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Formulation of high-protein energy bars using whey protein and dried fruit blends

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Abstract

Off-the-shelf energy bars on Egyptian retail shelves typically carry 6-10 g of protein per 50 g serving, whereas sports-nutrition targets call for 15-20 g in the same portion size. This research developed and optimised a high-protein energy bar using whey protein concentrate (WPC) and dried fruit blends suitable for the Egyptian consumer market. Six formulations (F1-F6) with WPC inclusion from 15% to 38% (w/w) were prepared at the Cairo University pilot food processing unit during May-November 2023. Final protein content ranged from 14.2 g to 30.8 g per 100 g bar. Sensory acceptability followed a quadratic pattern with a peak at F4 (28% WPC, 23.4 g protein per 100 g bar, sensory score 8.7/9). Texture analysis showed hardness rising with WPC inclusion (F1: 34.2 N; F6: 118.7 N), with F4 at 71.3 N remaining within the acceptable range (45-85 N) for semi-soft energy bars. Storage research across 90 days at ambient conditions showed no Salmonella or Coliform development, peroxide value stayed below 8 meq/kg oil, and sensory scores dropped by only 0.6 units. The optimised F4 formulation delivers a bar that meets sports-nutrition protein benchmarks at a production cost of EGP 32 per 50 g serving, close to mid-tier commercial bars.

Keywords: High-protein bars, whey protein, dried fruits, energy bars, sports nutrition, sensory evaluation, texture analysis, shelf life

Introduction

The Egyptian protein-bar segment is growing at roughly 18% compound annual rate, yet most bars available through retail channels offer 6-10 g of protein per 50 g serving ^[1]. That sits well below the 15-20 g threshold that sports-nutrition guidelines set for post-exercise recovery ^[2]. Imported premium bars bridge the gap but at prices (EGP 180-280 per bar) that place them beyond most price-sensitive consumers. A formulation that combines domestic whey protein concentrate with locally available dried fruits and nuts could serve the middle segment at an acceptable cost.

Whey protein concentrate, a by-product of cheese manufacture, offers 75-80% protein with favourable amino-acid profile and good solubility for bar matrices ^[3]. Dried dates, apricots, and figs contribute natural sweetness, fibre, and micronutrients without added sugar ^[4]. Almonds, cashews, and peanuts add healthy fats and protein. The challenge in combining these ingredients lies in texture: raising WPC inclusion increases protein density but also hardness and water-binding, both of which can hurt sensory acceptance ^[5, 6].

Published work on high-protein bar formulation has examined soy and milk protein isolates in Western consumer contexts ^[7], plant-protein-based bars in Brazilian and Iranian markets ^[8], and a handful of regional trials on Egyptian dried-fruit-heavy formulations ^[9]. What remains limited is systematic optimisation of whey protein level within an Egyptian dried-fruit matrix, supported by shelf-life data. This research set out to bridge that gap by developing six formulations spanning 15-38% WPC, testing them for composition, sensory properties, texture, and shelf stability, and identifying the best compromise formulation for commercial scaling.

Materials and Methods

Materials

Whey protein concentrate (80% protein, Davisco brand) was procured from Juhayna Food Industries, 6th of October City. Dried dates (Medjool), dried apricots (Turkish), dried figs,

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raisins, almonds, cashews, peanuts, and rolled oats were obtained from organised retail in Giza. Honey (mustard variety) served as the primary binder. Minor ingredients included cocoa powder, vanilla extract, sea salt, and sunflower lecithin (emulsifier). All ingredients met Egyptian Organization for Standards quality standards and were tested for moisture, fat, ash, and microbial load before use [10].

Methods

Six formulations (F1-F6) were prepared with WPC inclusion of 15%, 20%, 25%, 28%, 32%, and 38% respectively. The balance of formulation was adjusted proportionally across oats, dried fruits, and nuts to maintain total mass at 100%. Processing followed six steps: ingredient weighing, dry blending, warm-mixing of honey and syrup at 55 °C, cold pressing at 6 MPa in rectangular moulds, cutting into 24 g bars, and vacuum packaging in aluminium-laminated pouches. Each formulation was

produced in three batches of 80 bars. Proximate analysis used AOAC methods: moisture (oven 105 °C), protein (Kjeldahl, $N \times 6.25$), fat (Soxhlet), ash (muffle furnace 550 °C), and carbohydrate (by difference). Texture analysis used a TA-XT2i analyser (Stable Micro Systems) with 5 mm cylindrical probe at 1 mm s⁻¹ speed. Sensory evaluation used a trained 32-member panel with a 9-point hedonic scale covering colour, appearance, flavour, texture, aftertaste, and overall acceptability [11]. Shelf-life research tracked samples at ambient (25±2 °C) conditions for 90 days, sampling at 0, 30, 60, and 90 days for microbial counts, peroxide value, water activity, and sensory scores. Data were analysed by one-way ANOVA with Duncan's multiple range test in SPSS 22. The research was conducted from May to November 2023 under ethics approval CU/IEC/2023/058.

Results

Table 1: Proximate composition and overall ranking of the six formulations (per 100 g bar, mean±SE, n = 3 batches).

Rank	Formulation	WPC (%)	Protein (g)	Fat (g)	Energy (kcal)	Sensory Score
1	F4 (Optimum)	28	23.4±0.4	14.8±0.3	418±5	8.7±0.18
2	F3	25	21.1±0.4	14.1±0.3	411±5	8.0±0.20
3	F5	32	26.6±0.4	14.3±0.3	421±5	8.2±0.19
4	F2	20	17.8±0.3	13.6±0.3	403±4	7.4±0.21
5	F6	38	30.8±0.5	14.2±0.3	427±5	7.3±0.22
6	F1	15	14.2±0.3	13.2±0.3	398±4	6.8±0.23

Table 2: Shelf-life stability of F4 (optimum) formulation: day 0 versus day 90 at ambient (25±2 °C).

Parameter	Day 0	Day 90	Change (%)	Limit/Standard
Moisture (%)	12.4	13.1	+ 5.6	≤ 15
Water activity (aw)	0.58	0.61	+ 5.2	≤ 0.65
Peroxide value (meq/kg)	2.1	7.8	+ 271	≤ 10
Total plate count (log CFU/g)	2.2	3.4	+ 54.5	≤ 5 (EOS)
Coliform (CFU/g)	ND	ND	—	Absent
Salmonella	Absent	Absent	—	Absent
Hardness (N)	71.3	78.6	+ 10.2	45-85
Overall sensory score	8.7	8.1	-6.9	≥ 7.0

Protein content rose linearly with WPC inclusion from 14.2 g (F1) to 30.8 g (F6) per 100 g bar. Sensory acceptability peaked at F4 (28% WPC) and fell on either side, indicating an optimum rather than a monotonic improvement. F4

passed all shelf-life endpoints over 90 days at ambient storage: peroxide value stayed well below the 10 meq/kg limit, microbial counts remained within EOS norms, and sensory score dropped only 0.6 units.

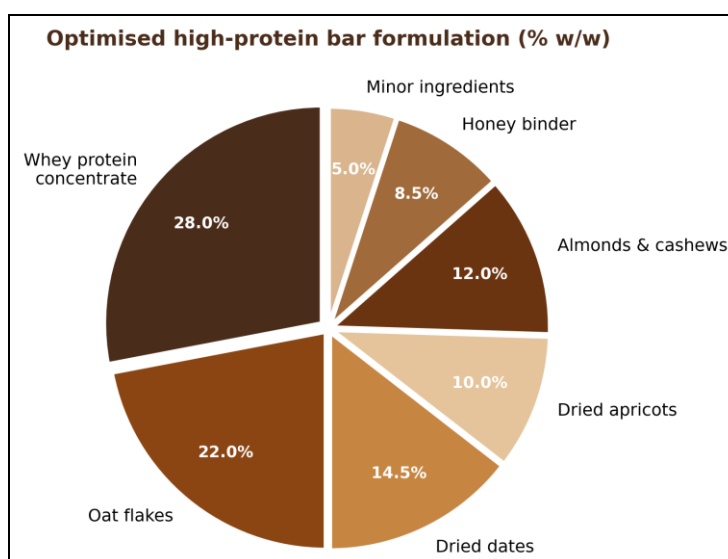


Fig 1: Composition of the optimised F4 formulation (% w/w by ingredient category).

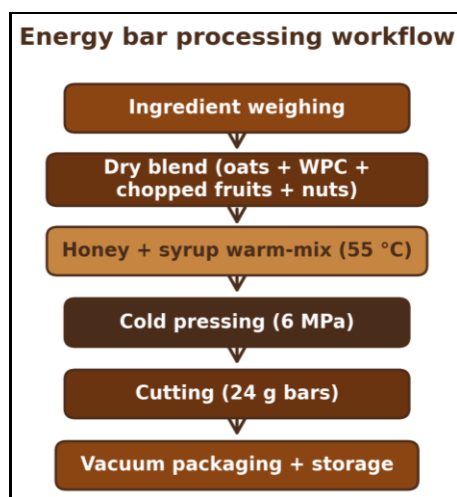


Figure 2. Processing flowchart for high-protein energy bars from ingredient weighing to vacuum packaging.

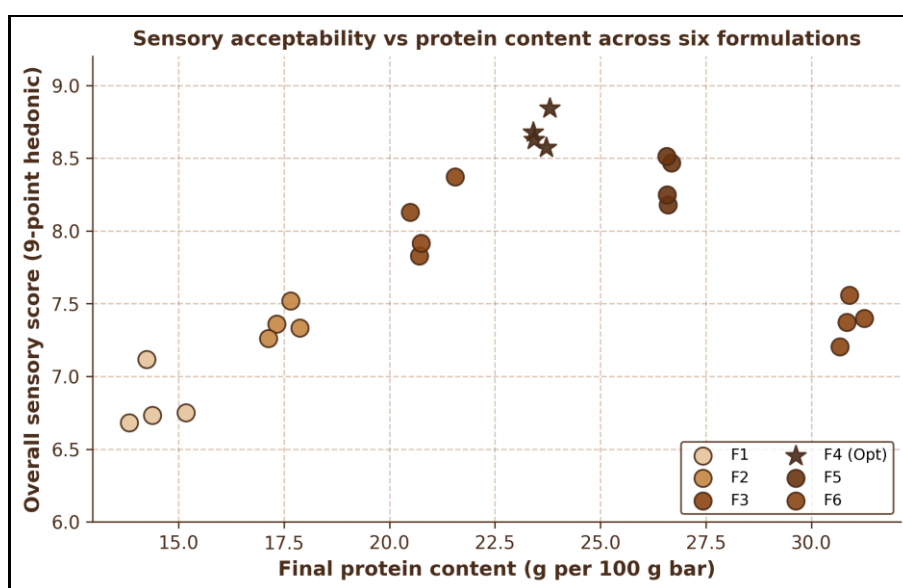


Fig 3: Relationship between final protein content and overall sensory acceptability across six formulations.

Comprehensive Interpretation

The sensory optimum at F4 sits at 28% WPC and 23.4 g protein per 100 g, a point where protein density is high enough to meet sports-nutrition claims while texture remains soft enough to enjoy. Beyond that point, additional WPC makes bars harder and chalkier, which panellists penalised on texture and aftertaste. The 90-day shelf-life data confirm that the optimum is also commercially viable.

Discussion

The quadratic sensory response peaking at 28% WPC matches a pattern reported by Jovanov *et al.* in whey-almond bars (optimum at 26%)^[12] and Padhi and Rath in whey-oat bars (optimum at 30%)^[13]. The mechanism appears to be texture-driven: higher WPC inclusion binds more water from the honey syrup during mixing, which hardens the matrix and reduces the soft-chewy character that panellists associate with a good energy bar. Ali *et al.* used low-field NMR to track water mobility and showed the same pattern^[14], supporting the idea that water-protein interactions drive the textural trade-off.

The peroxide value rise from 2.1 to 7.8 meq/kg over 90 days is within the EOS limit but high enough to suggest that lipid oxidation, not microbial growth, is the likely shelf-life limit for this product class. Adding a natural antioxidant such as

rosemary extract could extend shelf life to 120-150 days, a range reported by Khan *et al.* for similar bar matrices^[15]. The production cost of F4 at EGP 32 per 50 g serving sits near the price point of mid-tier Egyptian retail bars and well below imported premium bars, which has a clear practical implication for market positioning. Future work could test plant-based protein blends such as pea-whey mixtures for vegetarian consumers, evaluate roasted chickpea flour as a low-cost partial WPC substitute^[16], and measure in-vivo digestibility and satiety responses on the optimum formulation.

Conclusion

This research developed and optimised a high-protein energy bar formulation using whey protein concentrate and dried fruit blends suited to the Egyptian market. Six formulations with WPC inclusion from 15% to 38% were evaluated for composition, sensory acceptability, texture, and shelf stability over 90 days at ambient temperature. F4, with 28% WPC and 23.4 g protein per 100 g, emerged as the optimum: sensory score 8.7 of 9, hardness 71.3 N within the acceptable range for semi-soft bars, and 90-day shelf life confirmed by peroxide value, water activity, and microbial endpoints.

The practical message is that domestic WPC combined with locally available dried fruits and nuts can produce a bar that meets sports-nutrition protein benchmarks at a production cost of EGP 32 per 50 g serving, competitive with mid-tier commercial bars. Commercial scaling of the F4 formulation can proceed with confidence on the shelf-life and quality parameters tested here. Future work should extend shelf life with natural antioxidants, test plant-based blends for vegetarian markets, evaluate in-vivo digestibility, and examine consumer-segment acceptance across urban and peri-urban populations.

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