
Title:

Development, Optimization and Characterization of Protein- Energy Bars Using Response Surface Methodology

INTRODUCTION

Sports have long held a central place in human culture, transcending geographical and cultural boundaries to unite individuals through the universal language of competition and athleticism. From the ancient Olympic Games in Greece to the modern-day global sporting spectacles, sports have evolved into a dynamic and multifaceted arena that encompasses not only physical prowess but also mental fortitude, teamwork, and a reflection of societal values (Sports Nutrition Care Manual, 2020)

Sports nutrition plays a crucial role in optimizing athletic performance and promoting overall well-being among athletes and active individuals. It is the strategic art of fuelling the body with precise nutrients that enhance energy levels, endurance, strength, and recovery. The relationship between nutrition and sports performance is profound, as the right balance of nutrients can determine the difference between reaching peak athletic achievements and falling short of one's goals. In this realm, dietary choices are not only about sustenance but also about scientific precision, where understanding the body's nutritional demands can unlock the full potential of physical prowess. This introduction explores the fundamental principles of sports nutrition, shedding light on the dynamic interplay between food, metabolism, and athletic excellence (Potgieter, S., 2013).

The importance of adequate nutrition cannot be understated in supporting various aspects of athletic performance. This includes addressing energy demands, reducing fatigue, promoting efficient recovery, and overall health optimization. Factors such as the nature of the sport, variations in training frequency, intensity, and duration, age, general well-being, lifestyle choices, religious beliefs, economic status, and social standing can all influence an athlete's ability to meet their energy, macronutrient, micronutrient, and hydration requirements. Among

the crucial components of an athletics diet, protein plays a pivotal role in supporting muscle repair, growth and overall performance. During exercise, muscle tissues undergo stress and damage, protein helps repair and rebuild these tissues, leading to muscle growth and recovery. However, recognizing the significance of protein is only the first step, we also need to address the challenge of delivering this essential nutrient in a convenient and palatable form.

The term "Sports Foods" commonly denotes specially crafted food items that are commercially produced to cater to athletes' needs. These products belong to diverse categories, each designed to serve a distinct purpose in aligning with nutritional objectives crucial for enhancing training adaptation, facilitating recovery, and optimizing performance during competitions (Peeling P, et al, 2019)

Protein bars have emerged as a popular and convenient nutritional solution in today's fast-paced world, catering to the needs of individuals seeking a quick and portable source of sustenance. These bars, often densely packed with protein, are designed to provide an efficient way to supplement one's diet with this essential macronutrient. Whether used as a post-workout recovery snack, an on-the-go meal replacement, or a simple way to curb hunger between meals, protein bars offer a diverse range of options to suit various dietary preferences and fitness goals.

Protein is available in a variety of dietary sources. These include foods of animal and plant origins as well as the highly marketed sport supplement industry. The components comprising whey protein are abundant in essential amino acids and branched-chain amino acids, offering substantial nutritional value. These proteins exhibit a range of advantageous properties that contribute to overall well-being. Moreover, whey is a notable source of various vitamins and minerals. While its prominent role lies in sports nutrition, whey protein also finds application in diverse areas such as baked goods, salad dressings, emulsifiers, infant formulas, and medical nutritional products. Isolates stand out as the most refined iteration of soy protein products, boasting the highest protein content. Unlike flour and concentrates, isolates lack dietary fiber. This variant of soy protein emerged in the 1950s within the United States. Renowned for their exceptional digestibility, isolates seamlessly integrate into various food products, including sports drinks, health beverages, and even infant formulas (Hoffman, et al, 2004).

Cereals play an important role in today's lifestyles for their various uses as ready-to-eat products, instant products, cereal bars and energy bars. The consumption of cereals has been elaborated from the breakfast table to any time of the day and these products have become an integral part of consumer's diet (Berti et al., 2005).

Beyond nutritional content, taste and aroma are fundamental factors that influence consumers' choice of food products. These edibles are expected to offer a gratifying sensory experience, stemming from the intricate interplay of various sensory quality attributes (Sampaio et al., 2010). Consequently, the creation of novel food items holds significant significance for the sustenance of most businesses and intricately aligns with evolving consumer preferences and trends. As consumers become increasingly discerning, their brand selection process becomes more meticulous, underscoring the need for companies to adapt and innovate.

The development of protein bars necessitates a delicate balance between achieving desirable taste, texture, and nutritional characteristics. The conventional trial-and-error approach to formulate these bars can be time-consuming, resource-intensive, and often leads to suboptimal outcomes. In this context, the implementation of advanced statistical methods, such as Response Surface Methodology (RSM), has emerged as a valuable tool to streamline the product development process and optimize protein bar formulations (Nadeem et al. 2012)

In this context, response surface methodology (RSM) emerges as a powerful tool for the development and optimization of protein-energy bars. RSM is a statistical approach that aids in designing experiments, analyzing the effects of multiple variables, and optimizing the desired response. It provides a structured framework to explore the complex interplay between various formulation factors, processing conditions, and their impact on the final product's sensory, nutritional, and physical attributes. By systematically varying these factors and observing their effects, RSM allows researchers and food technologists to identify optimal formulation conditions that lead to improved product characteristics (Riswanto et al. 2019).

RATIONALE

The recommended nutritional regimen can have a better compliance when studies on development of sports specific convenience and cost-effective foods with good visual appeal, taste, textures, shelf life and high acceptability are carried out. Athletes are more likely to adhere to their nutritional plans if they enjoy the taste and texture of the food products. The formulation of protein bars must involve intricate interplay among various ingredients to achieve both nutritional excellence and sensory appeal. Conventional methods may not fully capture the complexities of these interactions. Hence, there arises a need for innovative approaches that can systematically optimize protein bar formulations. Response Surface Methodology (RSM) offers a structured framework to explore the synergistic effects of ingredients, concentrations, and processing parameters on the final product. By employing RSM, this study aims to streamline the protein bar development process, effectively balancing nutritional content, and consumer acceptability. Thus, the study intends to optimize protein in Protein- Energy Bar that fulfil not only nutritional criteria, but also customer expectations in terms of sensory appeal, cost effectiveness and shelf life.

OBJECTIVES

Broad Objective:

To develop a Protein-Energy Bar using Response Surface Methodology in order to replenish and bridge the gap in the macronutrients consumption as per the dietary requirement of individuals involved in fitness activity.

Specific Objectives:

1. To conduct an online market survey on food bars for various purpose (viz., athletes, fitness trainers, yoga bars, schoolchildren, astronauts, and for general purpose)
2. To set the levels of cereal and pulses ingredients ratio in the *crispies*
3. To standardize the bar formula
4. To optimize the levels of crispies, whey and pulse protein for the protein bars using Response Surface Methodology
5. To develop a nourishing Protein-Energy Bar with a good sensory score and commercial value
6. To conduct sensory analysis of the developed food product by semi trained panel
7. To study the chemical analysis of proximate principles of the developed food product
8. To study the textural attributes of the developed food product
9. To evaluate the shelf life of the standardized product
10. To conduct a cost analysis of the final product
11. To conduct an acceptability study on athletes and trainers

REVIEW OF LITERATURE

This chapter will focus on the available literature under following heads:

- Sports nutrition
- Importance of Nutrition for athletes
- Role of protein in athletic performances
- Market survey of sports nutrition supplements
- Assessment of dietary intake
- Categories of sports supplements
- Sports bars and its composition
- Protein Sources
- Physical properties and Role of sports bar
- Extruded foods
- Extruded sports foods
- RSM- response surface methodology
- RSM-CCRD (Central composite rota table design)
- Characteristics of Protein Bars
- Textural Properties
- Shelf-Life of Protein Bars
- Packaging and Labeling requirements of Sports Bars

METHODOLOGY

This chapter focusses on the various tools and techniques used for arriving at the results of the stated objectives. The detailed methods for the various phases of the study are presented as under the following heads:

Phase I: Online market survey on food bars.

Phase II: Standardization of the Protein energy bar, optimization of ingredients using Response Surface Methodology and development of Protein energy bar based on the responses.

Phase III: Sensory, Physico-Chemical, Textural and Microbial Analysis, Shelf-life Study, and Cost Analysis of the final product.

Phase IV: Acceptability trials by the Athletes, Coaches and Fitness Trainers.

INCLUSION AND EXCLUSION CRITERIA

For Sensory Evaluation:

Inclusion criteria

- Semi trained Panels (Staff and Students, normal health condition) of the Department of Foods and Nutrition, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda
- Subjects who are willing to participate

Exclusion criteria

- Subjects who do not belong to the Department of Foods and Nutrition, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda

For Acceptability Trials:

Inclusion criteria

- Athletes belonging to Department of Physical Education, The Maharaja Sayajirao University of Baroda

- Subjects who are willing to participate

Exclusion criteria

- Subjects who are not willing to participate

PHASE I:

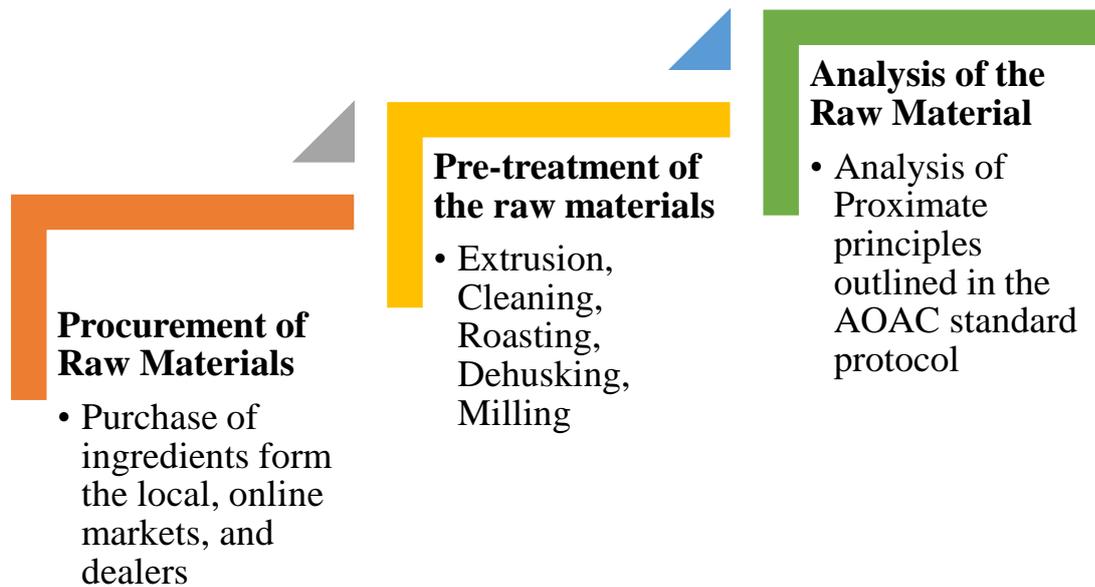
Web Survey on the Presence of Diverse Food Bars in the Market for:

- Brands
- Protein content
- Serving size
- Average cost

PHASE II:

EXPERIMENTAL DESIGN FOR PHASE-I

1. Procurement of Raw Materials
2. Pre-treatment of the raw materials
3. Analysis of the Raw Material



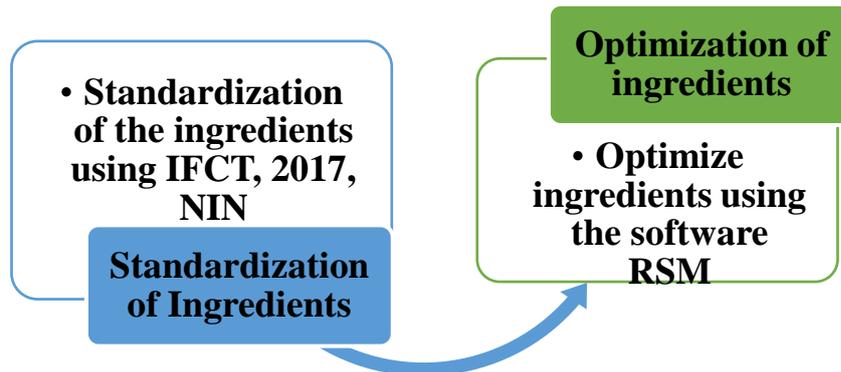
2.I.2. Tools And Techniques for Phase I:

PARAMETERS AND TOOLS

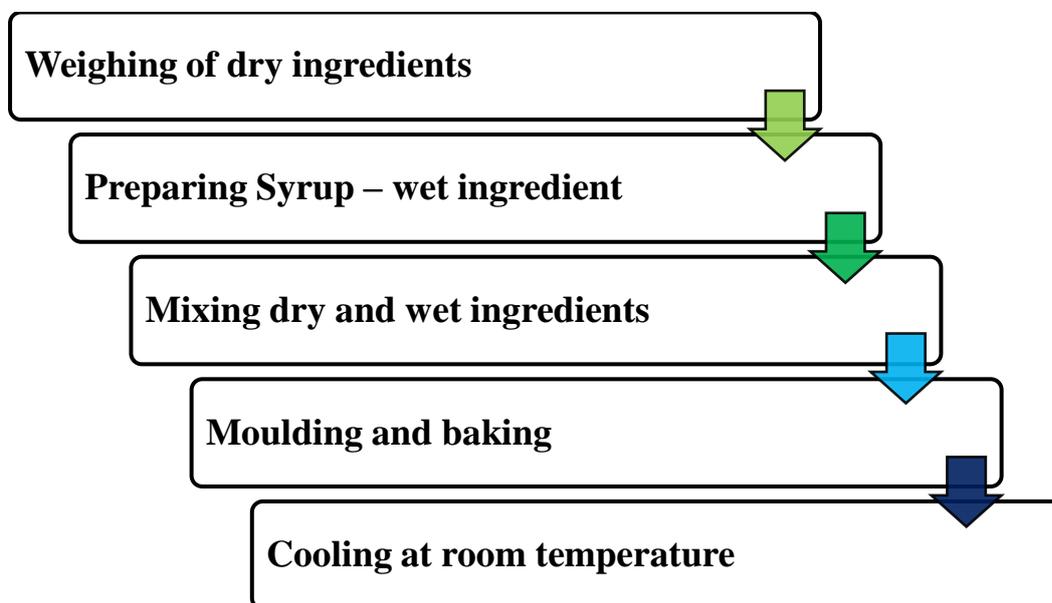
TOOLS	
Extrusion (Preparation of Crispies)	Co-rotating Twin Screw Extruder (Basic Technology Private Limited)
Proximate Analysis:	<ul style="list-style-type: none"> • Protein, Crude Fat, Crude Fiber, Moisture, and Ash: AOAC, 21st Edn, 2019 • Carbohydrate: By difference method • Energy: Food Labeling – Requirements for FDA Regulated products
Optimization of Ingredients	RSM [Design Expert software version 8.0.3 (Stat-Ease, Inc., USA)]
ORGANOLEPTIC ANALYSIS	
Semi Trained Panel	Composite Score Card (CSC) 9 –Point Hedonic Scale

EXPERIMENTAL DESIGN FOR PHASE-II

1. Standardization of Ingredients
2. Optimization of ingredients
3. Development of Bars



Development of the bars:



PHASE III

Sensory Evaluation (Semi Trained Panel)	Composite Score Card 9 – Point Hedonic Scale
Proximate Analysis:	Protein, Crude Fat, Crude Fiber, Moisture, and Ash: AOAC, 21st Edn, 2019 Carbohydrate: By difference method Energy: Food Labeling – Requirements for FDA Regulated products
Physico Chemical Properties:	Peroxide value, Free Fatty Acid (as oleic acid), Acid value: AOAC, 21st Edn, 2019 Water activity: Pardo, E., et., al., (2004)
Texture Analysis:	Texture Analyser - Stable Micro Systems, Surrey, UK
Microbial Analysis:	Yeast and Mould: IS 5403:1999 reaffirmed 2018 Total Coliforms: IS 5401 (Part 1) Total Bacteria Found: IS 5402 (Part 1)
Shelf-life Study:	The samples were analysed for sensory attributes, physico-chemical characteristics, textural properties and microbial quality at 15day intervals for 150 days
Cost Analysis & Labelling	

PHASE IV:

Acceptability Trial

1. Semi-structured Questionnaire
2. 9 – Point Hedonic Scale

RESULTS AND DISCUSSION

The results and discussion chapter of this study delves into the multifaceted realm of "Development, Optimization, and Characterization of Protein-Energy Bars Using Response Surface Methodology." This chapter presents a comprehensive analysis of the outcomes obtained through the systematic application of response surface methodology, shedding light on the intricate interplay between various ingredients and their impact on the final attributes of protein-energy bars. Through meticulous experimentation and data interpretation, the chapter unravels the nuances of formulation development, process optimization, and the characterization of these bars. By critically examining the achieved results, this section contributes to an enriched understanding of the factors influencing the sensory, nutritional, and physical properties of protein-energy bars, subsequently paving the way for informed decisions in product enhancement and innovation.

In this chapter, the result and discussion have been presented under the following heads below:

Phase I: Exploring the Online Food Bar Market: A Comprehensive Survey

The present phase was carried out with the objective to conduct an online market survey on various food bars available.

The following were the findings of the Phase:

- The market survey examined 250 products sourced from 33 diverse brands, and they were sorted into eight distinct groups according to their product claims:
 - 28% fell into the Energy bar category.
 - 25% were protein bars.
 - 19% belonged to the nuts and seeds category.
 - 14% were categorized as Snack bars.
 - 11% represented low carb bars.
 - 6.3% were meal replacement bars.
 - 13.6% constituted Vegan bars.
- Additionally, all these 250 products are available in a variety of flavor options.
- Based on the classification, 38.2% of the bars were categorized as high protein, containing more than 20 grams of protein per serving. Additionally, 33.4% were considered a moderate source of protein, with protein content ranging from 10 to 19 grams per serving, while 28.4% were classified as low protein, containing less than 10 grams of protein per serving.

- Among the 10 different sources of protein, the most frequently used in protein bar production was WPC, followed by SPI and WPI in descending order as a source.

Phase II: Standardization of the Protein energy bar, optimization of ingredients using Response Surface Methodology and development of Protein energy bar based on the responses.

- Raw materials (Crispies, WPC-80 and SPI, independent variables) were analyzed for its proximate composition.
- The primary protein source was found to be SPI, constituting 89.29 ± 0.01 grams per 100 grams of the product. Following closely was WPC-80, contributing 79.04 ± 1.18 grams per 100 grams. The crispies made with a ratio of cereal to pulses of 4:1 provided 23.22 ± 0.04 grams of protein per 100 grams of the product.
- Among the three sources, only crispies contained crude fiber.
- The moisture content in crispies was 8.54 ± 0.08 , while both SPI and WPC-80 had similar moisture levels.
- Crispies had the highest fat content at 2.05 ± 0.30 (g %), followed by SPI at 1.70 ± 1.47 (g %) and WPC-80 at 0.58 ± 0.11 (g %).
- To optimise the percentage of crispies, WPC-80, and SPI, the Central Composite Rotatable Design (CCRD) (four factor Response Surface Methodology, RSM) was utilised.
- Design Expert 8.0.3, a sophisticated statistics programme, was used.
- The system employed preliminary trial responses for an acceptable grade of protein bars, and the software proposed a standardised formulation based on the outcomes of the trials (n=20).
- On a Composite Score Card, and a 9-Point Hedonic Scale the sensory reactions of the items together with their formulation based on their run sequence was performed by a panel of 37 judges for various attributes.
- The results obtained as mean served as a secondary input on the software.
- Goals or responses (lowest score and highest score) were set for obtaining the best possible combination.
- Goals or responses (lowest score and highest score) that were set for obtaining the best possible combination as per the 9 Point Hedonic Scale.

- On Composite Score Card:
 - All 20 types of bars prepared using varying proportions of Crispies, WPC-80 and SPI were evaluated for sensory characteristics.
 - The F-value is determined by comparing the variability explained by the model to the unexplained variability.
 - The calculated F-values for various sensory characteristics like appearance, taste, flavor, texture, etc.
 - The F-values were 4.45, 8.20, 5.78, 9.05, 5.95, 6.54, 13.48, and 5.21, respectively.
 - All calculated F-values were higher than the critical F-values at a 5% level of confidence.
 - This indicates the significance of the model terms and suggests significant differences between the means of the groups for the evaluated sensory characteristics.
- On a 9-Point Hedonic Scale:
 - Table 2.8 (9-Point Hedonic Scale) showed F-values of 4.96, 5.93, 5.25, 9.02, and 7.98 for appearance, taste, flavor, texture, and serving size, respectively.
 - All calculated F-values were higher than the corresponding critical F-values at a 5% level of confidence.
 - This indicates the significance of the model terms and suggests significant differences between the means of the groups for the evaluated sensory characteristics.
- All 20 types of bars prepared using varying proportion of Crispies, WPC-80 and SPI were evaluated for sensory characteristics.
- In the regression model -A large R² value approaching to 1.00 suggests a better fit of the quadratic model.
- Analysis of the scores suggested quadratic model as a well fitted model for the sensory parameters.
- The adequate precision value which measures signal to noise ratio, the values of which should be greater than 4.0.
- In the present study, the APV for all the sensory scores were greater than 4, highlighting the suitability of the model to navigate the design.

- To Predict the Sensory Score, the Equations were Created using Multiple Regression, Considering the Impacts of Different Elements in Terms of Coded Components on a Composite Score Card and a 9-Point Hedonic Scale.
- Three-dimensional response surface plots were created to Predict the Sensory Score, using Multiple Regression, Considering the Impacts of Different Elements in Terms of Coded Components.
- Suggested solution from RSM analysis for Protein-Energy Bar was 7.3 % Crispies, 14.5 % WPC-80 and 13.7 % SPI, the remaining ingredients remained constant throughout the entire study.
- The results were also validated statistically by the t-test which gave non-significant effect between predicted and actual values.

Phase II: Characterization of Protein-Energy Bars

The Protein-Energy Bars were analysed for their proximate composition, sensory, physico-chemical, textural, and microbial characteristics. Storage Study was conducted on the above-mentioned parameters. Cost analysis was carried out for the Protein-Energy Bars to assess the economic feasibility.

- The Protein-Energy Bar had an energy content of 505 kcal per 100 grams, with 47.64 percent carbohydrates, 35.81 percent protein, 17.78 percent crude fat, 5.90 percent crude fiber, and 5.18 percent nitrogen.
- Free Fatty acid, peroxide value, and acid value accounted to 0.32 percent Oleic Acid, 0.60 (mEq of O₂/kg fat), and 0.63, 0.46 a_w respectively.
- With the mean total score 85 % on a composite score the Protein-Energy Bars exhibited good acceptability.
- With the mean overall acceptability of 7.85 the bars showed good acceptability on a 9-point hedonic scale.
- Total Bacteria Count (TBC) was found to be 1.5 log₁₀ CFU/g.
- With the water activity of 0.46 a_w the formulated bar was categorized as low moisture food, which are usually not prone to microbial spoilage in a proper condition for long, thus the yeast and mould and total coliforms were not found in the sample of product.
- Sensory evaluation showed high acceptability, with a mean liking score above 7 on a 9-Point Hedonic Scale, indicating favourable sensory attributes among panel members.

- Experimental analysis of storage characteristics of protein-energy bars stored at a cabinet temperature of 15 ± 2 for 150 days, and analysed at every 15-day interval:
 - It was observed that at 150 days the hardness achieved was approx. 117 N which is lesser than the hardness range for moderate harder bars.
 - Fracturability decreased up to 0.3 mm at 150th day of storage.
 - On storage the values found to be increasing significantly
 - The peroxide value was 2.17 mEq of O₂/ KG fat on the 150th day of storage which was within the limits as per FSSAI standards (standard limits below 20 mEq/kg (FSSAI 2019).)
 - The P-E Bar had water activity from 0.46 to 0.60 (0 day to 150 day of storage)
 - Foods with water activity below 0.7 are considered as low moisture foods and not usually subjected to microbial spoilage.
- Cost of the final bar was 36.41 ₹ per 70 g.

Phase IV: Acceptability Trial

The study included 120 individuals who were actively engaged in physical activities. These participants were recruited from the Physical Education Department of M S University and several gyms located within the city.

- The subjects comprised of 120 physically active individuals more than 84 % were belonging to age group 18-25 years, remaining were older.
- 60:40 was the male to female ratio.
- 49 % of the respondents preferred fruits over other snacks items as typically purchased snack.
- The second preferred snack was chocolate followed by bakery items (biscuits).
- Given a choice of a healthy food bar beside any other snack item, 93 % opted healthy bars as their preferred choice.
- 93% of the panel had prior experience with sports bars, using them as pre-post workout fuel, convenience food, meal replacements, or regular snacks.
- For the commercial bars Maximum satisfaction was observed with serving size and the nutritional claim, but taste, texture, and cost received less favourable feedback.
- Key criteria for bar selection were nutritional value, taste, cost, serving size, and texture.
- The daily budget for bars ranged from 80-100, and 18% of the panel would prefer bars regularly if available at a cost between 50-80.

- 65 % were willing to pay premium if the bars have enhanced nutritional component.
- The study bars were administered to the subjects and the responses were taken on a A semi structured.
 - The study bars 73 % subjects showed high satisfaction.
 - 98 % showed interest in the purchase of the study bars if sold in the market, while others were not sure.
 - Every single participant showed a strong inclination towards recommending these products to their friends.
- The study bars on a 9-point hedonic scale on appearance, taste, flavor, texture, and serving size scored between 7.9 to 8.2, indicating strong preference ("like very much").
- The consumer panel praised the bars, expressing satisfaction with the pleasure of eating, delightful mouthfeel, and enjoyable taste and texture.

CONSLUSION AND RECOMMENDATIONS

Conclusion: The online market survey focusing on protein bars has yielded invaluable insights into the diverse array of bars offered by different brands. These insights encompass essential aspects such as protein content and average cost per serving size. The culmination of these findings has been instrumental in crafting protein-energy bars tailored to the preferences and dietary requisites of athletes and other physically active individuals, particularly in terms of protein intake. Through meticulous optimization, a standard formula has been fine-tuned to attain exceptional sensory ratings. This optimization process has culminated in the creation of protein-energy bars that not only deliver a delightful taste and texture but also foster heightened consumer acceptance and adoption.

Furthermore, the nutritional analysis has confirmed these bars' alignment with the dietary needs of athletes and fitness enthusiasts, promoting enhanced performance and muscle recuperation. The protein-enriched bars boast a well-balanced nutritional profile, achieved by skillfully combining Soy Protein Isolate (SPI), Whey Protein Concentrate (WPC), and the extruded product. Notably, the energy distribution in the bars exhibits equilibrium, with a Carbohydrate:Protein:Fat ratio of 48:36:18, perfectly suited for power and endurance sports snack requirements.

The product quality has been rigorously assessed through physico-chemical, microbial, and textural parameter evaluations, affirming its excellence. Interestingly, the final product cost stands at 36.41 ₹, which is notably lower—almost threefold—than the high protein bars accessible on online platforms, thereby establishing the product's affordability and budget-friendly nature.

Recommendation: The optimization and manufacturing technology for Protein-Energy Bars holds immense potential for transfer to industries, taking into account the essential parameters required for the food industry. This technology not only promises to create a high-quality product but also addresses the distinct needs of athletes and fitness enthusiasts, thus positioning the Protein-Energy Bar as a sought-after nutritional supplement. Additionally, exploring the incorporation of antioxidants and micronutrients into the bars and conducting a comprehensive study of their profiles could further enhance the bars' nutritional value and benefits.

Furthermore, the development of nutrition bars catering to a wider range of formulations, tailored for the diverse needs of physically active individuals across varying age groups and gender-specific workout regimens, is a promising avenue. The proposition to conduct intervention trials involving athletes to evaluate the impact of supplementation on their performance can provide valuable insights into the practical efficacy of the bars.

Diversification remains key, with potential plans for creating different bar variants, such as introducing fresh flavours. Packaging strategies could involve offering the bars in various sizes, carefully designed to align with the convenience of on-the-go training schedules and lifestyles. Moreover, elevating the quality control measures for bar analysis, including the integration of sophisticated tests like ultrasonic viscosity to assess rheological properties more precisely, can contribute to ensuring consistent excellence in the bars' production and composition.

REFERENCES:

1. Academy of Nutrition and Dietetics. Sports Nutrition Care Manual. 2020
2. Berti, C., Riso, P., Brusamolino, A., and Porrini, M. 2005. Effect on appetite control of minor cereal and pseudocereal products. *British Journal of Nutrition*. 94 (5): 850- 858
3. Hoffman, J. R., & Falvo, M. J. (2004). Protein—which is best?. *Journal of sports science & medicine*, 3(3), 118.
4. Nadeem, M., Muhammad Anjum, F., Murtaza, M. A., & Mueen-ud-Din, G. (2012). Development, characterization, and optimization of protein level in date bars using response surface methodology. *The Scientific World Journal*, 2012.
5. Peeling P, Castell LM, Derave W, de Hon O, Burke LM. Sports Foods and Dietary Supplements for Optimal Function and Performance Enhancement in Track-and-Field Athletes. *Int J Sport Nutr Exerc Metab*. 2019 Mar 1;29(2):198-209. doi: 10.1123/ijsnem.2018-0271. Epub 2019 Feb 17. PMID: 30299192.
6. Potgieter, S. (2013). Sport nutrition: A review of the latest guidelines for exercise and sport nutrition from the American College of Sport Nutrition, the International Olympic Committee and the International Society for Sports Nutrition. *South African journal of clinical nutrition*, 26(1), 6-16.
7. Riswanto, F. D. O., Rohman, A., Pramono, S., & Martono, S. (2019). Application of response surface methodology as mathematical and statistical tools in natural product research. *Journal of Applied Pharmaceutical Science*, 9(10), 125-133.
8. Sampaio, C. R. P., Ferreira, S. M. R., & Canniatti-Brazaca, S. G. (2010). Caracterização físico-química e composição de barras de cereais fortificadas com ferro. *Alimentos e Nutrição*, 21(4), 607-616