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Effect of product mix and operating parameters of Twin screw extruder on chemical characteristics of extruded *peda*

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Abstract
Peda is *khoa* based traditional dairy sweets enjoyed by everyone due to its taste and health aspects. In this study, extruded *peda* prepared in the laboratory along with traditionally made control *peda* samples were assessed in respect of chemical quality. The optimized combinations of product mix with different operating parameters along with control samples were used for analysis. The chemical analysis of *peda* samples showed that the moisture, fat, protein, ash and total carbohydrate from 16.20% ($C_4T_2R_3$) to 18.45% ($C_0T_0R_0$); 16.16% ($C_0T_0R_0$) to 16.58% ($C_3T_3R_2$); 14.84% ($C_0T_0R_0$) to 15.74% ($C_4T_2R_3$); 2.85% ($C_0T_0R_0$) to 3.15% ($C_4T_2R_3$) and 47.70% ($C_0T_0R_0$) to 48.65% ($C_4T_2R_3$) respectively. The total carbohydrate, fat, protein and ash content were higher while moisture content was lower in extruded *peda* as compared to the control.

Keywords: Barrel temperature, extruded *peda*, *khoa*, screw speed, skim milk powder and twin screw extruder

Introduction
Extrusion technology offers a versatile and efficient method for processing various food products. Extrusion involves the use of heat, pressure and mechanical forces to expel a raw material through a die to produce a continuous product with a desired shape and texture (Riaz, 2000). The single or twin-screw food extruders are used. Presently, this technique is utilized to produce textured products of protein, snack, toast and confectionary products. In spite of its immense potential, it is only utilized for butter making in dairy. Few research work has been reported on manufacturing of processed cheese (Zuber *et al.*, 1987; Kazuo *et al.*, 1993; Adhikari *et al.*, 2009) [23, 14, 1], mozzarella cheese (Ferrari *et al.*, 2003), casein/caseinate manufacturing (Fichtali, 1990) [10], *sandesh* (Kumar and Das, 2007) [15] etc. using extrusion technique.

In India, about 55% of total milk production is used by unorganized sector or small entrepreneur or *halwais* (Bandyopadhyay *et al*., 2006) [5]. It has been anticipated that out of these around 7% of milk is utilized for production of heat desiccated Traditional Indian Dairy Products (TIDP). *Khoa* is one of the major TIDP. *Khoa, peda* have high marketable impact as it holds huge popularity throughout the country and comparatively longer shelf life than traditional dairy products (Naresh *et al.*, 2009) [17]. Conventionally, *peda* is prepared directly by concentrating milk to *khoa* concentration followed by addition of sugar or 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. Banerjee (1997) [6] reported a mechanized process for *khoa* making at 60 ^{0}C temperature and followed by addition of 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. Various studies also shown use of scraped surface heat exchangers are also used for *khoa* making (Dodeja *et al*., 1992) [8]. In view of the growing potential of extrusion process, a study was carried out to investigate the possibilities of initiating extrusion technology for production of acceptable quality extruded *peda* and the chemical analysis of extruded *peda* samples was studied.

Materials and Methods
Good quality fresh pasteurized full cream milk (Amul Gold, GCMMFL, Anand), skim milk powder (Sagar, Amul Fed Dairy) and *ghee* (Chhattisgarh State Cooperation Dairy Federation

Ltd., Raipur) and sugar of commercial grade were procured from local market of Raipur city and used for product development. Analytical grade chemicals and glassware were procured from approved firms and manufactures.

Optimisation of the levels of barrel temperature, screw speed and product mix

In the first phase of study conducted in the laboratory for manufacturing extruded *peda*, four product mixes namely C_1 (70% *khoa*, 0% SMP, 0% *ghee* and 30% sugar); C_2 (60% *khoa*, 5% SMP, 5% *ghee* and 30% sugar); C_3 (55% *khoa*, 10% SMP, 5% *ghee* and 30% sugar) and C_4 (50% *khoa*, 15% SMP, 5% *ghee* and 30% sugar) were selected and processed in a twin screw extruder system at three barrel temperatures i.e. (T_1, T_2, and T_3 at 60 ^{0}C, 70 ^{0}C and 80 ^{0}C respectively) and three screw speeds i.e. (R_1, R_2 and R_3 at 14 rpm, 21rpm and 28 rpm respectively) (which resulted in total 36 treatments. The experiments were replicated thrice and obtained fresh products were subjected to sensory evaluation. Sensory evaluation of extruded *peda* samples was done on the basis of '9 point hedonic scale' for sensory properties such as colour and appearance, flavour, sweetness, body & texture and overall acceptability by a panel of judges. The sensory data were then statistically analysed by using three factor factorial experiment design as described by Steel and Torrie (1980) [21]. On the basis of the results of sensory studies, following best three treatments were selected for further study.

1. $C_3T_3R_1$ (Product mix containing 55% *khoa*, 10% SMP, 5% *ghee* and 30% sugar; operating conditions: barrel temperature = 80^{0}C and screw speed = 14 rpm).
2. $C_3T_3R_2$ (Product mix containing 55% *khoa*, 10% SMP, 5% *ghee* and 30% sugar; operating conditions: barrel temperature = 80 ^{0}C and screw speed = 21 rpm)
3. $C_4T_2R_3$ (Product mix containing 50% *khoa*, 15% SMP, 5% *ghee* and 30% sugar; operating conditions: barrel temperature = 70 ^{0}C and screw speed = 28 rpm)

Twin screw extruder system

The twin- screw extruder is used to manufacture various food products due to its flexibility in nature. In the current experiment, a twin-screw extruder (Model: SY 30-IV, Jinan Saibainuo Technology Development Co. Ltd., China) was used for manufacturing of extruded *peda*. Along the barrel length, there were four temperature controlling sites in extruder, where heating was performed by four induction heaters. There was a provision of water jacket for cooling function in every heating zone. The speed of twin screw of extruder system was controlled by variable frequency drive (VFD), motor (3 phase, 7.5 HP) with gear box. The LCD computer control system was used to control all the parameters of the extruder while experiment.

Manufacture of control and extruded *peda*

The control sample of *peda* was manufactured according to standard procedure as described by Pal (1998) [19] and Aneja *et al.*, (2002) [3]. For manufacturing extruded *peda*, the working of extruder system was started after setting and stabilizing the barrel temperature and screw speed. The calculated amount of product mix was prepared as per treatments. It was then introduced into the feeding section of twin screw co-rotating extruder and processed at optimized system conditions. The extruder was cleaned after every run. All through the extrusion process, the product mix was handled by screw flight and conveyed forward 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 after cooling to room temperature, it was then formed manually to round balls of about 20-25 g each. Fresh experimental product along-with control samples were analyzed for chemical attributes.

Chemical analysis

The control *peda* sample and extruded *peda* samples produced under different combination of product mix and operating conditions were chemically analysed for moisture (ISI: 2785, 1964), fat (ISI: 1224, Part II, 1977), protein by Micro Kjeldhal's method as per Meneffee and Overman (1940) [16]; Ash **(**AOAC., 2000) [4] and total carbohydrate content was obtained by subtracting the estimated amount of protein, fat, ash and moisture from 100.

Result and Discussion

The chemical analysis of control and extruded *peda* samples were carried out to determine moisture, fat, protein, ash and total carbohydrate contents and results are presented in Table 1.

Table 1: Effect of product mix and operating parameters of TSE on chemical composition of extruded *peda*

Treatments	Chemical compositions (%)				
	Moisture	Fat	Protein	Ash	Total carbohydrate
$C_0T_0R_0$	18.45^a	16.16^b	14.84^c	2.85^c	47.70^c
$C_3T_3R_1$	17.13^b	16.55^a	15.12^b	3.01^b	48.19^b
$C_3T_3R_2$	17.20^b	16.58^a	15.15^b	2.97^b	48.10^b
$C_4T_2R_3$	16.20^c	16.26^b	15.74^a	3.15^a	48.65^a
S.E. (m) ±	4.25	0.21	0.71	0.07	0.75
F-value	743.66	6.52	35.05	15.27	81.01
C.D. at 5%	0.10	0.24	0.19	0.09	0.12

Moisture content

The control sample (i.e. $C_0T_0R_0$) had highest moisture content of 18.45% while the lowest moisture recorded in treatment $C_4T_2R_3$. This may be due to addition of varied proportion of skim milk powder (SMP) and different processing conditions like method of manufacturing, extent of desiccation etc. The samples of treatment $C_3T_3R_1$ and $C_3T_3R_2$ did not differ significantly in their moisture content. High barrel temperature (80^{0}C) and lower screw speed (14 rpm) might be the probable reason for more evaporation of moisture in the evaporation section of twin screw extruder which resulted in lowering of moisture content in experimental samples as compared to control. The treatment $C_4T_2R_3$ was found significantly ($p \leq 0.05$) different from the other samples. Higher concentration of SMP addition (i.e. 15%) in treatment $C_4T_2R_3$ resulted in increased total solids hence, lower moisture was recorded in finished products. Jadhao *et al.* (2021) [13] reported similar kind of trends for skim milk powder added burfi samples.

Fat content

The fat content in *peda* samples obtained from treatments $C_0T_0R_0$, $C_3T_3R_1$, $C_3T_3R_2$ and $C_4T_2R_3$ had 16.16, 16.55, 16.58 and 16.26% respectively. The lowest fat content was recorded for control sample. This might be due to higher moisture content in control sample. This result is in alignment with

findings reported by Nawadkar *el al.* (2010) [18]. The moderate fat content in *peda* gave smoothness to *peda* while very high fat content gave greasy *peda* and very low-fat content gave dry *peda*. The higher fat content in experimental samples than the control sample might be due to addition of ghee (5%). Statistically, samples of treatment $C_3T_3R_1$ and $C_3T_3R_2$ were at par with each other on fat content. Despite of the utilization of same formulations, the extruded *peda* obtained from treatment $C_3T_3R_2$ had more percentage of fat than the $C_3T_3R_1$. This could be due to the more shearing of fat globule at higher screw speed causes release of free fat, which resulted in increase in total free fat content. Sharma (2007) [20] reported a similar trend, increase in total fat content of *khoa* for all fat levels in milk with increase in rotor speed from 20 to 40 rpm. The increased level of fat available in the product helped in reducing adhering property of product with inner heating surface of barrel and also in lubricating the screw flight for smooth working on heating surface.

Among the experimental samples, the significant ($p \leq 0.05$) reduction in fat content was recorded in treatment $C_4T_2R_3$than others. This could be because of addition of more proportion of solid not fat, which lowered the fat content in $C_4T_2R_3$. Suryawanshi *et al.* (2014) [22] reported that the fat content in *peda* prepared from blend of cow milk with skimmed milk powder, decreased with increase in the level of skimmed milk powder addition which supports the present study.

Protein content

The protein content in control and experimental samples was recorded as 14.84, 15.12, 15.15 and 15.74% for treatments $C_0T_0R_0$, $C_3T_3R_1$, $C_3T_3R_2$ and $C_4T_2R_3$ respectively. Significantly ($p \leq 0.05$) lower protein content was recorded in control sample than experimental samples. Among the experimental samples, highest protein content was recorded for *peda* obtained from treatment $C_4T_2R_3$which contained higher proportion of SMP (15%). This result is in agreement with Jadhao *et al.* (2021) [13] reported increase in protein content (13.16 to 19.07%) with the increment of level of skim milk powder addition in low fat *burfi* preparation. Statistically, at par effect was found between extruded *peda* samples prepared from treatments $C_3T_3R_1$, and$C_3T_3R_2$. Slight lower amount of protein content was noticed intreatment $C_3T_3R_1$ sample. This might be due to some damage to heat sensitive amino acids during extrusion cooking at elevated barrel temperature for longer period. Constantin and Csatlos (2010) [7] reported similar kind of mechanism for slight decrease in protein content of the milk.

Ash content

Average ash content in *peda* samples recorded was 2.85, 3.01, 2.97 and 3.15 for treatments $C_0T_0R_0$, $C_3T_3R_1$, $C_3T_3R_2$ and $C_4T_2R_3$ respectively. It revealed that skimmed milk powder caused significant change in the ash content of final product. Control sample had lowest ash (2.85%). Higher ash content was observed in experimental sample made from treatment $C_4T_2R_3$, which might be due the addition of increasing level of SMP. Aider *et al.* (2007) [2] reported the replacement of higher amount of *khoa* with SMP. This could be associated to higher concentration of minerals especially calcium and potassium. The result of present investigation is in alignment with Suryawanshi *et al.* (2014) [22] who reported that the ash in *peda* prepared from cow milk blended with skimmed milk powder increases with increase in the level of skimmed milk powder addition.

Total carbohydrate content

The total carbohydrate content of *peda* obtained from treatments $C_0T_0R_0$, $C_3T_3R_1$, $C_3T_3R_2$ and $C_4T_2R_3$ was recorded as 47.70, 48.19, 48.10 and 48.65% respectively. Significantly ($p \leq 0.05$) lower carbohydrate content was recorded in control sample than the experimental sample. Among the experimental sample higher carbohydrate content were recorded for treatment $C_4T_2R_3$ which was found to be significantly ($p \leq 0.05$) different from rest of the samples. This could be due to the addition of varying level of SMP concentration in experimental samples. Skim milk powder contains more percentage of carbohydrate, mainly lactose. This might be responsible for higher total carbohydrate content in SMP added blends. The result of present investigation is alignment with Suryawanshi *et al.* (2014) [22] who reported that the carbohydrate content in *peda* prepared from blend of cow milk with skimmed milk powder increased with increase in the level of skimmed milk powder addition.

Conclusion

The best quality extruded *peda* in terms of chemical characteristics was produced at 80^0C of barrel temperature, screw speed rotating at 14 rpm and product mix containing of skim milk powder 10%, *khoa* 55%, ghee 5% and sugar 30%.

Future Scope

The mechanization of such Traditional Indian Dairy Products enables a consistent quality production at large scale. The utilization of milk protein powder or concentrate for making protein enriched *pedas*.

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