

CHAPTER 5

SUMMARY AND CONCLUSIONS

This phase of this study project entails summarising the results. This part is essential for scientific inquiry since it provides a platform for the researcher to properly distil the study's outcomes. The primary goal was to create sports nutrition bars that meet consumer demands for long-lasting quality, reasonable price, sensory attractiveness and nutritional value. In order to attain the best sensory qualities, the primary focus was on optimizing the formula and manufacturing the P-E Bars. Comprehensive assessment included investigations of physicochemical, microbiological and organoleptic aspects, using standardised processes. This chapter provides a thorough summary and conclusion of the results obtained from the study titled "Development, Optimisation and Characterization of Protein-Energy Bars Using Response Surface Methodology."

The results are categorised into four main phases according to the study's objectives.

Phase I: To conduct an online market survey on various food bars available.

Phase II: To standardize the formulation of P-E Bars, optimize ingredient composition using RSM and formulate the bars based on the obtained responses.

Phase III: To Conduct Organoleptical, Physico-Chemical, Texture, Microbial, Shelf-life and Cost Analysis of the P-E Bars.

Phase IV: To conduct acceptability trials involving athletes, coaches and fitness trainers.

Phase I: To conduct an online market survey on various food bars available.

5.1 Online Market Survey on Food Bars

In this phase of the research, online market survey was undertaken to comprehensively assess the landscape of food bars available to consumers. The methodology involved steps aimed at ensuring understanding of the various types of bars available on the

online platform. Initially, a broad market survey was conducted encompassing 32 brands offering 250 varieties of food bars, with a focus on their availability, popularity, protein content, serving size and price. Subsequently, these food bars were categorized according to their suggested usage, allowing for a structured analysis of their intended purposes and target demographics. Additionally, crucial information such as serving size, protein content per serving and cost for each of the surveyed bars was documented, providing valuable insights into their nutritional profiles and affordability. Lastly, the study examined the protein sources used in the food bars under survey, providing insight into the variety and origins of protein found in these products. This methodological approach sought to acquire complete data to guide studies on the creation and optimisation of protein-energy bars.

Salient Features of Phase I

5.1.1 Market Survey of Various Brands of Food Bars

- The survey covered 32 brands offering 250 varieties of bars.
- RiteBite leads the market with a substantial share of 20.8 per cent, indicating its dominance in the food bar industry.
- BB-BigBasket GoodDiet follows closely behind with a notable share of 12 per cent, reflecting its significant presence in the market.
- Yoga Bar secures a strong position with 10.4 per cent of the market share, underscoring its popularity among consumers.
- Phab and Health Horizons are notable contenders, each holding 4.8 per cent of the market share.
- Weetabix, Unibic, wild date and Afters (Happy Jar) each hold similar shares ranging from 3.2 per cent to 4 per cent, contributing to the diversity of the market.
- Brands like Nature Valley, Mojo Bar and Prayagh Nutri have a share of 2.4 per cent, adding to the competitive landscape.
- Lesser-known brands such as Sirimiri Nutrition Bar, Eat Bars, Plant power, Whey 91, Decathlon Domyos and Café Coffee Day N-urgy collectively hold shares ranging from 0.4 per cent to 0.8 per cent, indicating the presence of emerging players in the market.
- The brand having the maximum variants was Rite Bite by Max Protein, followed by Gooddiet by Big Basket and Yoga Bars

5.1.2 Food Bar Categorization according to Suggested Usage

- The bars were further categorized into eight distinct groups based on their suggested usage: protein bars, energy bars, meal replacement bars, bars with nuts and seeds, gluten-free bars, vegan bars, low-carb bars and snack bars.
- Among the examined food bars, protein bars and energy bars were the most common types, making up 23.1 per cent and 21.2 per cent of the total, respectively.
- Bars containing nuts and seeds accounted for a substantial portion, specifically 18.7 per cent, of the items examined. This indicates a desire for bars that offer both extra texture and nutritional benefits.
- Snack Bars closely followed, accounting for 12.1 per cent of all products surveyed, highlighting their significance as convenient snack choices.
- Conversely, the categories of vegan, low-carb, meal replacement and gluten-free bars accounted for less than 10 per cent of the products examined. More specifically, vegan bars represented 9.4 per cent of the items, low-carb bars represented 6 per cent, meal replacement bars represented 5.3 per cent and gluten-free bars represented 4.2 per cent. This data suggests that these specialized categories have a lesser market share.

5.1.3 Serving-size, Protein content per serving and Cost of the Surveyed Bars

- Out of the protein bars that were analyzed, 38.2 percent were classified as High Protein, meaning they contained more than 20 g of protein per serving. The bars had a mean serving size of 63.82 ± 12.7 g and offered an average of 24.75 ± 5.92 g of protein per serving. Nevertheless, they exhibited the highest average cost among the categories, amounting to Rs 118.71 ± 28 per bar.
- Approximately 33.4 per cent of the analyzed protein bars fell into the Moderate Protein category, offering protein content ranging between 10 to 19 g per serving. These bars had an average serving size of 44.80 ± 21.99 g and provided an average of 14.36 ± 6.08 g of protein per serving. The average cost of Moderate Protein bars was Rs 78.70 ± 36.19 , which was lower than that of High Protein bars.
- Among the protein bars that were examined, 28.4 per cent of them were classified as Low Protein because they contained less than 10 g of protein per serving. The bars had a smallest average serving size of 33.33 ± 7.63 g and had an average protein value of 5.68 ± 9.26 g per serving. Despite their lower protein content, Low Protein bars were priced at an average of Rs 70.83 ± 15.30 per bar.

5.1.4 Protein Sources of the Surveyed Food Bars

- WPC was the most commonly used source of protein, accounting for 39.3 per cent of the protein sources in the surveyed products.
- SPI followed closely behind, constituting 29.8 per cent of the protein sources, highlighting its significant presence in protein bar production.
- WPI accounted for 19.9 per cent of the protein sources, making it another prevalent choice among manufacturers.
- MPC and MPI collectively represented 24.1 per cent of the protein sources, showcasing the utilization of dairy-derived proteins in protein bars.
- PPI and Soy Nuggets contributed 8.4 per cent and 4.2 per cent respectively, indicating the incorporation of plant-based protein sources in protein bar formulations.
- Whey Protein Hydrolysate and Hydrolyzed Whey Protein Isolate comprised 4.7 per cent and 3.6 per cent respectively, suggesting a smaller but notable presence of hydrolysed forms of whey protein.
- Egg Albumin constituted a smaller share at 1.1 per cent of the protein sources, indicating a lesser utilization of egg-derived proteins in protein bar production.

Therefore, the findings from this phase of the study indicate that the extensive market analysis, which examined 250 items from 32 different brands across eight specific categories according to their usage, provides valuable insights into significant trends within the protein bar business. The categorization analysis demonstrated a distinct association between the protein content, serving size and pricing of the bars. It was observed that bars with greater protein levels typically had bigger portions and were priced more. Moreover, the prevalence of WPC as the primary protein source, trailed by SPI and WPI, underscores the industry's dependence on well-established protein sources recognized for their effectiveness and nutritional advantages. The results emphasize the ever-changing characteristics of the protein bar industry, influenced by the need of consumers for quick, healthy and tasty choices that match their dietary preferences and fitness objectives.

Phase II: To standardize the formulation of P-E Bars, optimize ingredient composition using RSM and formulate the bars based on the obtained responses.

5.2 Formulation of P-E Bars

The Protein-Energy Bars were carefully developed to enhance sensory characteristics. Extrusion was employed to impart texture and form to the raw component-Crispies. The nutritional analysis of the independent variables established the composition of the formulation in terms of protein, carbohydrate, fat and other essential components. The study employed Response Surface Methodology (RSM) to thoroughly examine various combinations of the independent variables in order to obtain the desired outcomes. The purpose of Protein-Energy Bars is to provide nutritional requirements while also catering to consumer preferences for sensory perception, cost-effectiveness and long shelf life.

Salient Features of Phase II

5.2.1 Proximate composition of selected raw materials used in the preparation of P-E Bars

- Crispies, an extrudate made from maize, ragi, gram flour and soy protein isolate, contained approximately 68.36 g of carbohydrates, 23.22 ± 0.04 g of protein and 2.05 ± 0.30 g of fat per 100 g.
- WPC-80 had a significantly lower carbohydrate content of 5.3 g per 100 g. However, the protein content was found to be 79.04 ± 1.18 g per cent.
- SPI contained 28.59 g of carbohydrates and 89.29 ± 0.01 g of protein per 100 g.
- In terms of fat content, WPC-80 had 0.58 ± 0.11 g per 100 g and SPI had 1.70 ± 1.47 g per 100 g.
- Crispies were the only product to contain crude fiber, with a content of 1.60 ± 0.21 g per 100 g.
- Regarding ash content, Crispies had 2.07 ± 0.08 g per 100 g, while WPC-80 had 3.90 ± 0.05 g per 100 g and SPI had 5.15 ± 3.05 g per 100 g.

5.2.2 Optimization of Levels of Crispies, WPC-80 and SPI for Development of P-E Bars using RSM

- Central Composite Rotatable Design (CCRD), a three-factor Response Surface Methodology (RSM), using an advanced statistical software program named Design Expert 8.0.3 was utilized to determine optimal ratios of Crispies, WPC-80 and SPI for the production of (P-E Bars).
- 20 experimental runs were provided by the software with the varying levels of Crispies (6.5–8.1 per cent), WPC-80 (14–15 per cent) and SPI (14–15 per cent).
- All 20 experimental P-E bars were assessed by 37 semi-trained judges using a CSC and a 9-Point Hedonic Scale (9-PHS).
- The CSC evaluated the bars based on appearance, taste, flavour, texture, mouthfeel, serving size, absence of defects and overall score. The 9-PHS assessed the bars for appearance, taste, flavour, texture and serving size.
- Influence of varying levels of Crispies, WPC-80 and SPI on Sensory Characteristics of Protein-Energy Bars on a CSC and a 9-PHS were obtained through regression analysis.
- In the regression model -A large R² value approaching 1.00 suggests a better fit of the quadratic model for both CSC and 9-PHS,
- The quadratic model was found to be the most precise in representing the optimization process for CSC and 9-PHS.
- For CSC, the quadratic model yielded high coefficient of determination (R²) values for Appearance (0.80), Taste (0.88), Flavor (0.84), Texture (0.89), Mouthfeel (0.84), Serving Size (0.85), Absence of Defects (0.92) and Overall Score (0.82).
- Similarly, 9-PHS displayed elevated coefficient of determination (R²) values for Appearance (0.82), Taste (0.84), Flavor (0.83), Texture (0.89) and Serving Size (0.88), indicating the robustness of the quadratic model in capturing the optimization process accurately.
- The adequate precision value which measures signal to noise ratio, the value of which should be greater than 4.0. And in the present study, the APV for all the sensory scores (CSC and 9-PHS) were greater than 4, highlighting the suitability of the model to navigate the design.

On a Composite Score Card

- Appearance: The linear effect of Crispies and SPI were statistically significant ($p < 0.05$), indicating a negative impact on appearance score. The quadratic effect of Crispies was not statistically significant, suggesting no notable non-linear impact on appearance. The quadratic effect of Whey Protein Concentrate (WPC-80) was statistically significant ($p < 0.05$), positively affecting appearance.
- Taste: Both Crispies and SPI had significant negative linear effects on taste score ($p < 0.05$). The interactive effect of Crispies and SPI was significant ($p < 0.05$), negatively impacting taste. The quadratic effect of Crispies was not statistically significant for taste, while the quadratic effect of WPC-80 was significant ($p < 0.05$), positively affecting taste.
- Flavor: SPI showed a significant negative linear effect on flavor score ($p < 0.05$). The quadratic effect of SPI was statistically significant ($p < 0.05$), positively influencing flavor.
- Texture: Crispies and SPI both had significant negative linear effects on texture score ($p < 0.05$). The interactive effect of Crispies and WPC-80 was significant ($p < 0.05$), negatively impacting texture. The quadratic effect of WPC-80 was statistically significant ($p < 0.05$), positively affecting texture.
- Mouthfeel: Crispies, SPI and the interactive effect of Crispies and WPC-80 had significant negative linear effects on mouthfeel score ($p < 0.05$). The quadratic effect of Crispies was not statistically significant for mouthfeel.
- Serving Size: Crispies had a significant negative linear effect on serving size score ($p < 0.05$). The quadratic effect of Crispies was statistically significant ($p < 0.05$), positively influencing serving size.
- Absence of Defects: SPI showed a significant negative linear effect on absence of defects score ($p < 0.05$). The quadratic effects of SPI and WPC-80 were both statistically significant ($p < 0.05$), positively influencing absence of defects.

On a 9-Point Hedonic Scale

- **Appearance:** Crispies and Soy Protein Isolate SPI showed significant negative linear effects, indicating that increasing levels of these factors negatively impacted appearance scores. The interaction between Crispies and SPI also had a significant negative effect, while the quadratic effect of WPC-80 had a significant positive impact.
 - **Taste:** All factors exhibited negative linear effects on taste scores, with Crispies and Soy Protein Isolate having the most pronounced impact. The quadratic effect of WPC-80 positively influenced taste scores.
 - **Flavor:** Similar to taste, Crispies and SPI negatively influenced flavor scores. The interaction between Crispies and SPI negatively affected flavor, while the quadratic effect of WPC-80 positively influenced flavor scores.
 - **Texture:** Crispies and SPI displayed significant negative linear effects on texture scores, while the quadratic effects of WPC-80 and SPI positively impacted texture.
 - **Serving Size:** Crispies, SPI and their interaction all negatively influenced serving size scores. However, the quadratic effects of WPC-80 and Soy Protein Isolate had positive impacts on serving size.
- Process optimization for P-E Bar manufacture aimed to identify the most favorable combination of Crispies, WPC-80 and SPI levels to achieve optimal sensory attributes.
 - Utilizing the Design Expert Package, RSM analysis suggested the most suitable solution, indicating Crispies at 7.3 per cent, WPC-80 at 14.5 per cent and SPI at 13.7 per cent, with a desirability of 1.
 - Predicted values of selected responses were compared with actual values, confirming the selected combination as the best one for achieving desired sensory attributes initially outlined in the study.
 - Statistical validation through t-test indicated a non-significant difference between predicted and actual values, further supporting the efficacy of the suggested solution in optimizing sensory responses for P-E Bar production.
 - The final product was subjected to chemical, physical, microbial and organoleptic characterization, shelf life and cost analysis.

Summary and Conclusions

- Thus, through this method, the optimal ratios of Crispies, WPC-80 and SPI were determined, aiming to achieve desired sensory attributes, nutritional composition and cost-effectiveness in the final product.

This phase concludes with the processing of raw ingredients for Protein-Energy Bars, involving formula optimization through Design Expert Software and Response Surface Methodology. The variable protein content, ranging from 23 per cent to 89 per cent in basic components, necessitated meticulous evaluation and optimization to meet nutritional requirements. Utilizing RSM, Design Expert Software recommended 20 trial runs to refine the P-E Bars recipe systematically, facilitating the identification of the optimal ingredient combination. Experimental responses served as vital tools for optimization, enabling enhancements in sensory qualities and nutritional content of the bars. The results indicated a high level of acceptance for the optimized composition, ensuring that the selected materials and processing parameters met quality standards and would be well-received by consumers. Statistical validation through the 't' test revealed no significant difference between anticipated and actual response values, affirming the reliability of the optimization process and the close alignment between expected and observed outcomes.

Phase III: To Conduct Organoleptical, Physico-Chemical, Texture, Microbial, Shelf-life and Cost Analysis of the P-E Bars.

5.3 Characterization and Pricing

Characterization and pricing are essential aspects of developing and promoting protein energy bars. Characterization entails the assessment of the nutritional content, chemical characteristics, sensory qualities, textural attributes, microbiological quality and shelf-life analysis. This guarantees that the product satisfies the intended nutritional profiles, physical qualities and customer preferences, while also complying with safety criteria. Pricing involves examining the expenses associated with manufacturing, such as the cost of raw materials, utilities, overhead, packaging and labelling. Manufacturers may achieve profitability in the competitive market by employing effective characterization and pricing strategies for P-E Bars that not only meet customer expectations but also achieve profitability in the competitive market.

Salient Features of Phase III

5.3.1 Proximate composition of the P-E Bars

- The findings illustrated the moisture content, total calorie value and percentages of protein, carbs, crude fat, crude fibre, ash and nitrogen for both 100 g and 70 g servings. The mean \pm SD values were reported for a serving size of 100 g, whereas the values for a serving size of 70 g were derived using a calculation method.
- The P-E Bar exhibited a low moisture content of 6.33 per cent for a 100 g serving and 4.43 per cent for a 70 g serving, indicating favorable shelf stability and texture preservation.
- With 505 Kcal for a 100 g serving and 354 Kcal for a 70 g serving, the P-E Bar provides significant energy, making it suitable for individuals engaged in intense physical activity.
- The protein content was notably high, with 35.81 per cent for a 100 g serving and 25.07 per cent for a 70 g serving, categorizing the product as a high-protein food, ideal for supporting muscle recovery and growth.
- The carbohydrate content was determined to be 47.64 per cent for a 100 g serving and 33.35 per cent for a 70 g serving, providing essential energy for physical performance and daily activities.
- The P-E Bar contained 17.78 per cent crude fat for a 100 g serving and 12.45 per cent for a 70 g serving, contributing to its energy density and satiety factor.
- The P-E Bar displayed a crude fiber content of 5.90 per cent for a 100 g serving and 4.13 per cent for a 70 g serving. Its ash content was recorded at 2.29 per cent for a 100 g serving and 1.60 per cent for a 70 g serving. Additionally, the nitrogen content, serving as an indicator of protein presence, was found to be 5.18 per cent for a 100 g serving and 3.63 per cent for a 70 g serving, reinforcing the protein-rich composition of the P-E Bar.

5.3.2 Chemical Characteristics of P-E Bars

- The protein-energy bars underwent analysis for Acid Value, Peroxide Value, Free Fatty Acid (FFA) and Water Activity to assess their quality indicators.
- The mean Acid Value was determined to be 0.63, serving as a crucial parameter for evaluating the freshness and stability of the bars.

Summary and Conclusions

- The Peroxide Value was found to be 0.60 mEq of O₂/kg fat, indicating the degree of oxidation in the bars and contributing to their overall quality assessment.
- The FFA of the P-E Bars was measured at 0.32 per cent oleic acid, reflecting a relatively low level that is desirable for maintaining product quality and freshness.
- The Water Activity level of the bars was recorded at 0.46 aw, indicating the amount of available water for microbial growth. A lower water activity level suggests a lower risk of microbial spoilage, contributing to product safety and extended shelf life.

5.3.2.1 Changes in the Chemical Characteristics during storage

- Protein Energy Bars (P-E bars) exhibit chemical characteristics that make them vulnerable to significant alterations during storage.
- A significant increase in peroxide value from 0.60 mEq of O₂/kg fat at day 0 to 2.17 mEq of O₂/kg fat at day 70 indicates oxidation during storage (ASLS). Despite this increase, the peroxide value remained below the acceptable limits (<10 mEq/kg) recommended by FSSAI (2019).
- The rise in free fatty acid content from 0.32 per cent Oleic Acid at day 0 to 1.61 per cent Oleic Acid at day 70 under accelerated condition (35 ± 2°C and 70 per cent RH) signifies fatty acid breakdown, potentially leading to rancidity and off-flavors, albeit within acceptable limits.
- An increase in acid value from 0.63 at day 0 to 3.19 at day 70 indicates an increase in free fatty acids during storage.
- The water activity of P-E Bars increased from 0.46 at day 0 to 0.60 at day 70 suggests that while it has risen, it remains below the threshold considered conducive to microbial growth and spoilage. This indicates that despite the composition changes over the storage period, the product has maintained its microbial stability and can be considered safe for consumption.

5.3.3 Texture analysis and influence on storage

- Texture analysis serves as a crucial method for assessing the quality of protein-energy bars, offering valuable insights into how storage conditions can influence their physical attributes.
- The protein energy bars exhibited a fracturability of 22.10 ± 2.30 mm and a hardness of 23.67 ± 1.15 N, indicating their delicate texture.

5.3.3.1 Changes in the Textural Characteristics during storage

- Texture plays a crucial role in the sensory experience of food, representing the physical interaction between the food and the consumer's body.
- Hardness, measured in Newtons (N), increased significantly ($p < 0.05$) over the 70-day storage period, rising from 23.23 N on day 0 to 116.87 N on day 70. This indicates a progressive hardening of the bars, rendering them more resistant to deformation.
- The fracturability of the bars, as measured in millimetres (mm), exhibited a notable decrease ($p < 0.05$) throughout the storage duration, diminishing from 22.10 mm on day 0 to 0.30 mm on day 70. This decline indicates a reduced susceptibility of the bars to fracturing or breaking over the specified time frame.

5.3.4 Organoleptic analysis and influence on storage

- Organoleptic analysis involves sensory assessment, covering attributes such as appearance, taste, flavor, texture, mouthfeel, serving size and overall acceptability, crucial for understanding consumer perceptions and product evolution, particularly during storage.
- An 18-member panel, comprising teachers and doctoral students from the Department of Foods and Nutrition, served as semi-trained judges for the sensory evaluation.
- The Protein Energy Bar received a favorable rating for visual attractiveness, scoring an average of 8.4 ± 0.7 and 7.80 ± 0.5 on the CSC and 9-PHS, respectively, indicating its appealing appearance.
- The taste of the bar was well-received, earning an average score of 12.5 ± 1.0 and 7.87 ± 0.3 on the CSC and 9-PHS, respectively, while the flavor was positively assessed with a mean score of 8.3 ± 0.5 and 7.85 ± 0.4 on the CSC and 9-PHS, respectively, indicating good taste and flavor profiles.
- The bar was highly rated for its texture, scoring an average of 16.4 ± 0.8 and 7.38 ± 0.5 on the CSC and 9-PHS, respectively, suggesting a pleasing mouthfeel, with an average score of 8.5 ± 0.5 .
- The bar received a satisfactory rating for portion size, scoring an average of 13.9 ± 0.6 and 8.35 ± 0.5 on the CSC and 9-PHS, respectively and was found to be defect-free, with a mean score of 8.6 ± 0.5 .
- The Protein-Energy Bar garnered a mean score of 85.1 ± 0.7 and 7.85 ± 0.3 on the CSC and 9-PHS, respectively, indicating overall positive reception by the panel.

5.3.4.1 Changes in the Organoleptic Characteristics during storage

- The visual appeal scores of Protein-Energy Bars decreased significantly from 8.11 ± 0.32 to 7.22 ± 0.73 on the CSC and from 7.83 ± 0.51 to 5.67 ± 0.77 on the 9-PHS over 70 days of storage at cabinet temperature ($35 \pm 2^\circ\text{C}$) and 70 per cent RH.
- The taste and flavor scores decreased notably from 12.5 ± 0.99 to 7.44 ± 0.78 and from 8.28 ± 0.46 to 5.22 ± 0.43 , respectively, on the CSC. On the 9-PHS, taste scores declined from 7.89 ± 0.32 to 5.44 ± 0.78 and flavor ratings decreased from 7.83 ± 0.38 to 5.33 ± 0.77 , indicating significant changes in sensory perception.
- The mean texture scores decreased significantly from 16.44 ± 0.86 to 11.61 ± 0.92 on the CSC and from 7.39 ± 0.50 to 5.00 ± 0.69 on the 9-PHS over the storage period, suggesting alterations in the texture profile.
- The perception of mouthfeel declined significantly from 8.44 ± 0.51 to 5.94 ± 0.24 on the CSC, with a slight decrease below 60 percent on the 70th day. On the 9-PHS, values decreased from 8.33 ± 0.49 to 7.28 ± 0.90 , indicating a slight decline in acceptability.
- The overall sensory scores, measured on the CSC, ranged from 8.11 ± 0.32 to 7.22 ± 0.73 over the storage period, indicating a slight decrease in overall acceptability.

5.3.5 Microbial Quality and influence on storage

- The fresh sample of Protein Energy Bars exhibited a Total Bacterial Count (TBC) of $1.5 \pm 0.083 \log_{10} \text{ cfu/g}$, falling under the category of low moisture foods with a water activity of $0.46 \pm 0.02 \text{ aw}$ and a moisture content of 6.33 ± 0.07 percent.
- The Total Bacterial Count of the stored Protein Energy Bars increased from 1.34 ± 0.02 on day zero to 2.50 ± 0.02 after 70 days of storage at $35 \pm 2^\circ\text{C}$ and 70 % RH.
- Throughout the storage period, *E. coli* was not detected in the Protein Energy Bars, suggesting hygienic manufacturing processes and minimal contamination.
- No yeast and mold were detected in the Protein Energy Bars during the entire storage period, indicating the absence of airborne contamination and high-quality raw materials.
- The absence of *E. coli*, yeast and mold counts in the study bars suggests that the bars were manufactured under sanitary conditions using high-quality ingredients, contributing to their overall safety and quality.

5.3.6 Cost Calculation for Production of Standardized Protein Energy Bars

- Cost analysis provide insights into the economic feasibility of manufacturing P-E Bars, considering both raw material expenses and production overheads.
- The production of 10 kg of P-E Bars required raw materials costing 4136 rupees.
- Utilities such as electricity, heat energy and packaging and Labeling were computed to be 103.89 rupees, 64.17 rupees and 429 rupees respectively for the production of P-E Bars.
- The overhead cost for producing 10 kg of P-E Bars amounted to 468.56 rupees.
- Combining raw material cost, utility costs and overhead costs, the total cost of producing 10 kg of P-E Bars was calculated to be 5201.62 rupees per batch.
- When converted to cost per piece of P-E Bar (70g), the production cost was determined to be 36.41 rupees.
- Effective labelling ensures transparency and helps consumers make informed choices about the product's suitability for their dietary needs and preferences.

The Protein-Energy Bar displayed favourable nutritional attributes, with a caloric content of 505 kcal per 100 g and well-balanced proportions of carbohydrates (47.64 per cent), protein (35.81 per cent) and fat (17.78 per cent). Additionally, it contained significant amounts of fibre (5.90 per cent) and nitrogen (5.18 per cent). The product demonstrated excellent stability, with low levels of free fatty acids (0.32 per cent oleic acid) and peroxide value (0.60 mEq of O₂/kg fat), as well as a minimal acid value of 0.63 and a water activity of 0.46 aw, categorizing it as a low-moisture food resistant to microbial decomposition. The Total Bacteria Count (TBC) of 1.5 log₁₀ CFU/g further supported its microbiological safety. Additionally, the sensory evaluation revealed high acceptance among panel members, with a mean liking score above 7 on a 9-Point Hedonic Scale, indicating positive sensory qualities. Moreover, the cost analysis indicated that the final bar was economically feasible, priced at 36.41 Indian Rupees per 70 g, thus affirming its market viability. Overall, these findings underscore the product's nutritional value, safety, sensory appeal and economic feasibility, positioning it as a promising option in the protein-energy bar market.

Phase IV: To Conduct Acceptability Trials Involving Athletes, Coaches and Fitness Trainers

5.4 Acceptability Trials Involving Athletes, Coaches and Fitness Trainers

This phase addressed the key topic of acceptability trials to examine physically active people's reception and preferences for the study bar. The study used a semi-structured questionnaire to assess demographics, snack preferences, predisposition to healthy bars, satisfaction with the study bars, food bar perception and cost sensitivity. P-E Bars were rated on a 9-point hedonic scale.

The study targeted athletes from the Department of Physical Education, University Pavilion, The Maharaja Sayajirao University of Baroda and gym trainers in Vadodara.

Salient Features of Phase IV

5.4.1 Assessment of General Information and Fitness Habits of the Test Subjects

- A total of 120 individuals participated in the study, primarily falling within the age range of 18-25 years (84.17 per cent), with the remaining participants being 26 years or older.
- The gender distribution was approximately 60 per cent male and 40 per cent female, indicating a slightly higher representation of males.
- All participants, including athletes and gym trainers, showed a 100 per cent positive response rate regarding their regular engagement in exercise or gym attendance.

5.4.2 The Individuals' Preferences for Snacks and their Previous Experience

Snack Preferences by Age Group:

- In the 18-25 age group, fruit was the top choice, preferred by 40 per cent of participants, followed by chocolate (25.83 per cent), bakery items (10.83 per cent) and chips (6.67 per cent).
- Among individuals aged 26-35, fruit remained the preferred snack (49.17 per cent), followed by bakery items (22.5 per cent), chocolate (6.67 per cent) and chips (5 per cent).
- Fruit was consistently the preferred snack for both age groups, but there were notable differences in preferences for chocolate, chips and bakery items between the two groups.

Preference for Healthy Bars:

- A vast majority (93.33 per cent) preferred healthy bars over traditional sweets or chocolate, indicating a strong inclination towards healthier snack choices.
- All respondents expressed acceptance of healthy bars, with only 6.67 per cent showing uncertainty, suggesting some degree of hesitation towards this option.

Familiarity with Sports Bars:

- The data showed a high level of familiarity with sports bars, with 92.5 per cent of respondents reporting having consumed them before.
- Only 7.5 per cent of participants indicated no prior consumption of sports bars, suggesting widespread exposure to these products.

Reasons for Consuming Sports Bars:

- Around 30 per cent of respondents cited using sports bars as pre- or post-workout fuel, emphasizing their perceived benefits in enhancing exercise performance and aiding in recovery.
- Convenience was a significant factor, with 23.33 per cent of participants mentioning portability and ease of consumption on the go.
- Meal replacement was identified as a motivating factor by 21.67 per cent of respondents, indicating the perceived utility of sports bars as a convenient meal substitute or supplement.
- Snacking emerged as the primary reason for consuming sports bars for 17.5 per cent of respondents, highlighting their versatility as a snack option for various dietary preferences and needs.

5.4.3 Inquiry on the Satisfaction and Identification of Factors that Influence the Choice

Levels of Satisfaction with Current Sports Bars:

- Taste and texture were significant factors influencing satisfaction, with 37.84 per cent rating taste as dissatisfactory and 22.52 per cent rating it as very dissatisfactory.
- Criteria for nutritional content received the highest satisfaction rating, with 52.25 per cent rating it as very satisfied.
- Purchase price was a point of contention, with 44.14 per cent dissatisfied with current pricing.
- Quantity received high satisfaction, with 87.39 per cent rating it as very satisfied.

Factors Influencing Choice of Sports Bars:

- Taste was the most crucial factor, with 95.83 per cent rating it as very important.
- Nutritional value was highly prioritized, with 97.5 per cent considering it very important.
- Price played a significant role, with 85 per cent rating it as very important.
- Quantity was valued, with 72.5 per cent rating it as very important.

Budget Range Preferences:

- The majority preferred the 80-100 Rupees range (42.5 per cent).
- 22.5 per cent favoured the 100-150 Rupees range.
- Relatively fewer participants opted for lower (50-80 Rupees, 17.5 per cent) or higher (>200 Rupees, 6.67 per cent) budget ranges.

Willingness to Pay for Extra Nutritional Advantages:

- Over 65 per cent of participants were ready to pay a higher price for sports bars with extra nutritional benefits.
- Around 28.33 per cent showed reluctance to pay more.
- A smaller proportion (6.67 per cent) expressed doubt or hesitation about spending more for extra nutritional advantages.

5.4.4 Post-Consumption Assessment and Feedback of the Subjects

Participants provided feedback on their experience with the study bar, assessing satisfaction levels, willingness to repurchase, likelihood of recommending it and offering suggestions for improvement.

Level of Satisfaction with Consumed Sports Bar:

- A high level of satisfaction with the product was indicated by 72.5 percent of participants who rated their satisfaction as "very satisfied."
- An additional 27.5 per cent reported being satisfied, further emphasizing the positive sentiment towards the sports bar.
- No participants expressed dissatisfaction, highlighting the overall positive reception of the product.

Intentions to Purchase in the Future:

- An overwhelming 98.33 per cent expressed a desire to purchase the sports bar again in the future, indicating a strong intent among participants to continue consuming the product.
- No respondents indicated a lack of interest in future purchases.
- A small percentage (1.67 per cent) responded with "Maybe," suggesting some level of reservation or apprehension.

Willingness to Recommend to Others:

- All participants (100 per cent) unanimously expressed their intention to recommend the sports bar to a friend, showing complete endorsement and confidence in the product.
- This reflects a high level of satisfaction among consumers and the potential for positive word-of-mouth promotion.

Comments and Feedback:

- Positive comments highlighted the satisfying sweetness, great taste and enjoyable texture of the sports bar.
- Participants appreciated the soft and pleasant mouthfeel, as well as its filling and satisfying nature.
- There were no suggestions for improvement, indicating a high level of satisfaction with the product's flavor, texture and overall experience.

5.4.5 Organoleptic Evaluation using a 9- Point Hedonic Scale

- The sports bar's flavour, texture, scent and overall attractiveness were all rated by participants on a 9-point hedonic scale, which ranged from strongly dislike to extremely like.
- Participants rated the appearance of the sports bar with a mean score of 8.02 ± 0.81 on the 9Point Hedonic Scale, indicating that it was visually appealing.
- Taste received a high mean score of 8.15 ± 0.74 , suggesting that participants found the flavor of the sports bar satisfactory.
- Flavor also received a positive response, with a mean score of 8.10 ± 0.82 , indicating favorable perceptions of its taste profile.
- The serving size of the sports bar was well-received, as reflected by its high mean score of 8.22 ± 0.63 on the 9Point Hedonic Scale.
- Texture received a slightly lower mean score of 7.90 ± 0.90 , suggesting that while generally satisfactory, there may be room for improvement in this aspect.

Summary and Conclusions

- Overall, the sensory scores indicate generally positive responses from the participants, reflecting a favorable reception of the sports bar's sensory attributes, with minor considerations for potential refinement in texture.

The phase of the study highlights the widespread familiarity and usage of sports bars among participants, with 93 percent having prior experience utilizing them for various purposes such as pre-post workout fuel, convenience food, meal replacements, or regular snacks. While maximum satisfaction was observed with serving size and nutritional claims, taste, texture and cost received less favorable feedback, indicating areas for potential improvement. Key criteria for bar selection were identified as nutritional value, taste, cost, serving size and texture, reflecting the importance of these factors in consumer decision-making. The daily budget for bars ranged from 80-100 Rupees, with a significant portion of the panel expressing willingness to purchase bars regularly if available at a lower cost between 50-80 Rupees. The study bars received strong preference scores on a 9-PHS for appearance, taste, flavor, texture and serving size, indicating widespread positive reception among consumers. The consumer panel praised the bars for their pleasurable eating experience, delightful mouthfeel and enjoyable taste and texture, highlighting their potential to meet consumer preferences and expectations in the market.

The study demonstrates that protein-energy bars with higher protein levels tend to offer larger portions and command higher prices, with WPC emerging as the predominant protein source, followed by SPI and WPI. Through systematic experimentation and optimization, the bars were refined to achieve optimal sensory qualities and nutritional content, resulting in high consumer acceptance. Statistical validation confirmed the reliability of the optimization process, reinforcing the alignment between anticipated and observed outcomes. Overall, these findings highlight the bars' nutritional value, safety, sensory appeal and economic viability, positioning them as a promising option in the protein-energy bar market. The bars received consistently high preference scores across various sensory attributes, affirming their positive reception among consumers and their potential for success in the marketplace.