{b}	7.47^{bc}	6.80^{a}	6.83^{b}
C_2T_2 R_2	7.27^{b}	7.00^{bc}	7.47^{bc}	7.33^{bc}	7.37^{c}
C_2T_2 R_3	7.53^{b}	6.87^{b}	7.40^{bc}	7.90^{c}	7.13^{bc}
C_2T_3 R_1	7.47^{b}	6.60^{b}	7.63^{c}	7.33^{b}	6.97^{bc}
C_2T_3 R_2	6.90^{a}	6.23^{b}	7.63^{c}	7.70^{bc}	6.80^{b}

C_2T_3 R_3	7.20^{b}	6.73^{b}	7.53^{bc}	7.67^{bc}	7.47^{c}
C_3T_1 R_1	7.50^{b}	6.83^{b}	7.57^{c}	7.33^{b}	7.40^{c}
C_3T_1 R_2	7.20^{b}	6.67^{b}	6.73^{a}	7.20^{ab}	7.00^{b}
C_3T_1 R_3	7.13^{b}	6.87^{b}	6.40^{a}	7.27^{b}	7.53^{c}
C_3T_2 R_1	7.47^{b}	6.73^{b}	7.40^{bc}	7.40^{b}	6.97^{b}
C_3T_2 R_2	7.67^{b}	7.40^{d}	7.20^{bc}	7.47^{b}	7.40^{c}
C_3T_2 R_3	7.13^{b}	7.00^{b}	7.33^{bc}	7.33^{b}	7.37^{c}
C_3T_3 R_1	7.53^{b}	7.90^{d}	7.67^{c}	7.60^{b}	7.67^{c}
C_3T_3 R_2	7.40^{b}	7.20^{c}	7.73^{c}	7.80^{c}	7.67^{c}
C_3T_3 R_3	7.63^{b}	7.47^{d}	7.67^{c}	7.47^{b}	7.60^{c}
C_4T_1 R_1	7.40^{b}	7.33^{c}	7.33b^{c}	7.56^{bc}	7.13^{bc}
C_4T_1 R_2	7.33^{b}	6.97^{b}	7.50b^{c}	7.30^{b}	7.37^{c}
C_4T_1 R_3	7.20^{b}	6.80^{b}	6.53^{a}	7.27^{b}	7.03^{bc}
C_4T_2 R_1	6.37^{a}	6.60^{b}	6.67^{a}	6.80^{a}	6.73^{b}
C_4T_2 R_2	7.27^{b}	7.20^{cd}	7.20^{bc}	7.47^{b}	7.27^{c}
C_4T_2 R_3	7.20^{b}	7.27^{cd}	7.40^{bc}	7.73^{bc}	7.70^{c}
C_4T_3 R_1	7.27^{b}	7.47^{d}	7.20^{bc}	7.60^{bc}	7.43^{c}
C_4T_3 R_2	7.20^{b}	7.40^{d}	7.53^{bc}	7.20^{a}	7.40^{c}
C_4T_3 R_3	6.93^{a}	7.53^{d}	6.67^{a}	7.13^{a}	7.20^{bc}
F-value	0.84	2.40	1.97	2.54	2.82
SE (m)	0.17	0.44	0.21	0.23	0.49
CD (5 %)	0.73	0.69	0.54	0.49	0.68

Conclusion

The sensory attributes of any milk products in terms of overall acceptability is paramount for consumer requirements. The extruded *peda* made from treatment combination of code $C_3T_3R_1$ (representing product mix C_3 containing of 10:55 feed composition for skim milk powder and *khoa* respectively, 80^0C barrel temperature and 14 rpm screw speed); combination code $C_3T_3R_2$ (representing product mix C_3 containing of 10:55 feed composition for skim milk powder and *khoa* respectively, 80^0C barrel temp. and 21 rpm screw speed) and code $C_4T_2R_3$ (representing product mix C_4 containing of 15:50 feed composition for skim milk powder and *khoa* respectively, 70^0C barrel temp. and 28 rpm screw speed) resulted in the best quality product in terms of overall acceptability. It can be concluded that, the twin screw co-rotating extruder could be used for cooking of *khoa*, sugar, SMP mix to get the soft grade extruded *peda* with desired sensory quality.

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