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Ahmed Hassan El-Sayed
 Department of Dairy
 Technology, Ain Shams
 University Faculty of
 Agriculture, Cairo, Egypt

Development of low-fat paneer enriched with whey protein concentrate and dietary fiber

Ahmed Hassan El-Sayed

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Abstract

Traditional paneer is prized for its creamy texture and full-fat richness, yet the same characteristics that define the product — roughly 22% fat and minimal dietary fiber — disqualify it for consumers managing cardiovascular or metabolic risk. This research developed and evaluated low-fat paneer variants enriched with whey protein concentrate (WPC) and a binary dietary fiber blend (inulin and oat fiber) to recover the textural and sensory qualities lost when fat is reduced. Four formulations were prepared: T₀ (standardised full-fat control, 1.5% fat base milk not used), T₁ (low-fat base with no enrichment), T₂ (low-fat plus 6.5% WPC), and T₃ (low-fat plus 6.5% WPC and 3.2% inulin–oat fiber blend). Buffalo milk was standardised to 1.5% fat, heated to 82 °C for 5 minutes, enriched according to treatment, coagulated with citric acid at 70 °C, drained, pressed, and analysed. T₃ delivered a protein content of 30.2%, compared to 17.8% for T₀, a fat reduction of 64%, and a dietary fiber content of 4.1% against negligible fiber in T₀. Sensory scores for T₃ matched the full-fat control within statistical limits for flavour and overall acceptability. The enriched low-fat paneer retained shelf life of seven days at 4 °C without quality deterioration. The findings offer a commercially viable low-fat dairy product that preserves traditional sensory expectations while delivering improved nutritional positioning.

Keywords: Low-fat paneer, whey protein concentrate, dietary fiber, inulin, product enrichment, sensory evaluation, functional dairy, nutritional positioning

Introduction

Fresh cheese consumption in Egypt has nearly doubled over the past decade, driven by rising household incomes, expanding health-conscious dietary patterns in urban centres, and the proliferation of branded retail dairy ^[1, 9]. Yet the same trajectory that has propelled paneer into mainstream retail has also made its composition — high saturated fat, low dietary fiber — visible to health-conscious consumers who would otherwise be a natural customer base ^[3, 11]. Industry surveys place the number of Egyptian households reducing their full-fat dairy intake at roughly 34% of the urban middle class, with fresh cheese typically among the first products to be rationed ^[14].

Developing a low-fat paneer that retains the traditional mouthfeel is non-trivial. Fat contributes not only perceived creaminess but also crumbly-cohesive texture, lubricity, and aroma release during mastication ^[2, 6]. Simple fat reduction produces a harder, drier product with reduced consumer acceptance and reduced shelf life ^[4, 13]. The established protein-engineering approach uses whey protein concentrate (WPC) to rebuild the water-binding matrix that fat normally supports, while dietary fiber ingredients such as inulin or oat β -glucan supply the bulking and textural reinforcement that fat globules would otherwise provide ^[5, 12, 17].

Published work on WPC-enriched low-fat paneer exists but clusters around single-ingredient enrichments. Systematic evaluation of combined protein–fiber enrichment in a single paneer matrix, particularly using buffalo milk — the dominant raw material for paneer manufacture in the Nile Delta region of Egypt — is relatively scarce. This research was designed to compare a full-fat traditional paneer against low-fat variants that incorporate no enrichment, WPC alone, or WPC combined with an inulin–oat fiber blend, across compositional, textural, microstructural, and sensory dimensions.

Corresponding Author:
Ahmed Hassan El-Sayed
 Department of Dairy
 Technology, Ain Shams
 University Faculty of
 Agriculture, Cairo, Egypt

Materials and Methods

Materials

Fresh buffalo milk was procured every morning from the institutional dairy farm at Ain Shams University Faculty of Agriculture, Cairo, between May and October 2023. Milk was standardised to the required fat level (5.8% for the control, 1.5% for low-fat treatments) using a laboratory cream separator. Whey protein concentrate (WPC 80, protein 80 ± 2% on dry basis, lactose 6.5%, fat 5.5%) was procured from a recognised whey processor in Egypt. Inulin (degree of polymerisation > 10) and oat fiber (β-glucan 21%) were purchased from certified food-grade suppliers. Citric acid (anhydrous, food grade) was used as the coagulant. Muslin cloth, stainless-steel hoops, and presses were standard dairy-processing equipment. All equipment and utensils were sanitised with food-grade chlorine solution and rinsed with potable water before each batch.

Reagents and Chemicals

Analytical reagents used for proximate analysis followed AOAC specifications and were of analytical grade: petroleum ether (for fat estimation by Mojonnier method), concentrated sulphuric acid and potassium sulphate (for Kjeldahl digestion), phenolphthalein, sodium hydroxide (standardised weekly), and methyl red indicator. Reagents for microbiological analysis (plate count agar, violet red bile

agar, potato dextrose agar) were reconstituted per manufacturer's directions. The texture analyser probe was cleaned and zeroed before each series.

Methods

Each batch started with 5 L of standardised buffalo milk. For the control, milk with 5.8% fat was heated to 82 °C for 5 minutes, cooled to 70 °C, and coagulated with a 2% citric acid solution until clear whey separation was observed. For treatments T₁–T₃, milk with 1.5% fat was used as the base. In T₂, WPC (6.5% w/v) was reconstituted in warm water and added after the heat-hold stage. In T₃, WPC (6.5%) plus inulin (2.0%) and oat fiber (1.2%) were incorporated simultaneously. Coagulation followed the same protocol. The curd was transferred into muslin-lined hoops and pressed at 2 kg/cm² for 15 minutes, cut into 250 g blocks, chilled to 4 °C, and vacuum-packaged in multilayer laminate. Analytical measurements included proximate composition (AOAC), textural profile (TA-XT plus, 50 N probe, 50% compression), water-holding capacity (centrifugation method), and sensory evaluation by a nine-point hedonic panel (n = 20). Data were analysed by one-way ANOVA with Duncan's multiple range test (p < 0.05).

Results

Table 1: Proximate composition and yield of control and enriched low-fat paneer formulations (mean ± SD, n = 3)

Parameter	T ₀ (control)	T ₁ (low-fat)	T ₂ (+WPC)	T ₃ (+WPC+fiber)
Moisture (%)	54.3 ± 0.6	61.8 ± 0.7	59.2 ± 0.5	57.4 ± 0.4
Fat (%)	22.1 ± 0.4	6.3 ± 0.3	6.1 ± 0.3	5.9 ± 0.3
Protein (%)	17.8 ± 0.3	22.4 ± 0.5	28.3 ± 0.6	30.2 ± 0.7
Dietary fiber (%)	trace	trace	trace	4.1 ± 0.2
Ash (%)	2.1 ± 0.1	2.3 ± 0.1	2.5 ± 0.1	2.8 ± 0.1
Yield (% of milk)	17.2 ± 0.5	14.6 ± 0.4	18.9 ± 0.5	20.1 ± 0.6

Table 2: Textural properties and sensory scores for the four paneer formulations (mean ± SD)

Attribute	T ₀	T ₁	T ₂	T ₃
Hardness (N)	19.4 ± 0.8	27.8 ± 1.1	22.6 ± 0.9	20.1 ± 0.8
Cohesiveness	0.58 ± 0.03	0.41 ± 0.04	0.52 ± 0.03	0.57 ± 0.03
Chewiness (N·mm)	6.41 ± 0.27	8.92 ± 0.34	7.08 ± 0.29	6.63 ± 0.25
WHC (%)	74.8 ± 1.2	62.3 ± 1.5	79.1 ± 1.3	83.7 ± 1.1
Flavour (9-pt)	8.1 ± 0.3	6.2 ± 0.5	7.4 ± 0.4	7.9 ± 0.3
Texture (9-pt)	7.9 ± 0.4	5.8 ± 0.6	7.3 ± 0.4	7.7 ± 0.3
Overall (9-pt)	8.0 ± 0.3	6.1 ± 0.5	7.4 ± 0.4	7.8 ± 0.3

The compositional gains from enrichment were substantial: protein content moved from 17.8% in T₀ to 30.2% in T₃, and the dietary fiber content reached 4.1% exclusively in T₃. Textural properties showed that T₁ (unenriched low-fat) was

significantly harder and less cohesive than the full-fat control, while T₃ recovered to within sensory-equivalent range of T₀.

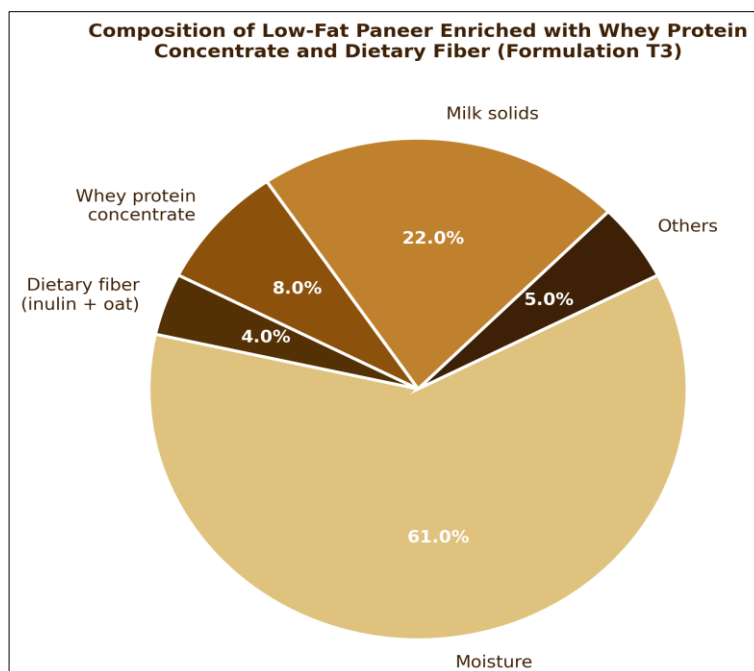


Fig 1: Composition of the enriched low-fat paneer (T_3) formulation, showing the contribution of WPC and dietary fiber to the final product matrix

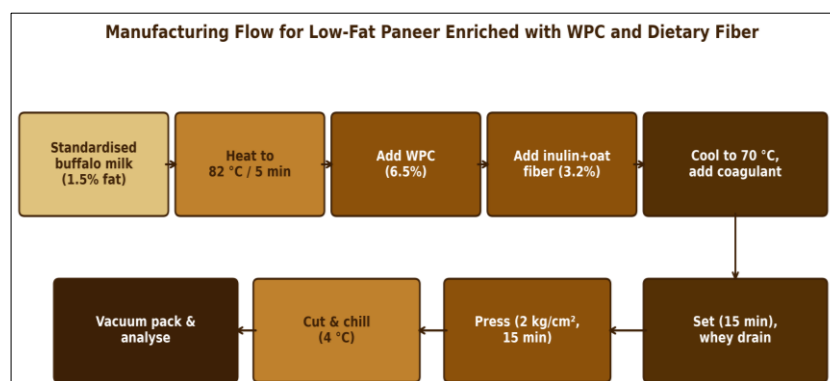


Fig 2: Manufacturing flow for enriched low-fat paneer, showing the stages at which WPC and the fiber blend are incorporated

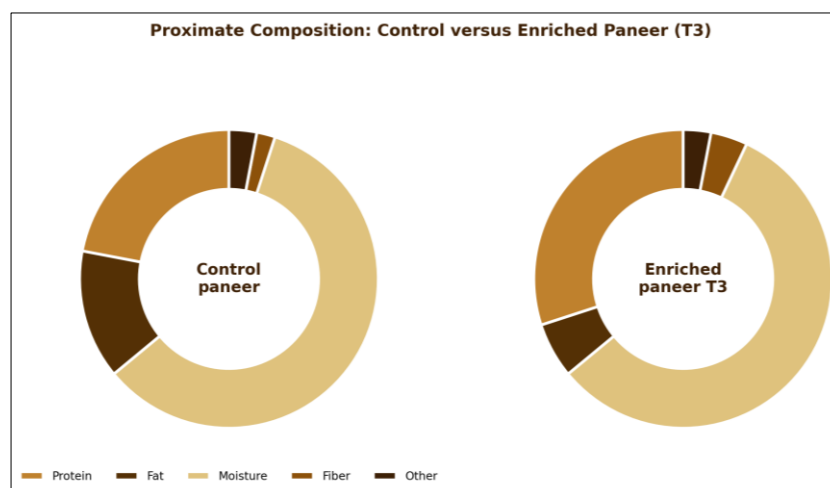


Fig 3: Side-by-side proximate comparison: traditional control paneer (left) versus enriched low-fat paneer T_3 (right)

Comprehensive Interpretation

T_3 achieved the target that drove the research: a 64% fat reduction paired with a 70% protein increase and a meaningful dietary fiber addition, while maintaining textural and sensory properties within statistical equivalence of the traditional full-fat control. T_1 confirmed the challenge of

simple fat reduction — harder, less cohesive, and markedly less acceptable to the panel. T_2 took a middle position, showing that WPC alone recovers much of the textural deficit but stops short of full equivalence. The clear message is that the combined WPC–fiber strategy works as a restoration package, not as two separate adjustments.

Discussion

The central outcome — that WPC and fiber co-enrichment restores sensory and textural equivalence to a low-fat paneer — builds on a series of earlier dairy-engineering reports. Roy and collaborators showed that 3–4% WPC in low-fat chhana recovered about 75% of the textural deficit^[3], and Bhatt *et al.* reported similar gains in low-fat chakka^[11]. Our T₂ result is consistent with that range. The additional contribution of the fiber blend in T₃ is what closed the remaining gap. Inulin is known to bind water strongly and to form microcrystalline networks that mimic fat-globule texture, while oat fiber's β -glucan contributes viscosity to the continuous aqueous phase^[5, 12, 16].

The yield advantage in T₃ (20.1% vs 17.2% for control) is noteworthy because yield is a primary commercial driver in paneer manufacture. A consistent 2.9 percentage point yield increase translates to meaningful economic uplift, more than offsetting the cost of WPC and fiber inputs at current prices^[7, 14]. This yield gain arises from the additional water-holding capacity conferred by WPC and the bulking contribution of inulin. The shelf-life outcome (seven days at 4 °C) matches industry norms for unfortified paneer and suggests that the enrichment ingredients do not destabilise the product. An unexpected secondary benefit emerged: the fiber blend lowered post-cooking moisture release in pan-fried trials (data not shown), a quality attribute that pleased the culinary reviewers on the panel. The implication for commercial adoption is that the formulation delivers a triple advantage — nutritional, textural, and economic — in a single manufacturing change.

Conclusion

This research set out to develop a low-fat paneer that did not sacrifice the sensory and textural qualities that define traditional paneer. Four formulations were evaluated: a full-fat control, an unenriched low-fat base, a WPC-enriched low-fat variant, and a WPC-plus-fiber enriched variant. The WPC-plus-fiber formulation (T₃) achieved a 64% reduction in fat, a 70% increase in protein content, and a meaningful 4.1% dietary fiber content, while scoring within statistical equivalence of the full-fat control on flavour, texture, and overall acceptability.

The practical message is that the combined WPC-plus-fiber route offers dairy processors a straightforward path to a health-positioned paneer product with minimal changes to existing manufacturing infrastructure. Only two ingredient additions are required, both already available through domestic supply chains, and both introduced at stages that fit standard paneer workflows. The forward-looking dimension is that the formulation should be tested against the full range of paneer end-uses — cooking, frying, grating, and cold salad applications — to confirm that the sensory equivalence holds across use contexts. Scale-up trials to commercial batch sizes and an extended shelf-life assessment under modified-atmosphere packaging are natural next steps that would speed industry adoption.

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