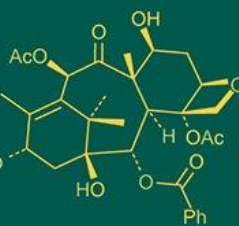
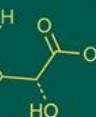
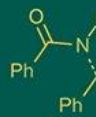


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Influence of twin-screw extrusion processing parameters on the microstructural characteristics of peda

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Abstract

Peda, a heat-desiccated khoa-based traditional Indian milk sweet, is conventionally manufactured by halwais through labour-intensive batch processes that limit consistency and large-scale output. Twin-screw extrusion (TSE) has been explored as a continuous, multifunctional alternative capable of performing kneading, cooking and shaping in a single pass, but the structural consequences of this severe thermo-mechanical treatment on the product have received little attention. The present study examines the influence of TSE processing parameters, namely barrel temperature (60-80 °C) and screw speed (14-28 rpm), together with partial replacement of khoa by skim milk powder (SMP) and ghee, on the microstructure of peda as revealed by scanning electron microscopy (SEM). A co-rotating twin-screw extruder (Model SY 30-IV) was used to process four product mixes (C1-C4) containing 0-15 per cent SMP at three barrel temperatures and three screw speeds. Based on sensory screening of the resulting thirty-six treatment combinations, three extruded samples, C3T3R1 (10% SMP, 80 °C, 14 rpm), C3T3R2 (10% SMP, 80 °C, 21 rpm) and C4T2R3 (15% SMP, 70 °C, 28 rpm), were selected for detailed comparison against traditionally prepared control peda (C0T0R0). SEM micrographs of the control sample revealed a compact but uneven protein matrix with large and small voids resulting from manual scraping and uneven heating. Extruded samples exhibited progressively smaller, more uniformly distributed protein granules with reduced void space; the effect intensified with increasing screw speed and SMP level, reflecting greater shear-induced disruption of the casein-whey protein network and incorporation of finer SMP particles. The C3T3R1 micrograph, produced at the lowest screw speed and highest barrel temperature, was found to be the closest match to the control structure, consistent with its superior sensory and textural performance. The findings demonstrate that screw speed and barrel temperature exert a measurable and predictable effect on the microstructural organisation of extruded peda, and that the operating window of 80 °C barrel temperature with 14 rpm screw speed and 10 per cent SMP substitution offers a microstructure most comparable to the traditional product.

Keywords: Peda, Twin-screw extrusion, Scanning electron microscopy, Microstructure, Processing parameters, khoa

1. Introduction

Traditional dairy products occupy a central place in Indian dietary, cultural and religious life, and their manufacture provides considerable rural employment and value addition to surplus milk (Jha *et al.*, 2014) ^[20]. It is estimated that about half of the milk produced in India is converted into such products by the unorganised halwai sector through processes of heating, heat-acid coagulation, heat desiccation and fermentation (Bandyopadhyay *et al.*, 2006) ^[6]. Among the heat-desiccated khoa-based sweets, peda enjoys a particularly prominent commercial position because of its country-wide popularity and comparatively long shelf life (Naresh *et al.*, 2009) ^[25]. Peda is essentially manufactured by heating a mixture of khoa and sugar in an iron pan until a granular, firm body and characteristic flavour develop, with khoa itself prepared by continuous heating and stirring of milk to a dough-like consistency

(De, 1980; Aneja *et al.*, 2002) ^[5]. Despite its popularity, commercial production of peda has remained largely confined to small halwai units because the process is energy-inefficient, labor-intensive and difficult to standardise (Bandyopadhyay & Khamrui, 2007) ^[7]. Several attempts have been made to mechanise individual steps of peda manufacture, including the kesar peda process developed by the National Dairy Development Board, in which heated khoa is blended with sugar and flavour in a planetary mixer and then shaped using a Rheon or dedicated peda-forming machine (Banerjee, 1997), a peda-pressing machine integrated with a ball-forming rounder (Aksar Food Machines, 2013) ^[4], and a piston-cylinder-die forming system for extruding khoa-peda mass into discs (Singh *et al.*, 2015) ^[34]. These devices mechanise shaping alone and have not been widely adopted by industry, largely because they do not integrate the kneading, cooking and forming steps into a single continuous unit.

Extrusion technology, in which single- or twin-screw machines transport, mix, knead, shear and cook a food mass before forcing it through a shaping die, offers a route to such integration (Riaz, 2000) ^[30]. The twin-screw extruder, in particular, combines high shear, controlled thermal input and continuous conveying within one barrel, and has already been adapted for several heat-desiccated and acid-coagulated dairy products, including kneading and ball-forming of chhana for rasogolla and sandesh manufacture (Kumar & Das, 2007) ^[23] and continuous cooling of khoa using a jacketed screw conveyor (Shaw *et al.*, 2015) ^[32]. Internationally, twin-screw systems have been used to manufacture processed cheese (Zuber *et al.*, 1987; Cavalier *et al.*, 1990; Kazuo *et al.*, 1993; Adhikari *et al.*, 2009) ^[2, 10, 22, 38], fibrous mozzarella analogues (Ferrari *et al.*, 2003) ^[16] and texturised milk protein powders, confirming that extrusion can reproducibly deliver the combination of heat and mechanical work needed to transform dairy mixes into structured products.

The intensity of heat and shear delivered during extrusion is governed chiefly by barrel temperature and screw speed, and these same variables determine the extent to which the casein-whey protein network, fat globules and sugar/lactose crystals of the feed material are broken down, redistributed and re-agglomerated. Because the sensory body and texture of peda are a direct consequence of this granular protein architecture, characterisation of the product microstructure provides a more fundamental explanation of processing effects than sensory or textural measurements alone (Patil *et al.*, 1992; Adhikari, 1993) ^[1, 29]. Scanning electron microscopy (SEM) has been the method of choice for this purpose in indigenous dairy products: it has been used to show that working of khoa reduces protein granule size and inter-granular void space (Patil *et al.*, 1992) ^[29], that acidic coagulation of milk produces coarser khoa granules than neutralised milk (Choudhary *et al.*, 2017) ^[12], and that market peda subjected to non-uniform heat treatment develops large lactose aggregates and excessive void space

(Das *et al.*, 2018) ^[14]. However, no study has yet examined how the operating parameters of a twin-screw extruder, specifically barrel temperature and screw speed, shape the resulting microstructure of peda in comparison with the traditionally prepared product.

The present paper addresses this gap. It reports the scanning electron microscopic evaluation of peda manufactured using a co-rotating twin-screw extruder at three-barrel temperatures, three screw speeds and four khoa-skim milk powder-ghee-sugar product mixes, and compares the resulting micrographs of the best-performing extruded treatments with those of conventionally prepared control peda. The specific objectives were (i) to characterise, by SEM, the microstructure of control peda prepared by the traditional karahi method, (ii) to characterise the microstructure of extruded peda manufactured under selected combinations of barrel temperature, screw speed and product mix, and (iii) to relate the observed microstructural differences to the underlying processing conditions so as to identify the operating window that most closely reproduces the granular architecture of traditional peda.

2. Materials and methods

The study was carried out in the Departments of Dairy Technology in collaboration with the Department of Dairy Engineering, Dairy Chemistry and Dairy Microbiology, College of Dairy Science and Food Technology, Chhattisgarh Kamdhenu Vishwavidyalaya, Raipur (Chhattisgarh), India.

2.1 Raw materials

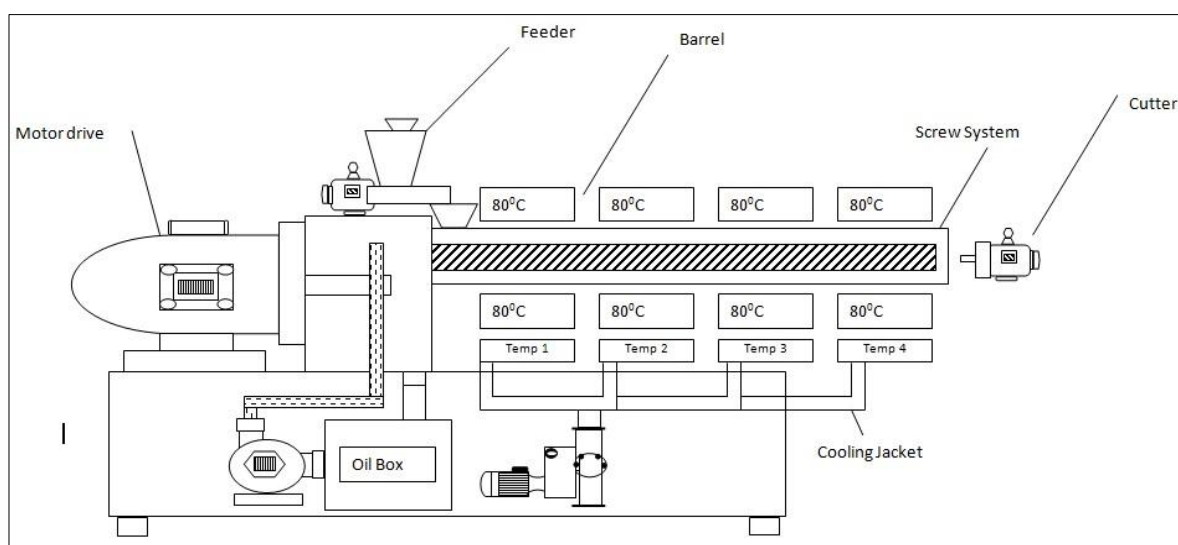
Fresh pasteurised full-cream milk (6.15% fat, 9.27% solids-not-fat), branded skim milk powder, branded khoa and branded ghee were procured from the local market of Raipur city. Good quality cane sugar was obtained from a local grocer, and low-density polyethylene pouches (5 × 4 × 2.5 cm, 130 µm thickness) were used for primary packaging of the fresh product. All chemicals and glassware used for analysis were of standard analytical grade.

2.2 Twin-screw extruder

A co-rotating twin-screw extruder (Model SY 30-IV, Jinan Saibainuo Technology Development Co. Ltd., China) was used to manufacture the extruded peda. The machine comprised a feeding system, an extruding system (twin screws rotating in the same anticlockwise direction within a barrel), a cutting system, a four-zone electrical heating system with individual water-jacket cooling, a lubrication system and a touch-screen control system. The complete specifications of the extruder are given in Table 1, and a schematic line diagram of the machine is shown in Figure 1. The barrel carried four independently adjustable heating zones, each fitted with a cooling water jacket, and screw speed was regulated through a variable-frequency drive coupled to a 7.5 HP three-phase motor.

Table 1: Specifications of the twin-screw extruder used for production of extruded peda

Particulars	Specification
Diameter of screw	2.6 cm
Root diameter	1.9 cm
Number of flights	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 screw section	65 cm
Helix angle	17°
Diameter of barrel	5.7 cm
Barrel length	65 cm
Length of feeding zone	7 cm
Length of heating zone	58 cm
Diameter of die orifice	2 cm

**Fig 1:** Line diagram of the co-rotating twin-screw extruder used for manufacture of extruded peda

2.3 Product mix formulations

Khoa was partially replaced with skim milk powder at four levels (0, 5, 10 and 15%) to give product mixes C1-C4, while ghee was added at a constant 5 per cent in C2-C4 to compensate for the fat lost on replacing khoa, and sugar was

held constant at 30 per cent in all mixes (Table 2). The level of SMP substitution was restricted to a maximum of 15 per cent because higher levels were found in preliminary trials to impart a powdery taste and an under-cooked character to the finished product.

Table 2: Product mix formulations used for manufacture of extruded peda (per cent)

Ingredient	C1	C2	C3	C4
Khoa	70	60	55	50
Skim milk powder	0	5	10	15
Ghee	0	5	5	5
Sugar (ground)	30	30	30	30
Total	100	100	100	100

2.4 Selection of the processing parameters

Preliminary trials indicated that barrel temperatures below 60 °C produced under-cooked peda mass, whereas temperatures above 80 °C produced an over-cooked product; consequently, three-barrel temperature levels (60, 70 and 80 °C, designated T1, T2 and T3) were selected for

the main study. Likewise, since higher screw speeds were known to yield an excessively pasty extrudate (Chennigararaju *et al.*, 2005) ^[11], three relatively low screw speeds (14, 21 and 28 rpm, designated R1, R2 and R3) were selected to retain the characteristic grainy body of peda (Table 3).

Table 3: Selected processing parameters of the twin-screw extruder

Parameter	Level 1	Level 2	Level 3
Barrel temperature (°C)	60 (T1)	70 (T2)	80 (T3)
Screw speed (rpm)	14 (R1)	21 (R2)	28 (R3)

2.5 Manufacture of control and extruded peda

Khoa was prepared in the laboratory from fresh pasteurised full-cream milk by continuous boiling, stirring and scraping in a karahi until the pat-formation stage. One portion of this khoa was used, together with sugar, to prepare control peda (coded C0T0R0) by the traditional method of Pal (1998)^[26] and Aneja *et al.* (2002)^[5], involving desiccation in the karahi at about 90 °C, cooling to 30 °C and hand-moulding. The remaining khoa was used to prepare the four product mixes (C1-C4), which were fed into the twin-screw extruder and processed at the three-barrel temperatures and three screw speeds described above, giving a total of thirty-six treatment combinations replicated thrice. The extruded mass emerging from the die was cooled to room temperature, hand-rolled into balls of 20-25 g and packed in low-density polyethylene pouches.

The thirty-six fresh extruded samples were evaluated by a panel of judges using a nine-point hedonic scale for colour and appearance, body and texture, sweetness, flavour and overall acceptability, and the sensory scores were analysed using a three-factor factorial design (Steel & Torrie, 1980)^[35]. On this basis, three treatment combinations were carried forward to the detailed comparative study: C3T3R1 (10% SMP, 55% khoa, 5% ghee, 30% sugar; 80 °C barrel temperature; 14 rpm screw speed), C3T3R2 (identical product mix to C3T3R1 but processed at 21 rpm) and C4T2R3 (15% SMP, 50% khoa, 5% ghee, 30% sugar; 70 °C barrel temperature; 28 rpm screw speed). These three extruded samples were compared with the control peda (C0T0R0) for chemical, textural, sensory and microstructural quality.

2.6 Microstructure (sem) analysis

The microstructure of control and extruded peda samples was examined by scanning electron microscopy following the general procedure described by Kalab *et al.* (1988)^[21], Patil *et al.* (1992)^[29] and Adhikari (1993)^[1]. Samples were prepared in the laboratory and despatched to the Sapience

Bio-analytical Research Laboratory, Bhopal, for SEM imaging. Micrographs of each sample were recorded at two magnifications, 500× and 1000×, to allow examination of both the overall granular architecture and the finer detail of the protein-fat-sugar matrix.

2.7 Statistical analysis

Data on the chemical and textural attributes of the fresh control and extruded peda samples were analysed using a Completely Randomised Design with four treatment combinations (one control and three experimental) and four replications, following the statistical procedures outlined by Steel and Torrie (1980)^[35]; these results are presented here only as supporting evidence for the microstructural observations, which were interpreted descriptively in relation to the known processing conditions of each sample.

3. Results and discussion

3.1 Chemical background of the control and extruded samples

Before considering the microstructure, it is useful to note the chemical composition of the four peda samples, since the proportions of moisture, fat and protein influence the appearance of the protein-fat matrix under the electron beam (Table 4). The control sample (C0T0R0) had the highest moisture content (18.45%) and the lowest fat (16.16%) and protein (14.84%) contents. Replacement of khoa with skim milk powder and ghee in the extruded samples raised the protein, fat, ash and carbohydrate contents while lowering moisture, with the effect being most pronounced in C4T2R3, which contained the highest level of SMP (15%) and was processed at the highest screw speed (28 rpm). The lower moisture and higher solids content of the extruded samples are consistent with greater evaporative loss during extrusion at high barrel temperature and the additional total solids contributed by SMP (Suryawanshi *et al.*, 2014; Velpula *et al.*, 2018)^[36, 37].

Table 4: Chemical composition of control and extruded peda samples

Treatment	Moisture (%)	Fat (%)	Protein (%)	Total carbohydrate (%)
C0T0R0 (control)	18.45	16.16	14.84	47.70
C3T3R1	17.13	16.55	15.12	48.19
C3T3R2	17.20	16.58	15.15	48.10
C4T2R3	16.20	16.26	15.74	48.65

3.2 Microstructure of control peda

Scanning electron micrographs of the control peda (C0T0R0) at 500× magnification (Figure 2) showed a compact but uneven surface, partly obscured by fat, in which granules of heat-coagulated protein had coalesced into a continuous matrix interspersed with numerous small pores. This non-uniform, large-and-small-void appearance is consistent with the manual scraping and uneven heat transfer inherent to karahi-based desiccation, and corresponds closely with the microstructure reported for laboratory-made peda by Das *et al.* (2018)^[14]. At the higher magnification of 1000× (Figure 3), the spaces between granules were seen to be filled with a viscous, supersaturated solution of lactose, un-coagulated protein and fat, and the fat globules occupying these inter-granular spaces were noticeably larger than those observed in any of the extruded samples.

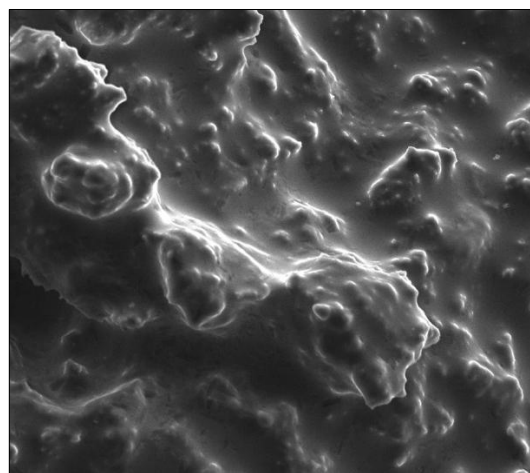


Fig 2: SEM micrograph of control peda (C0T0R0) at 500× magnification (bar = 100 µm)

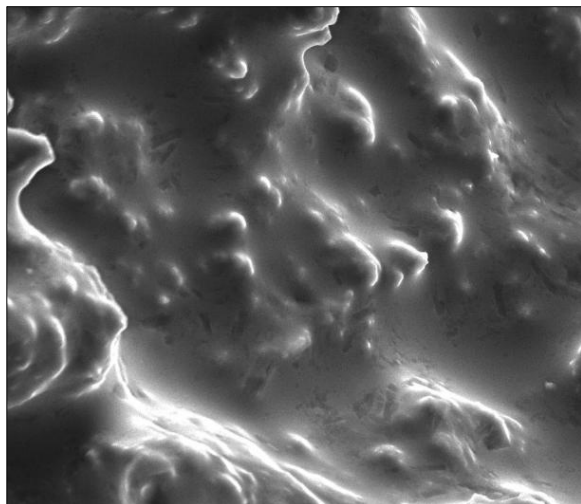


Fig 3: SEM micrograph of control peda (C0T0R0) at 1000× magnification (bar = 50 µm)

3.3 Microstructure of extruded peda

3.3.1 Treatment c3t3r1 (10% smp, 80 °C, 14 rpm)

Among the extruded samples, C3T3R1, processed at the highest barrel temperature (80 °C) but the lowest screw speed (14 rpm), produced the protein network most different from, yet structurally closest to, the control. At 500× magnification (Figure 4) the micrograph showed compact protein agglomerates with a marked reduction in void space relative to the control. Because residence time within the barrel increases as screw speed decreases, the product mix at 14 rpm remained in contact with the heated barrel and screw root for longer, allowing more complete heat-induced desiccation of the casein-whey protein complex; the matrix consequently appeared as agglomerated, irregularly shaped protein particles joined by thick bridges into a continuous network. At 1000× magnification (Figure 5), the coalesced agglomerates and thick protein bridges were clearly visible together with small lactose crystals and a moderately viscous inter-granular liquid phase, indicating that, despite the additional shear of extrusion, the relatively gentle screw speed limited further breakdown of the protein granules.

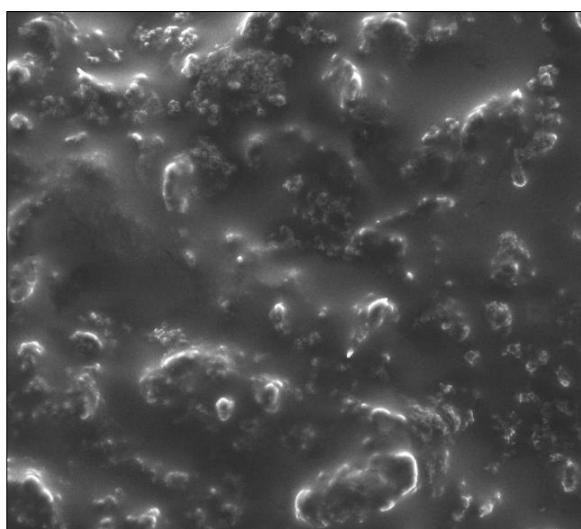


Fig 4: SEM micrograph of extruded peda (C3T3R1) at 500× magnification (bar = 100 µm)

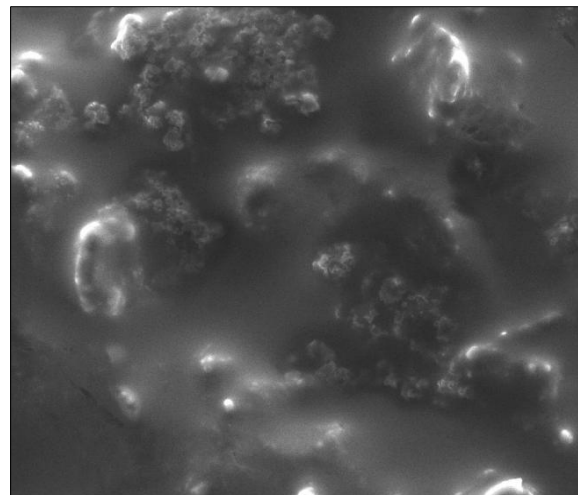


Fig 5: SEM micrograph of extruded peda (C3T3R1) at 1000× magnification (bar = 50 µm)

3.3.2 Treatment c3t3r2 (10% smp, 80 °C, 21 rpm)

Sample C3T3R2 was prepared from the same product mix as C3T3R1 and at the same barrel temperature (80 °C), but at a higher screw speed of 21 rpm, which allows the influence of screw speed on microstructure to be isolated. At 500× magnification (Figure 6), the micrograph showed a coalesced, ragged protein matrix joined in compact thick bridges, with granules noticeably smaller than those of the control and somewhat smaller and more closely packed than those of C3T3R1. This finer dispersion is attributable to the greater shear stress generated by the higher screw speed, which ruptures and re-disperses the protein granules to a greater extent than the slower-turning screw used for C3T3R1; a similar relationship between screw speed and finer dispersion of structural elements has been reported for Cryo-SEM images of low-temperature extruded ice cream (Shrivastav & Goswami, 2017) ^[33]. At 1000× magnification (Figure 7), the agglomerated protein matrix was seen to be interlinked strongly into a compact, scale- or layer-type structure, with thread-like casein micelles arranged in a regular, folded pattern, a configuration distinct from the loosely coalesced bridges seen in C3T3R1.

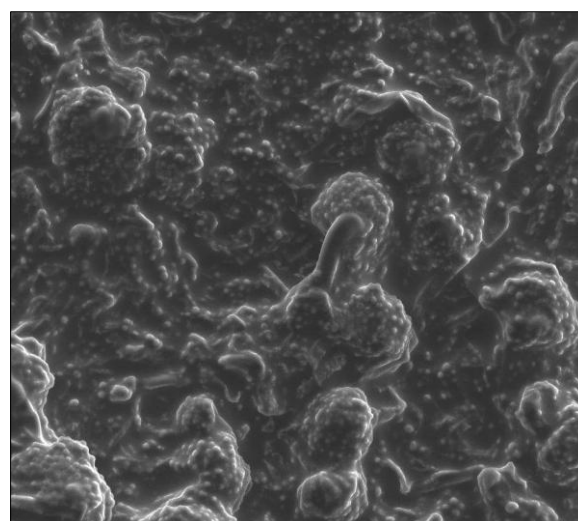


Fig 6: SEM micrograph of extruded peda (C3T3R2) at 500× magnification (bar = 100 µm)

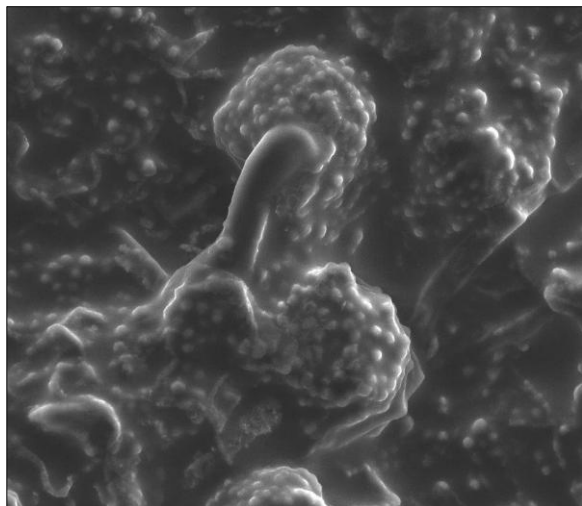


Fig 7: SEM micrograph of extruded peda (C3T3R2) at 1000× magnification (bar = 50 µm)

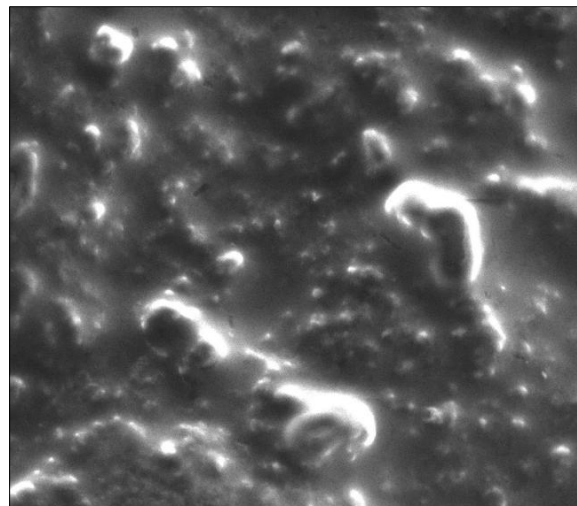


Fig 9: SEM micrograph of extruded peda (C4T2R3) at 1000× magnification (bar = 50 µm)

3.3.3 Treatment c4t2r3 (15% smp, 70 °C, 28 rpm)

Sample C4T2R3 combined the highest level of SMP substitution (15%) with the lowest barrel temperature (70 °C) and the highest screw speed (28 rpm) among the selected treatments. At 500× magnification (Figure 8), the micrograph showed a continuous mass of agglomerated protein with fat globules embedded throughout, giving the surface a slightly fuzzy appearance, together with non-uniform, medium-sized grains and conspicuously large lactose crystals, broadly similar to the developed lactose crystals reported in unworked khoa by Patil *et al.* (1992) [29]. The combination of high shear (28 rpm) with a comparatively short residence time and lower barrel temperature (70 °C) appears to have been less effective than the conditions used for C3T3R1 and C3T3R2 in achieving uniform desiccation and dispersion of the higher SMP load, resulting in the more heterogeneous appearance of this sample. At 1000× magnification (Figure 9), the surface remained uneven, with viscous liquid filling the inter-granular spaces in a manner reminiscent of the control sample, but with a coarser distribution of lactose crystals consistent with the larger total-solids contribution of the 15 per cent SMP addition.

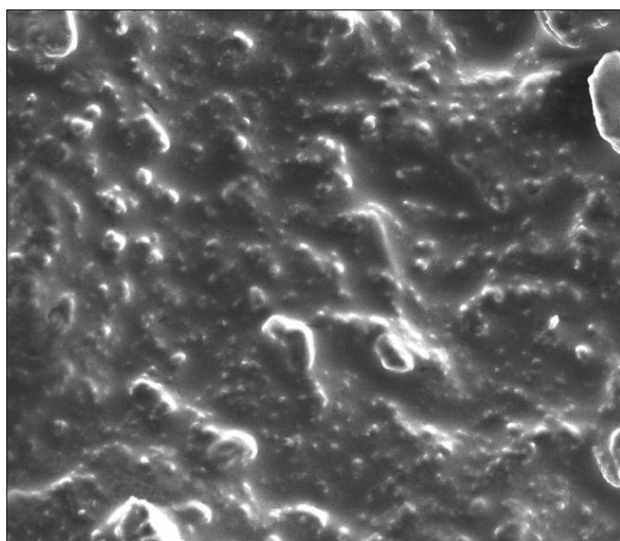


Fig 8: SEM micrograph of extruded peda (C4T2R3) at 500× magnification (bar = 100 µm)

3.4 Comparative effect of processing parameters on microstructure

Taken together, the micrographs indicate that screw speed, barrel temperature and SMP level each contribute, in a distinguishable way, to the final microstructure of extruded peda. Increasing screw speed from 14 rpm (C3T3R1) to 21 rpm (C3T3R2) at a constant barrel temperature of 80 °C and constant product mix produced a finer, more compact and more uniformly dispersed granular structure, reflecting the additional mechanical shear imparted to the protein-fat-sugar matrix as the screws turn faster; this finding parallels the observation that increasing rotor speed in mechanical khoa-making equipment increases the disruption of fat globules and protein aggregates (Sharma, 2007) [31]. Lowering the barrel temperature from 80 °C to 70 °C while simultaneously raising both the SMP level (to 15%) and the screw speed (to 28 rpm), as in C4T2R3, reduced the degree of uniform desiccation achieved and resulted in a more heterogeneous matrix with larger lactose crystals, suggesting that adequate barrel temperature is necessary to fully integrate higher levels of SMP into the protein network within the limited residence time available at high screw speed.

These microstructural trends are consistent with the textural behaviour of the same samples. Hardness, gumminess and chewiness values increased progressively from the control (1629.69 g, 294.49 g and 55.32 g.mm, respectively) through C3T3R1 and C3T3R2 to C4T2R3 (1884.29 g, 335.06 g and 69.34 g.mm, respectively), a trend that mirrors the increasingly compact, fine-grained protein matrix observed by SEM as SMP level and screw speed increased. The closer resemblance of the C3T3R1 micrograph to that of the control sample is also reflected in its sensory performance: of the three extruded treatments, C3T3R1 received the highest scores for body and texture, flavour and overall acceptability, supporting the conclusion that a microstructure approximating that of the traditional product is associated with greater consumer acceptability. The combination of high barrel temperature (80 °C) with low screw speed (14 rpm) and a moderate (10%) SMP substitution therefore represents the most favourable operating window, among those tested, for reproducing the granular architecture characteristic of traditional peda within a continuous twin-screw extrusion process.

Conclusion

Scanning electron microscopy revealed clear and systematically explicable differences between the microstructure of traditionally prepared control peda and peda manufactured using a co-rotating twin-screw extruder. The control sample displayed a compact but uneven protein matrix with large and small voids, attributable to manual scraping and non-uniform heating in the karahi. Extrusion produced more compact, finer-grained protein networks, with the degree of granule refinement increasing as screw speed and skim milk powder substitution increased, while inadequate barrel temperature relative to the SMP load and screw speed led to a more heterogeneous structure with larger lactose crystals. Among the treatments evaluated, the combination of 80 °C barrel temperature, 14 rpm screw speed and a product mix containing 10 per cent skim milk powder, 55 per cent khoa, 5 per cent ghee and 30 per cent sugar (treatment C3T3R1) produced a microstructure most closely resembling that of the control sample and was also associated with the best sensory and textural performance among the extruded products. These results confirm that barrel temperature and screw speed are key levers for controlling the microstructural, and hence textural and sensory, quality of extruded peda, and they identify a practical operating window for further scale-up of twin-screw extrusion as a continuous manufacturing route for this traditional Indian milk sweet.

References

- Adhikari AK. Microstructure and texture of khoa and gulabjamun made from cow's milk: Heat induced changes during processing and frying. *J Sci Food Agric*. 1993;61(1):7-15.
- Adhikari K, Cole A, Grun I, Heymann H, Hsieh FH, Huff H. Physical and sensory characteristics of processed cheeses manufactured by extrusion technology. *J Sci Food Agric*. 2009;89(8):1428-1433.
- Aider M, Halleux D, Belkacemi K. Production of granulated sugar from maple syrup with high content of inverted sugar. *J Food Eng*. 2007;80(3):791-794.
- Aksar Food Machines. Peda pressing machine. Aksar Food Machines; 2013.
- Aneja RP, Mathur BN, Chandan RC, Banerjee AK. Technology of milk products. New Delhi: Dairy India Publication; 2002^[8].
- Bandyopadhyay M, Mukherjee RS, Chakraborty R, Raychaudhari U. A survey on formulations and process techniques of some special Indian traditional sweets and herbal sweets. *Indian Dairyman*. 2006;58(5):23-25.
- Bandyopadhyay P, Khamrui K. Technological advancement on traditional Indian desiccated and heat-acid coagulated dairy products. *Bull Int Dairy Fed*. 2007; 4:1-10.
- Banerjee AK. Processes for commercial production. 5th ed. New Delhi: Dairy India; 1997.
- Bourne MC. Food texture and viscosity: Concept and measurement. 2nd ed. San Diego: Academic Press; 2002.
- Cavalier C, Queguiner C, Cheftel JC. Preparation of cheese analogues by extrusion cooking. In: Zeuthen P, Cheftel JC, Eriksson C, Gormley TR, Linko P, Paulus K, editors. Processing and quality of foods. Amsterdam: Elsevier Science Publishers; 1990. p. 1373-1383.
- Chennigararaju BH, Agrawala SP, Makker SK. Evaluation of improvised plasticizer for continuous manufacture of Butter-G. *Indian J Dairy Sci*. 2005;58(2):80-84.
- Choudhary S, Arora S, Kumari A, Narval V, Tomar SK, Singh AK. Effect of developed acidity and neutralization of milk on sensory, micro-structural and textural changes in khoa prepared from cow and buffalo milk. *J Food Sci Technol*. 2017;54(2):349-358.
- Constantin AM, Csatos C. Research on the influence of microwave treatment on milk composition. *Bull Transilvania Univ Brasov*. 2010;3(52):157-162.
- Das S, Bandyopadhyay AK, Ghatak PK. Heat induced changes of peda as determined by microstructure and texture. *Asian J Agric Food Sci*. 2018;6(4):140-145.
- De S. Indian dairy products. In: Outline of dairy technology. New Delhi: Oxford University Press; 1980. p. 385-389.
- Ferrari E, Gamberi M, Manzini R, Pareschi A, Persona A, Regattieri A. Redesign of the mozzarella cheese production process through development of a micro-forming and stretching extruder system. *J Food Eng*. 2003;59(1):13-23.
- Guy R. Extrusion cooking: Technologies and applications. Cambridge: CRC Press/Woodhead Publishing; 2001.
- Gupta SA. Sensory evaluation of food industry. *Indian Dairyman*. 1976;28(8):293-295.
- Harper JM. Extrusion of food. Vol. 1. Boca Raton: CRC Press; 1981.
- Jha A, Kumar A, Jain P, Om H, Singh R, Bunkar DS. Physicochemical and sensory changes during the storage of lal peda. *J Food Sci Technol*. 2014;51(6):1173-1178.
- Kalab M, Gupta SK, Desai HK, Patil GR. Development of microstructure in raw, fried and cooked paneer made from buffalo, cow and mixed milks. *Food Microstruct*. 1988; 7:83-91.
- Kazuo I, Tsuguaki N, Kiyoshi T, Haruyoshi Y. Preparation of the processed cheese possessing fibrous structure by extrusion cooking. *Nippon Shokuhin Kogyo Gakkaishi*. 1993;40(3):170-175.
- Kumar R, Das H. Performance evaluation of single screw vented extruder for production of sandesh. *J Food Sci Technol*. 2007;44(1):100-105.
- Londhe GK. Development of a process for manufacture and shelf-life extension of brown peda [doctoral dissertation]. Karnal: National Dairy Research Institute; 2006.
- Naresh L, Venkateshaiah BV, Arun Kumar H, Venkatesh M. Studies on effect of microwave heat processing on physico-chemical sensory and shelf life of peda. *Indian J Dairy Sci*. 2009;62(4):262-266.

26. Pal D. Technology of khoa based sweets. In: CAS short course on advances in traditional dairy products. Karnal: National Dairy Research Institute; 1998.
27. Patel HG. A study in peda manufacture. Indian Dairyman. 1986;38(5):253-257.
28. Patel HG, Salunke S, Thakar PN. Chemical, microbiological, rheological and sensory characteristics of peda made by traditional and mechanized methods. J Food Sci Technol. 2006;43(2):196-199.
29. Patil GR, Patel AA, Wojtas PA, Kalab M. Microstructure and texture of khoa. Food Struct. 1992;11(2):155-163.
30. Riaz MN. Extruders in food applications. Lancaster: Technomic Publishing; 2000.
31. Sharma NK. Feasibility studies on manufacture of khoa from low fat milk using three stage scraped surface heat exchanger [master's thesis]. Karnal: National Dairy Research Institute; 2007.
32. Shaw A, Sawhney IK, Minz PS. Thermal performance evaluation of continuous khoa cooling system. Indian J Dairy Sci. 2015;68(4):321-325.
33. Shrivastav A, Goswami TK. Low temperature extrusion of ice cream: A review. J Food Nutr Popul Health. 2017;1(2):1-4.
34. Singh G, Sawhney IK, Minz PS. Multi factor optimization for mechanized formation of khoa peda. Indian J Dairy Sci. 2015;68(5):425-434.
35. Steel RGD, Torrie JH. Principles and procedures of statistics: A biometrical approach. 2nd ed. New York: McGraw-Hill; 1980.
36. Suryawanshi SU, Shelke RR, Wadhwa SN, Kokate PG. Chemical composition of peda prepared from cow milk blended with skimmed milk powder. Asian J Anim Sci. 2014;9(1):106-108.
37. Velpula S, Bhadania AG, Pinto SV, Upadhyay JB, Aravind T, Umapathy KS. Sensory and chemical quality of bottle gourd halwa prepared using skim milk powder. Asian J Dairy Food Res. 2018;37(1):50-55.
38. Zuber F, Megard D, Cheftel JC. Continuous emulsification and gelation of dairy ingredients by HTST extrusion cooking: Production of processed cheeses. Int J Food Sci Technol. 1987;22(6):607-626.