

## CHAPTER 4

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### RESULTS AND DISCUSSION

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The final stage of the research process involves presenting and interpreting the findings. This section is often regarded as the cornerstone of scientific inquiry, where the researcher articulates the results of the study. Its main objective was to effectively communicate and deliberate on ideas in a manner that is comprehensible and applicable to the reader. The goal of this study was to create nutritious food bars that meets consumer demands for shelf life, cost effectiveness and sensory appeal in addition to nutritional requirements. In order to produce food items with the best possible sensory qualities, this study aimed at optimising the processing of the Bar. The physicochemical, microbiological and organoleptic characterization were carried out according to standard procedures. This chapter presents and discusses the findings from the current study, "Development, Optimisation and Characterization of Protein-Energy Bars Using Response Surface Methodology."

The findings are arranged into four primary sections based on the study's objectives.

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

The following subsections include the outcomes that fall under this phase:

#### **4.1 Online Market Survey on Food Bars**

##### 4.1.1 Market Survey of Various Brands of Food Bars

##### 4.1.2 Food Bar Categorization according to Suggested Usage

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

##### 4.1.4 Protein sources of the surveyed food bars

**Phase II:** To standardize the formulation of Protein-Energy Bars, optimize ingredient composition using Response Surface Methodology and formulate the bars based on the obtained responses.

The results included in this phase are displayed in the below mentioned subsequent subsections:

## **4.2 Formulation of Protein-Energy Bars**

4.2.1 Analysis of Raw ingredients

4.2.2 Optimization of Levels of Crispies, WPC-80 and SPI for Development of Protein-Energy Bars using RSM

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

The subsequent subsections include the outcomes that are covered under this phase:

## **4.3 Characterization and Pricing**

4.3.1 Proximate composition

4.3.2 Physico-Chemical Characteristics and influence on storage

4.3.3 Texture analysis and influence on storage

4.3.4 Organoleptic analysis and influence on storage

4.3.5 Microbial Quality and influence on storage

4.3.6 Cost Analysis

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

The findings of this phase are presented under the following sub sections:

## **4.4 Acceptability trials involving athletes, coaches and fitness trainers.**

The findings of this section are segregated into four segments as under:

4.4.1 Assessment of general information and fitness habits of the test subjects

4.4.2 The individuals' preferences for snacks and their previous experience

4.4.3 Inquiry on the satisfaction and identification of factors that influence the choice

4.4.4 Post-consumption assessment and feedback of the subjects

4.4.5 Organoleptic evaluation using a 9- point hedonic scale

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

#### **4.1 Online Market Survey on Food Bars**

The foundation of this research lays in understanding the current landscape of the food bar market through an online survey. This phase aimed to identify brands, trends, suggested usage, protein content, serving size and average cost, providing valuable insights for the subsequent development and optimization stages.

##### **4.1.1 Market Survey of Various Brands of Food Bars**

The food bar industry is seeing tremendous growth due to the increasing customer desire for quick and healthy snacks. Protein bars are especially favoured by individuals who prioritise their health. A comprehensive online survey was done from November 2021 to May 2022 to get insights into the market landscape. The study specifically examined the availability, variety and essential characteristics of snack bars on online platforms. The survey included a diverse selection of both domestic and international products that were only available to Indian consumers through online platforms. Figure 4.1.1 shows the percent distribution of variants available with various brands of food bars. In the analysis of protein food bars, 250 products underwent scrutiny regarding their brand affiliation, protein content, serving size and purchase cost. These products represented a diverse range of 32 brands. The dominance of certain brands in terms of product variants has important implications for consumer choice and market dynamics. A brand offering a wide range of variants may enjoy a competitive edge by appealing to a broader audience base with varying tastes, dietary needs and lifestyle preferences. This underscores the strategic importance for brands to continuously innovate and expand their product lines to stay relevant in a highly competitive market. As can be seen from the figure 4.1.1 RiteBite emerged as the leading brand, capturing 20.8% of the market. Following closely behind was BB BigBasket GoodDiet with a share of 12%, while Yoga Bar secured 10.4% of the market, illustrating its strong presence. Other notable brands included Phab and Health Horizons, each accounting for 4.8% of the market share. Weetabix, Unibic, Wild Date and Afters (Happy Jar) held similar shares of 4%, 3.2%, 3.2% and 3.2% respectively.

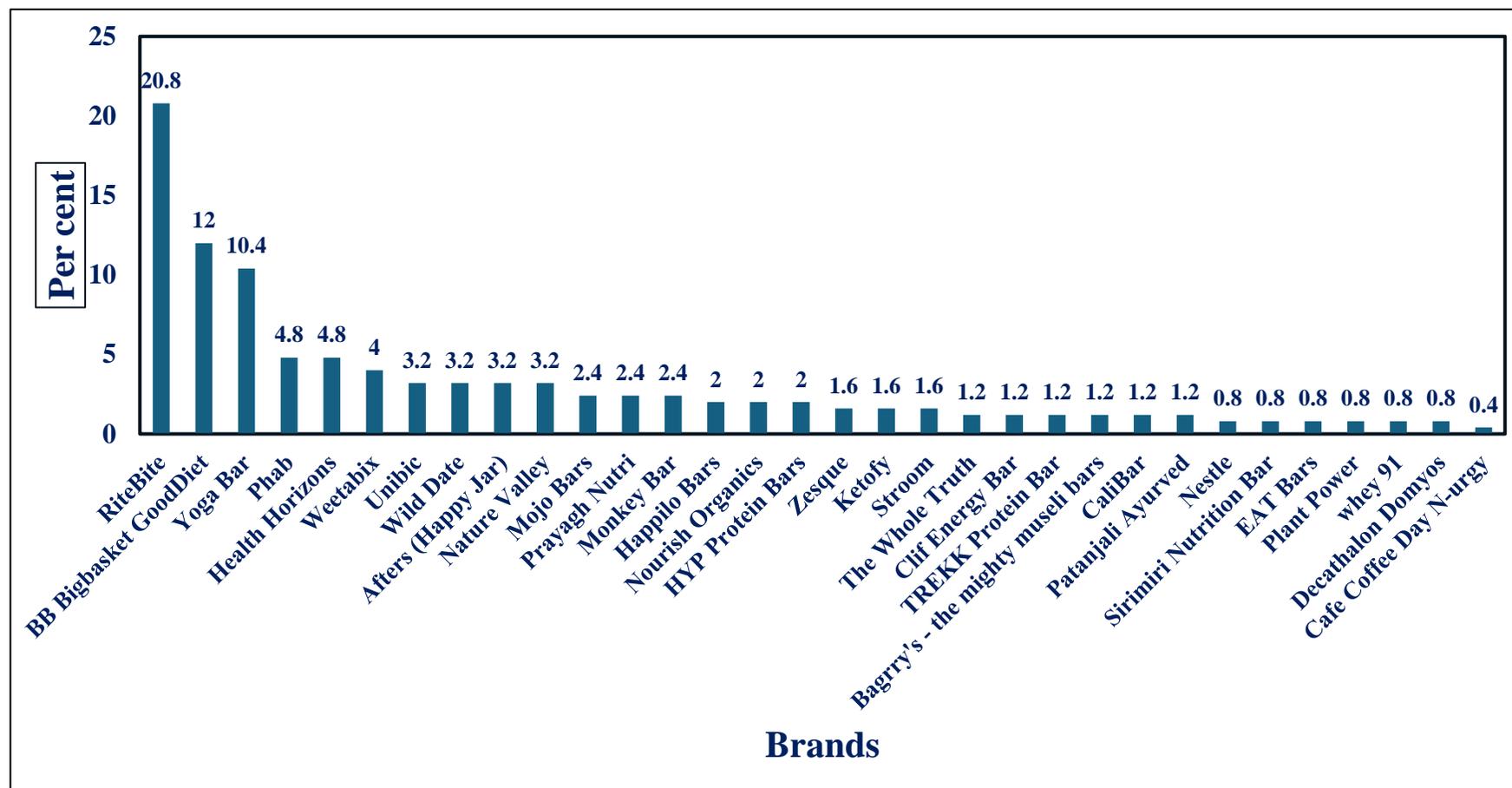
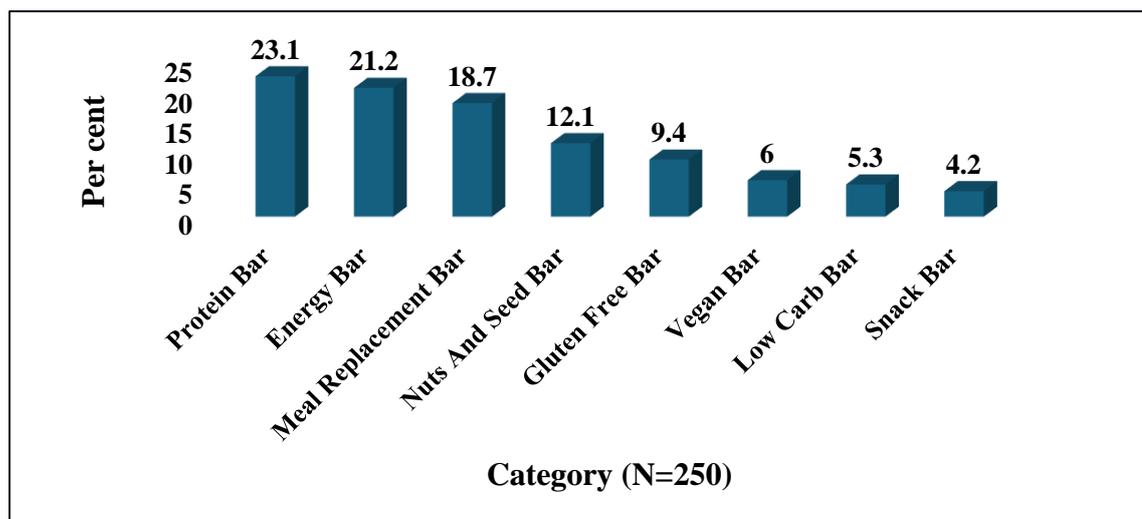


Figure: 4.1.1 Brand Landscape of Food Bars (%) (N=250)

The market was further populated by brands such as Nature Valley, Mojo Bar and Prayagh Nutri, each with a share of 2.4%. Among the lesser-known brands, Sirimiri Nutrition Bar, Eat Bars, Plant power, Whey 91, Decathlon Domyos and Café Coffee Day N-urgy held shares ranging from 0.8% to 0.4%. This diverse array of brands showcases the competitive nature of the food bar market, with established names vying for consumer attention alongside emerging players seeking to carve out their niche.

#### **4.1.2 Food Bar Categorization according to Suggested Usage**

Food bars often have suggested usage listed on them according to their intended function. For instance, some bars may be advertised as post-workout recovery bars to help with muscle repair and refill glucose levels, while others would be suggested as pre-workout snacks to give quick energy. In addition, there is a broad range in the nutritional makeup of these bars; they may be anything from meal replacement bars that offer a balanced blend of macronutrients (proteins, carbs and fats) and micronutrients (vitamins and minerals) to high-protein bars that are advertised for muscle growth. varied food bars have varied target markets. Athletes and fitness enthusiasts can be the target market for certain bars, while those searching for healthier snack options or quick meal options for busy lifestyles or weight management might be the target market for others. Categorizing food bars based on their suggested usage can provide a valuable information to further create a product that meets the needs and preferences of consumers as presented in the figure 4.1.2.



**Figure: 4.1.2 Classification of Food Bars Based on their Suggested Usage (%)**

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Based on their recommended uses, the examined bars were further divided into eight categories: protein bars, energy bars, meal replacement bars, bars with nuts and seeds, gluten-free bars, vegan bars, low-carb bars and snack bars. The percentage distribution of these food bar variations among the designated categories is shown in figure 4.2.1. Protein bars and energy bars accounted for 23.1 and 21.2 percent of the surveyed items, respectively and were the most common varieties. Meal Replacement Bars accounted to 18.7 per cent of the surveyed products. Bars with added nuts and seeds came next, closely (12.1 per cent). On the other hand, less than 10 per cent of the bars in the study were gluten free, vegan, low carb and snack bar covering 9.4, 6, 5.3 and 4.2 percent share of the respective category, suggesting that these categories have a lesser market share.

This analysis underscores the dominance of energy and protein bars in the food bar market, suggesting a strong consumer preference for products catering to energy replenishment and muscle-building needs. The relatively lower representation of snack bars, vegan bars and low-carb options highlights potential areas for market expansion and diversification to accommodate varying dietary preferences and lifestyle choices. Additionally, the presence of meal replacement and gluten-free bars underscores the growing demand for convenience and dietary inclusivity among consumers.

### **4.1.3 Serving-size, Protein content per serving and Cost of the Surveyed Bars**

Protein bars are expanding popularity as a snack option for people trying to increase their protein intake. Since there are so many alternatives on the market, it's important to understand important aspects like protein content, serving size and pricing in order to make an informed choice. This part of the study aimed to analyze these parameters across a range of surveyed protein bars to provide valuable insights for the formulation of the Protein-Energy Bars. Each surveyed protein bar was assessed for its protein content, serving size and cost. The data was then analysed to determine average values and trends.

Table 4.1.1 presents data on various protein bars, including their protein levels, average serving sizes, average protein per serving and average cost. They were then divided into groups based on the amount of protein in each serving of the bars in the survey that was conducted for the study.

**Table 4.1.1 Protein levels, Average Serving-size, Protein content per serving and Cost of the Surveyed Bars**

<b>Protein Levels (g/serving)</b>	<b>No of Products (%) (N=250)</b>	<b>Available Serving Size (g)  (Mean ± SD)</b>	<b>Average Protein per Serving (g)  (Mean ± SD)</b>	<b>Average Cost of the Bars (Rs)  (Mean ± SD)</b>
<b>High Protein (&gt;20g)</b>	38.2	63.82 ± 12.7	24.75 ± 5.92	118.71 ± 28
<b>Moderate Protein (10-19 g)</b>	33.4	44.80 ± 21.99	14.36 ± 6.08	78.70 ± 36.19
<b>Low Protein (&lt;10 g)</b>	28.4	33.33 ± 7.63	5.68 ± 9.26	70.83 ± 15.30

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According to the Food Safety and Standards (Advertising and Claims) Regulations, 2018, food items that are high in protein must fulfil a certain amount of protein per serving in order to be marketed as "high protein" (FSSAI, (Advertising and Claims) Regulations, 2018). The Polaris Market Report (2023) also detailed the protein content found in the high-protein bars. However, the exact requirement for protein per serving to qualify as "high protein" may vary depending on the specific regulations outlined in the document. Bars with less than 10 g of protein per serving were classified as low protein, bars with 10 to 19 g per serving were classified as moderate protein and bars with 20 g or more of protein per serving were classified as high protein. As shown in the table 4.1.1, 38.2 per cent of the examined protein bars fell into the high protein category, defined as having more than 20 g of protein per serving. These bars exhibited an average serving size of  $63.82 \pm 12.7$  g, with an average protein content of  $24.75 \pm 5.92$  g per serving (with the highest value of 35 g protein per serving, the lowest being 20 g protein per serving). However, it is noteworthy that these bars also exhibited the highest average cost among the three categories, with an average price of Rs  $118.71 \pm 28$  per bar. This suggests that while High Protein bars offer a substantial protein content per serving, they may come at a higher cost to consumers. Approximately 33.4 per cent of the analyzed protein bars fell into the moderate protein category, with protein content ranging between 10 to 19 g per serving. These bars had an average serving size of  $44.80 \pm 21.99$  g and provided an average of  $14.36 \pm 6.08$  g of protein per serving. The average cost of moderate protein bars was Rs  $78.70 \pm 36.19$ , which was lower than that of High Protein bars. This suggests that moderate protein bars offer a balance between protein content and cost, making them a potentially attractive option for consumers seeking moderate protein intake at a relatively affordable price point. Among the examined protein bars, 28.4 per cent fell into the low protein category, offering less than 10 g of protein per serving. These bars had the smallest average serving size of  $33.33 \pm 7.63$  g and provided an average protein content of  $5.68 \pm 9.26$  g per serving. Despite their lower protein content, Low Protein bars were priced at an average of Rs  $70.83 \pm 15.30$  per bar. The results showed a clear relationship with protein levels: cost dropped as serving sizes increased in proportion to protein content. This indicates that while Low Protein bars may be more affordable, they may not be the optimal choice for individuals seeking a significant protein boost in their diet.

Different types of protein bars cater to various nutritional needs and timing preferences for athletes. They may be used to supplement total protein consumption, which is important for maintaining muscular health. In their study, Jäger et al (2017) found that taking high-protein bars, with 20-40g of protein per serving, are recommended for post-exercise consumption to maximise MPS and muscle hypertrophy, making them ideal post-game snacks for athletes. Protein ingestion after resistance exercise is an efficient approach to abruptly induce a favourable muscle protein balance, which should lead to muscle development or hypertrophy over time. Low-protein bars may be good snacks or meal replacements for athletes during low activity or as part of a balanced diet.

The cost per gram of product can vary significantly depending on the protein source used in its formulation. A study by Maughan *et al.* (2018) also supports this notion, highlighting the variability in the costs of protein products and protein-containing foods. This variability can stem from factors such as the source of the protein (e.g., animal-based, or plant-based), production methods, processing techniques, market demand and geographical location, among others. As a result, consumers may observe diverse price ranges when purchasing protein products, reflecting the wide array of options available in the market.

### **4.1.4 Protein Sources of the Surveyed Food Bars**

Protein in protein bars was derived from a wide range of sources, each contributing to the nutritional composition of the product. The common sources of protein utilized in protein bars were identified by examining product labels. Among the bars that were studied, ten main sources of protein were commonly used. These included Whey Protein Isolate (90-95), Hydrolyzed Whey Protein Isolate (90-95), Soy Protein Isolate (85-90), Whey Protein Hydrolysate (80-90), Pea Protein Isolate (80-90), Milk Protein Isolate (80-85), Egg Albumin (80-85), Whey Protein Concentrate (70-80), Milk Protein Concentrate (70-80) and Soy Nuggets (40-50). The protein content range for these sources was compiled from the research conducted by Kaur *et al.* (2022), comparing alternative proteins to animal proteins. The focus was on digestibility as a key indicator of protein bioavailability and susceptibility to proteolysis. Higher digestibility of proteins has been associated with improved health outcomes. Among the protein sources depicted in figure 4.1.3, the majority, 60 per cent, were derived from milk and its products, indicating a significant reliance on dairy-based proteins. Plant-based

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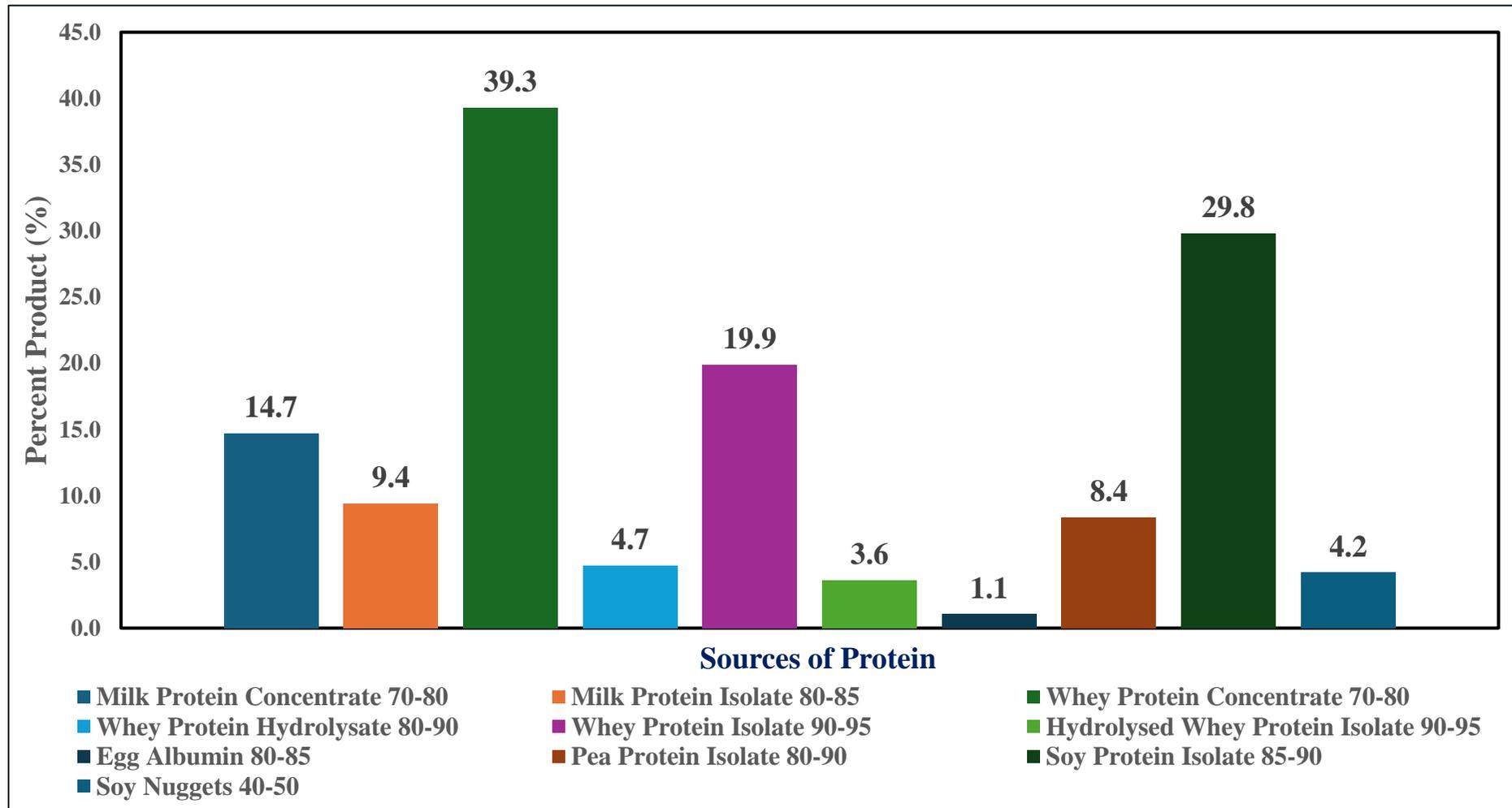
sources contributed to 30 per cent of the total protein, showcasing a notable presence in the protein landscape. Eggs accounted for the remaining 10 per cent, suggesting a comparatively smaller but still noteworthy contribution to overall protein intake. In terms of bioavailability, whey protein ranks highest at 100, followed by egg protein at 88-100, casein at 80 and soy protein at 74 (Millward *et al.* 2008).

As shown in the figure 4.1.3, Whey Protein Concentrate emerges as the most prominent contributor, constituting 39.3 per cent of the total protein product despite its lower protein content range of 70-80 per cent. Conversely, SPI, with its higher average protein content of 85-90 per cent, contributes substantially with 29.8 per cent. Other sources such as PPI, MPI and MPC also make notable contributions, ranging from 8.4 per cent to 14.7 per cent. Interestingly, despite its relatively high protein content, HWPI contributes only 3.6 per cent to the total protein product, indicating potential differences in market demand or processing costs. These findings underscore the importance of considering both protein content and contribution when selecting protein sources for various applications, highlighting the diverse nutritional profiles and functionalities of different protein types. Milk protein concentrates encompass both casein and whey proteins, offering protein concentrations varying from 70 per cent to 85 per cent (Kaur *et al.* 2022). They are manufactured via ultra-filtration, protein precipitation from milk, or dry blending milk proteins with other components. In contrast to skim milk powder or whole milk powder, milk protein concentrates boast higher protein content and lower lactose levels (Agarwal *et al.* 2015). Milk protein isolate is derived by partially extracting non-protein constituents (lactose and minerals) from skim milk to yield a final dry product containing 90 per cent or more protein by weight (Shaikh *et al.* 2022).

Whey protein is rich in essential amino acids, especially branched-chain amino acids like leucine and is quickly digested. It is derived from the clear liquid portion of milk remaining after cheese production once coagulation and curd removal have taken place. All components of whey offer abundant essential and branched-chain amino acids, rapidly increasing plasma amino acid levels, which is crucial for preserving muscle mass. Various techniques are employed to separate and purify whey proteins from whey, resulting in different concentrations (Shankar & Bansal 2013). There are three primary forms: whey protein concentrate, whey protein isolate and hydrolysed whey protein. Converting whey protein concentrate into whey protein isolate involves substantial

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removal of fat and lactose, making it suitable for individuals with lactose intolerance. Hydrolyzed whey protein is essentially pre-digested, leading to faster release of amino acids. This enhanced bioavailability promotes greater muscle protein synthesis. Whey protein is readily accessible as a dairy industry by-product (Kaur *et al.* 2022). The study by Tang *et al.* (2009) investigated the effects of whey protein, casein protein and soy protein isolate on muscle protein synthesis in young men, both when the participants were at rest and after engaging in resistance exercise. The findings demonstrated that whey protein had a much greater capacity to enhance muscle protein synthesis in comparison to soy protein isolate.



**Figure 4.1.3 Protein sources of the Surveyed Food Bars**

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The study conducted by Banaszek et al. (2019) examined the impact of whey protein isolate and pea protein isolate supplementation on muscular strength and body composition in people undertaking high-intensity functional exercise. The findings demonstrated that the supplementation of whey protein led to more significant enhancements in muscular strength when compared to pea protein. This suggests that there may be variations in the effectiveness of various protein sources in improving athletic performance.

Among the four main categories of soybean utilization—flour, nuggets, concentrates and isolates—soy flour represents the least refined form. While retaining most of the bean's protein content, concentrates contain fewer soluble carbohydrates compared to flour, rendering them more palatable. Soy isolates, on the other hand, represent the most refined form of soy protein, boasting the highest protein content. Unlike flour and concentrates, isolates lack fiber and are easily digestible. Soy protein isolate offers the maximum protein concentration at 90 per cent, followed by soy protein concentrate at 70 per cent and soy protein flour at 50 per cent (Hoffman and Falvo, 2004). Pea protein isolate is a highly refined form of protein extracted from yellow peas. Through a process that involves removing most of the non-protein components, PPI achieves a high protein concentration. This isolate form typically contains at least 80 per cent protein by weight, making it a popular choice among individuals seeking plant-based protein sources (Keefer *et al.* 2020).

Products incorporating egg albumin as a protein source tend to be low in fat and carbohydrates. Egg protein possesses high biological value and is digested at a slower rate than casein, resulting in a prolonged release of amino acids into the bloodstream (Hida *et al.*, 2012).

**Result Highlights: Phase I**

• ***Market Survey Overview:***

- *250 products from 32 different brands were scrutinized.*
- *These products were categorized into eight specific groups based on recommended usage.*
- *Diversity in product offerings reflects evolving consumer preferences and emerging trends in the nutrition bar industry.*

• ***Product Characteristics:***

- *All 250 products come in various flavor options.*
- *Bars with high protein content exhibited larger serving sizes at comparatively higher costs.*

• ***Relationship between Protein Content and Cost:***

- *A clear relationship was observed between protein levels and cost.*
- *Cost dropped as serving sizes increased in proportion to protein content.*

• ***Protein Sources:***

- *Ten diverse protein sources were identified.*
- *The most prevalent protein source used in the production of protein bars was WPC.*
- *SPI and WPI followed in decreasing order of usage.*

**Phase II: To standardize the formulation of Protein-Energy Bars, optimize ingredient composition using Response Surface Methodology and formulate the bars based on the obtained responses.**

P-E Bar had gained immense popularity as convenient and nutritious snacks among athletes, fitness enthusiasts and individuals seeking on-the-go sustenance. These bars serve as a convenient source of essential macronutrients, including proteins and carbohydrates, while offering various flavors and textures to cater to diverse consumer preferences. According to Srebernich et al. (2016), the RSM indicated that a cereal bar with an acceptable texture and sensory score may be made with a reasonable number of components. Moreover, optimizing the formulation of protein-energy bars to meet specific nutritional targets while maintaining desirable sensory attributes had demanded a systematic and scientific approach (Jetavat *et al.*, 2020).

RSM has emerged as a powerful statistical tool for optimizing complex formulations in food manufacturing research and industries. By systematically varying the levels of key ingredients and analysing the resulting responses, RSM has enabled researchers to identify the optimal formulation that met predefined objectives. In the context of protein-energy bars, RSM had offered a structured approach to fine-tuning ingredient composition to achieve desired sensory attributes (Nadeem et al. 2012). This phase of the research aimed to utilize RSM to standardize the formulation of protein-energy bars and optimize ingredient composition based on predefined response variables, i.e. the sensory attributes. Through a series of carefully designed experiments, varying levels of key ingredients such as WPC-80, SPI and Cereal-Pulses Crispies (Extruded product) were systematically tested to assess their individual and interactive effects on the final product's characteristics. The responses of interest included sensory attributes such as appearance, taste, flavor, texture, mouthfeel, serving size, absence of defects and overall acceptability. These attributes were assessed on semi-trained Sensory panel on a CSC and a 9-PHS. The obtained data were analyzed using RSM techniques to develop predictive models that described the relationship between ingredient composition and the desired responses. These models serve as valuable tools for formulators and food technologists to guide the development of protein-energy bars with consistent quality and optimal nutritional profiles (Kulshrestha et al. 2012).

### **4.2 Formulation of Protein-Energy Bars**

The formulation of P-E Bar involved a multi-step process aimed at optimizing their nutritional composition and sensory attributes. Initially, a specified set of raw ingredients were processed through extrusion, a key step in ensuring the desired texture and structure of the bars. The specific contents of the formulation's protein, carbohydrate, fat and other nutrients were then ascertained by nutritional calculations. Following that, the selected ingredients were analysed for its proximate composition in order to determine which independent factors may be optimised. These factors were chosen because they may have an effect on the nutritional profile and sensory qualities of the finished product. By methodically examining different combinations of the selected variables to obtain the desired responses, the formulation process was optimised through the use of RSM, a statistical optimisation approach. By using this method, the study sought to create Protein-Energy Bars that satisfies nutritional requirements while also fulfilling customer expectations in terms of sensory appeal, cost effectiveness and shelf life.

#### **4.2.1 Analysis of Raw Materials**

The percentage of nutrients provided per serving (one fifth for snack foods) of food products was determined relative to the daily nutrient requirements of athletes and physically active individuals (ILSI- India, NIN, SAI, 2007). For the development of Protein Energy Bars, a blend of maize, ragi, gram and soy flour was extruded to create crispies. This process aimed to achieve several objectives: enhancing mouthfeel by adding crunch, reducing bulkiness, providing ingredient diversity by combining four grains and improving shelf life through high-temperature short-time processing. The extrusion process effectively condensed multiple ingredients into a single product, optimizing texture and extending product shelf stability.

The independent variables, identified as the raw materials, underwent proximate composition analysis, with the results presented in table 4.2.1. The compositions of the remaining ingredients were calculated using the IFCT (Longvah et al., 2017).

**Table 4.2.1 Proximate Composition of Raw Materials**

<b>Constituents</b>	<b>Crispies</b>	<b>WPC-80</b>	<b>SPI</b>
Moisture (g %)	8.54 ± 0.08	4.12 ± 0.04	4.72 ± 0.20
Carbohydrate <sup>#</sup> (g %)	68.36	5.3	28.59
Protein (g %)	23.22 ± 0.04	79.04 ± 1.18	89.29 ± 0.01
Crude Fat (g %)	2.05 ± 0.30	0.58 ± 0.11	1.70 ± 1.47
Crude Fiber (g %)	1.60 ± 0.21	--	--
Ash (g %)	2.07 ± 0.08	3.90 ± 0.05	5.15 ± 3.05
<b>Values in Mean ± SD</b>			
<b># Values by difference</b>			

Table 4.2.1 presented the composition of various constituents (expressed in g per 100 g) for Crispies, WPC-80 and SPI. Crispies contained approximately 68.36 g of carbohydrates per 100 g, whereas WPC-80 and SPI contained 5.3 g and 28.59 g, respectively. The protein content of Crispies, WPC-80 and SPI was reported as 23.22 ± 0.04 g per cent, 79.04 ± 1.18 g per cent and 89.29 ± 0.01 g per cent, respectively. Crispies had approximately 2.05 ± 0.30 g per cent crude fat, while WPC-80 and SPI contained 0.58±0.11 g per cent and 1.70 ± 1.47 g per cent crude fat, respectively. Crispies were the only product to contain crude fiber, which was reported as 1.60 ± 0.21 g per cent. In terms of ash content, Crispies had 2.07±0.08, WPC-80 had 3.90 ± 0.05 and SPI had 5.15 ± 3.05 g per cent. Crispies exhibited the highest carbohydrate content among the three products, while SPI displayed the highest protein content, followed closely by WPC-80. Crispies also had the highest crude fat content and were the sole product to contain crude fiber. Additionally, SPI demonstrated the highest ash content. These findings highlight the diverse nutritional compositions especially the protein content of Crispies, WPC-80 and SPI, offering insights into their potential applications in the development of Protein-Energy Bars.

Using a twin-screw extruder and a mix of maize, ragi and soy protein isolate flours, a protein-rich extruded puff product was created. In the study by Jatav and Bhatt (2020) extruded puff product was the most favoured version among customer, with a full protein supply, created from a blend of maize flour, rice flour and 10 per cent SPI. Moreover, the addition of SPI resulted in improvements to the product's bulk density and expansion ratio.

The results for Whey Protein Concentrate-80 in table 4.2.1 align with the findings of the study done by Rutherford and Moughan (1998). The composition of WPC-80 was analysed in this investigation. The analysis revealed that WPC-80 had an estimated protein level of 79.8 percent, signifying a substantial amount of protein. In addition, it had a fat content of 2.5 percent, an ash content of 8.5 percent and a lactose content of 5.5 percent. The data indicate that WPC-80 is a highly concentrated protein source with comparatively low amounts of fat and lactose. Overall, the compositional properties of WPC-80 make it a potentially desirable component in food and beverage products, especially those that need a high protein.

### **4.2.2 Optimization of Levels of Crispies, WPC-80 and SPI for Development of Protein-Energy Bars using RSM**

Using CCRD, a three-factor Response Surface Methodology (RSM), optimum ratios of Crispies (6.5–8.1 per cent), WPC-80 (14–15 per cent) and SPI (14–15 per cent) were established. A sophisticated statistical programme called Design Expert 8.0.3 was employed to optimise the levels of Crispies, WPC-80 and SPI in order to produce P-E Bars. The software recommended a standard formulation after conducting 20 experiments and analysing the results.

#### **4.2.2.1 Influence of varying level of Crispies, WPC-80 and SPI on Sensory Characteristics of Protein-Energy Bars (P-E bars) on a Composite Score Card and a 9-Point Hedonic Scale**

Sensory qualities are crucial for product acceptance. Tables 4.2.2 and 4.2.3 show sensory responses for products made according to their run sequence. P-E bars were rated on a CSC for appearance, taste, flavor, texture, mouthfeel, serving size, absence of defects and overall score. They were also rated on a 9-PHS for appearance, taste, flavor, texture and serving size by 37 semi-trained judges. The mean of the scores were entered to the software to get the regression equation of the attributes.

**Table 4.2.2 Experimental design matrix and sensory attributes (CSC) of Protein-Energy Bars**

Run No.	Crispies (g)	WPC-80 (g)	SPI (g)	Sensory Scores (Composite score card)							
				Appearance (10)	Taste (15)	Flavor (10)	Texture (20)	Mouthfeel (10)	Serving size (15)	Absence of defects (10)	Overall score (10)
1	45	90	90	8.0	12.1	8.1	15.9	8.3	13.6	8.3	8.1
2	45	95	90	8.5	13.1	8.5	16.5	8.5	13.7	8.4	8.2
3	45	90	90	8.0	12.1	8.1	15.9	8.3	13.6	8.3	8.1
4	45	85	90	8.5	13.5	8.6	17.2	8.8	13.8	8.7	8.5
5	40	95	85	9.0	13.3	8.6	17.6	8.8	14.4	9.0	8.8
6	45	90	95	8.0	12.5	8.2	15.8	7.9	13.8	8.5	8.1
7	45	90	85	8.5	12.8	8.4	16.9	8.8	14.0	8.7	8.4
8	50	85	85	9.1	13.7	8.7	17.8	8.8	14.2	8.9	8.6
9	45	90	90	8.7	12.5	8.4	16.3	8.3	13.8	8.5	8.3
10	40	85	85	8.8	13.5	8.8	18.0	8.9	13.8	9.0	8.6
11	45	90	90	8.0	12.1	8.1	15.9	8.3	13.6	8.3	8.1
12	50	85	95	8.0	13.0	8.3	16.4	8.1	13.9	8.5	8.1
13	45	90	90	8.0	12.1	8.1	15.9	8.3	13.6	8.3	8.1
14	40	90	90	8.2	12.7	8.3	16.6	8.2	13.9	8.5	8.1
15	50	95	85	8.3	12.7	8.3	15.5	8.3	14.0	8.4	8.0
16	40	85	95	8.3	13.2	8.5	16.7	8.4	14.0	8.6	8.4
17	50	90	90	8.2	12.6	8.3	16.4	8.2	14.0	8.3	8.0
18	50	95	95	8.6	12.8	8.4	17.4	8.2	13.9	8.6	8.3
19	40	95	95	9.0	13.5	8.6	18.1	8.9	14.3	9.0	8.6
20	45	90	90	8.0	12.1	8.1	15.9	8.3	13.6	8.3	8.1

**Table 4.2.3 Experimental design matrix and sensory attributes (9-PHS) of Protein-Energy Bars**

Run No.	Crispies (%)	WPC-80 (%)	SPI (%)	Sensory scores (9-point Hedonic Scale)				
				Appearance	Taste	Flavor	Texture	Serving size
1	7.3	14.5	14.5	7.76	7.61	7.66	6.58	8.09
2	7.3	15.3	14.5	7.79	7.88	7.88	7.12	8.12
3	7.3	14.5	14.5	7.52	7.61	7.55	6.58	8.09
4	7.3	13.7	14.5	7.90	7.98	7.92	7.39	8.19
5	6.5	15.3	13.7	8.15	8.15	8.09	7.91	8.39
6	7.3	14.5	15.3	7.39	7.42	7.48	6.94	8.04
7	7.3	14.5	13.7	8.00	8.12	8.06	7.79	8.48
8	8.1	13.7	13.7	8.21	8.05	8.04	8.16	8.43
9	7.3	14.5	14.5	7.76	7.64	7.73	7.06	8.12
10	6.5	13.7	13.7	8.06	8.18	8.09	8.00	8.22
11	7.3	14.5	14.5	7.52	7.61	7.55	6.58	8.09
12	8.1	13.7	15.3	7.55	7.67	7.61	7.24	8.00
13	7.3	14.5	14.5	7.76	7.61	7.55	6.58	8.09
14	6.5	14.5	14.5	7.85	7.73	7.73	7.30	8.12
15	8.1	15.3	13.7	7.52	7.64	7.73	7.03	8.20
16	6.5	13.7	15.3	7.64	7.79	7.85	7.39	8.15
17	8.1	14.5	14.5	7.76	7.63	7.63	6.89	8.09
18	8.1	15.3	15.3	7.85	7.76	7.70	7.33	8.00
19	6.5	15.3	15.3	8.30	7.94	7.94	8.18	8.39
20	7.3	14.5	14.5	7.76	7.61	7.55	6.58	8.09

**Table 4.2.4 Partial Coefficients of Regression Equations of Suggested Models for Sensory Attributes of Protein-Energy Bars Incorporated with Crispies, WPC-80 and SPI using CSC.**

Terms		Sensory scores (Composite score card)							
		Appearance (10)	Taste (15)	Flavor (10)	Texture (20)	Mouthfeel (10)	Serving size (15)	Absence of defects (10)	Overall score (10)
<b>Intercept</b>		8.13	12.33	8.21	16.08	8.29	13.69	8.38	8.12
<b>Linear</b>	<b>A: Crispies</b>	- 0.109 <sup>ns</sup>	- 0.147**	- 0.079**	- 0.344*	- 0.152*	- 0.027 <sup>ns</sup>	- 0.135*	- 0.142*
	<b>B: WPC-80</b>	0.064 <sup>ns</sup>	- 0.147**	- 0.052 <sup>ns</sup>	- 0.088 <sup>ns</sup>	- 0.036 <sup>ns</sup>	0.052 <sup>ns</sup>	- 0.027 <sup>ns</sup>	- 0.027 <sup>ns</sup>
	<b>C: SPI</b>	- 0.189*	- 0.107 <sup>ns</sup>	- 0.077**	- 0.149 <sup>ns</sup>	- 0.219*	- 0.049 <sup>ns</sup>	- 0.064*	- 0.090**
<b>Interactiv</b>	<b>AB</b>	- 0.124 <sup>ns</sup>	- 0.169**	- 0.025 <sup>ns</sup>	- 0.280**	- 0.091 <sup>ns</sup>	- 0.136*	- 0.106*	- 0.102**
	<b>AC</b>	- 0.039 <sup>ns</sup>	- 0.048 <sup>ns</sup>	0.032 <sup>ns</sup>	0.155 <sup>ns</sup>	- 0.057 <sup>ns</sup>	- 0.068 <sup>ns</sup>	0.016 <sup>ns</sup>	0.027 <sup>ns</sup>
	<b>BC</b>	0.234*	0.161**	0.097*	0.636*	0.155*	- 1.27 <sup>ns</sup>	0.121*	0.098 <sup>#</sup>
<b>Quadrati</b>	<b>A<sup>2</sup></b>	0.074 <sup>ns</sup>	0.111 <sup>ns</sup>	0.071 <sup>ns</sup>	0.314 <sup>ns</sup>	- 0.101 <sup>ns</sup>	0.209*	0.008 <sup>ns</sup>	- 0.079 <sup>ns</sup>
	<b>B<sup>2</sup></b>	0.307*	0.735*	0.272*	0.669*	0.323*	- 0.037 <sup>ns</sup>	0.153*	0.254*
	<b>C<sup>2</sup></b>	0.115 <sup>ns</sup>	0.067 <sup>ns</sup>	- 0.015 <sup>ns</sup>	0.139 <sup>ns</sup>	0.043 <sup>ns</sup>	0.199*	0.201*	0.131 <sup>ns</sup>
<b>R<sup>2</sup></b>		0.80	0.88	0.84	0.89	0.84	0.85	0.92	0.82
<b>Model F-value</b>		4.45	8.20	5.78	9.05	5.95	6.54	13.48	5.21
<b>APV</b>		6.13	8.13	8.82	9.65	8.01	8.29	11.86	8.20
<b>Suggested Model</b>		Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
*: p < 0.05; **: p < 0.1, <sup>ns</sup> : Non-significant; APV= Adequate Precision Value, R <sup>2</sup> = Coefficient of determination									

**Table 4.2.5 Partial Coefficients of regression equations of suggested models for sensory attributes of Protein-Energy Bars incorporated with Crispies, WPC-80 and SPI using 9-PHS**

Terms		Sensory scores (9-point Hedonic Scale)				
		Appearance	Taste	Flavor	Texture	Serving size
Intercept		7.69	7.65	7.64	6.77	8.11
Linear Level	A: Crispies	- 0.112*	- 0.105*	- 0.099*	- 0.213*	- 0.056*
	B: WPC-80	0.025 ns	- 0.030 ns	- 0.017 ns	- 0.061 ns	0.012 ns
	C: SPI	- 0.121*	- 0.156*	- 0.143*	- 0.179*	- 0.114*
Interactive Effect	AB	- 0.144*	- 0.056 ns	- 0.039 ns	- 0.217*	-0.081*
	AC	- 0.008 ns	0.043 ns	- 0.009 ns	- 0.035 ns	- 0.070*
	BC	0.197*	0.086**	0.062 ns	0.262*	0.037 ns
Quadratic Level	A2	0.098 ns	-0.028 ns	-0.018 ns	0.169 ns	-0.029 ns
	B2	0.136 ns	0.223*	0.202*	0.328**	0.020 ns
	C2	-0.011 ns	0.066 ns	0.076 ns	0.436*	0.127*
R2		0.82	0.84	0.83	0.89	0.88
Model F-value		4.96	5.93	5.25	9.02	7.98
APV		7.05	8.89	7.88	8.65	10.38
Suggested Model		Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
*: p < 0.05; **: p < 0.1, ns: Non-significant; APV= Adequate Precision Value, R2= Coefficient of determination						

When the sensory quality scores were analyzed using the above-mentioned sensory evaluation methods, it was revealed that the quadratic model was the best fit for the optimization process, as shown in table 4.2.4 and table 4.2.5 for CSC and 9-PHS respectively. Through successive regression analysis, the quadratic model for sensory factors as mentioned above using a composite score card and a 9-point hedonic scale was established.

In a linear regression study, the F-value measures the overall significance of the model. It is determined by comparing the variability described by the model to the variability that the model does not explain. A larger F-value indicated that the model explains a greater proportion of the variation in the data. In table 4.2.4 and table 4.2.5, the model F-values for various sensory characteristics such as appearance, taste, flavor, texture, mouthfeel, serving size, absence of defects (AOD) and overall score were calculated. For the composite scores, the F-values were 4.45, 8.20, 5.78, 9.05, 5.95, 6.54, 13.48 and 5.21 respectively. For the 9-PHS, the F-values were 4.96, 5.93, 5.25, 9.02 and 7.98 respectively, for appearance, taste, flavor, texture and serving size. It was observed that all the calculated F-values were higher than the corresponding critical F-values at a 5 per cent level of confidence. This indicated the significance of the model terms and suggested that there were significant differences between the means of the groups for the evaluated sensory characteristics.

The coefficient of determination, denoted as  $R^2$ , is a statistical measure that represents the proportion of the variation in the dependent variable that was explained by the independent variable(s). The coefficient of determination ( $R^2$ ) for appearance, taste, flavor, texture, mouthfeel, serving size, absence of defects and overall score were 0.80, 0.88, 0.84, 0.89, 0.84, 0.85, 0.92 and 0.82, respectively (Composite score) as mentioned in the table 4.2.4 and for appearance, taste, flavor, texture and serving size scores were 0.82, 0.84, 0.83, 0.89 and 0.88, respectively (9-point hedonic) as shown in table 4.2.5, reflecting a strong relationship between the independent variable(s) and the dependent variable and that the model can explain a significant portion of the variance in the dependent variable. A higher  $R^2$  value, close to 1.00, indicated a better fit for the quadratic model.

Adequate Precision Value (APV) is a measure used in Design of Experiments (DOE) to evaluate the variability of the experimental data. To determine adequate precision, it is necessary to consider the Signal-to-Noise Ratio, (signal is the effect of the factors being studied and noise is the random variation in the data) which should be at least 4.0 indicating that the signal is at least 4 times stronger than the noise. An APV value greater than 4.0 indicated that the experimental error is relatively small compared to the effects of the factors being studied. The findings from tables 4.2.4 and 4.2.5 of the study highlighted the precision values obtained for various sensory attributes, such as appearance, taste, flavor, texture, mouthfeel, serving size, absence of defects and overall score. When using a composite score card, the precision values were determined to be 6.13, 8.13, 8.82, 9.65, 8.01, 8.29, 11.86 and 8.20 for each respective attribute. Alternatively, when employing a 9-Point Hedonic Scale, the precision values for appearance, taste, flavor, texture and serving size scores were found to be 7.05, 8.89, 7.88, 8.65 and 10.38. These results suggested that the measured response effectively reflected the impact of the factors on the system being investigated. The precision values indicated that the measurements provided reliable and consistent information about the effects of the factors on the sensory attributes of interest.

The 3D response surface for sensory attributes, as influenced by Crispies, WPC-80 and SPI, was evaluated using both the composite scorecard (CSC) out of 10 and the 9-point hedonic scale (9-PHS), as detailed in Annexure XXXI.

### **4.2.2.2 Response Surface of Appearance Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (10) and a 9-PHS**

The perception of product quality is often influenced by the visual aspects of the product, including its design, aesthetics and overall presentation. In the context of evaluating Protein-Energy Bars, CSC with a maximum score of 10 and a 9-PHS were used to assess different formulations. table 4.2.2 and table 4.2.3 provide the scores for appearance, which ranged from 8.0 to 9.1 and 7.39 to 8.30, respectively. Among the formulations tested, those with 8.1 per cent (50g) Crispies, 13.7 per cent (85g) WPC-80 and 13.7 per cent (85g) SPI (Run number: 8) received the highest ratings according to the CSC. Similarly, the formulation with 6.5 per cent (40g) Crispies, 15.3 per cent (95g) WPC-80 and 15.3 per cent (95g) SPI (Run number: 19) according to the 9-PHS method of evaluation was also highly rated by the panellists. On the other hand, the

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formulations with 7.3 per cent (45g) Crispies, 14.5 per cent (90g) WPC-80 and 14.5 per cent (90g) SPI (run number: 1, 3, 6, 11, 13 and 20), as well as 8.1 per cent (50g) Crispies, 13.7 per cent (85g) WPC-80 and 15.3 per cent (95g) SPI (Run number: 12), received the lowest ratings on the CSC. In terms of the 9-PHS, the formulation with 7.3 per cent (45g) Crispies, 14.5 per cent (90g) WPC-80 and 15.3 per cent (95g) SPI (run number: 6) received the lowest rating from the panellists.

The coefficient of determination ( $R^2$ ) is used to determine the extent to which the model accounts for variability in the data and a high  $R^2$  value of 0.80 and 0.82 in table 4.2.4 and table 4.2.5, indicated that the model is well suited to the data for both the composite and hedonic methods of evaluation respectively. Additionally, the APV value of 6.13 (Composite score) and 7.05 (Hedonic score) was appreciably higher than the minimum desirable value of 4.00 for APV, suggesting that this response was a good choice for navigating the design. Furthermore, Model F-values of 4.45 (Composite score) and 4.96 (Hedonic score) suggested that the model had a statistically significant effect on the response variable.

According to the findings presented in table 4.2.4 and table 4.2.5, at linear level, the influence of WPC-80 on the visual appeal of Protein-Energy Bars was not statistically significant at the 0.05 significance level, as indicated by the respective values of 0.064 and 0.025 on the CSC and 9-PHS. This implies that there was no significant relationship between these variables when keeping Crispies and SPI constant. However, Crispies displayed a negative score (-0.109) on the CSC, indicating a non-significant association with the appearance of the bars. On the hedonic scale, Crispies had a negative and statistically significant effect (-0.112) on the appearance, suggesting that they had a significant negative impact on the bars' visual appeal. Furthermore, SPI had a significant negative effect ( $p < 0.05$ ) on both the CSC (-0.189) and 9-PHS (-0.121) evaluations of appearance. This signifies that as the independent variable SPI increases while keeping all other factors constant, the score for appearance decreases.

The findings presented in table 4.2.4 and table 4.2.5 demonstrated the interactive effects of various independent variables on the dependent variable. Specifically, the results indicate that Crispies-WPC-80 (AB) had a non-significant negative effect (-0.124) on appearance based on the composite score card, while showing a significant negative effect (-0.144) on appearance according to the hedonic scale. Moreover, when

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considering the interaction between Crispies-SPI (AC), there was a non-significant negative effect (-0.124) on appearance based on the composite score and a slight negative effect (-0.008) on the hedonic scale, with other independent variables held constant. In contrast, the interaction between WPC-80-SPI (BC) yielded a positive effect on the appearance of the bars on both the CSC (0.234) and the 9-PHS (0.197), with other independent variables held constant. This positive effect was statistically significant at  $p < 0.05$ , indicating that the combination of WPC-80 and SPI had a favourable impact on the appearance of the Protein-Energy Bars.

In a regression model, a quadratic term or squared factor represents the squared value of an independent variable and reflects the effect of ingredients at the highest level used in product standardization. The findings from table 4.2.4 and 4.2.5 indicate that the quadratic term of Crispies ( $C^2$ ) did not have a statistically significant effect on the appearance, as denoted by the non-significant p-values of 0.074 and 0.098 for the CSC and the 9-PHS, respectively. Similarly, for WPC-80 ( $B^2$ ), the quadratic terms also showed a non-significant effect on the appearance of the Protein-Energy Bars. The partial regression coefficient of 0.136 suggested that the quadratic term of WPC-80 did not significantly influence the appearance on the 9-PHS. However, it showed a positive effect of 0.307 ( $p < 0.05$ ) when evaluated on the CSC, indicating that the linear component of WPC-80 had a significant positive impact on the appearance. Contrarily, the quadratic term of SPI ( $C^2$ ) demonstrated a non-significant effect on appearance at  $p < 0.05$ . The partial regression coefficient of 0.115 on the Composite Score Card suggests that the quadratic term of SPI did not have a statistically significant influence on appearance. Moreover, there was a small non-significant negative effect on the hedonic scale, with a partial regression coefficient of -0.011.

To predict the appearance score, the following equations were created using multiple regression, considering the impacts of different elements in terms of coded components.

### **On a Composite Score Card:**

Out of 10	=	+8.13 - 0.1096 A + 0.0643 B - 0.1895 C - 0.1241 AB - 0.0388 AC + 0.2340 BC + 0.0738 A <sup>2</sup> + 0.3073 B <sup>2</sup> + 0.1152 C <sup>2</sup>
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**On a 9-Point Hedonic Scale:**

Out of 9.0	=	$+7.69 - 0.1120 A + 0.0252 B - 0.1212 C - 0.1439 AB - 0.0076 AC + 0.1970 BC + 0.0975 A^2 + 0.1364 B^2 - 0.0105 C^2$
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Where,

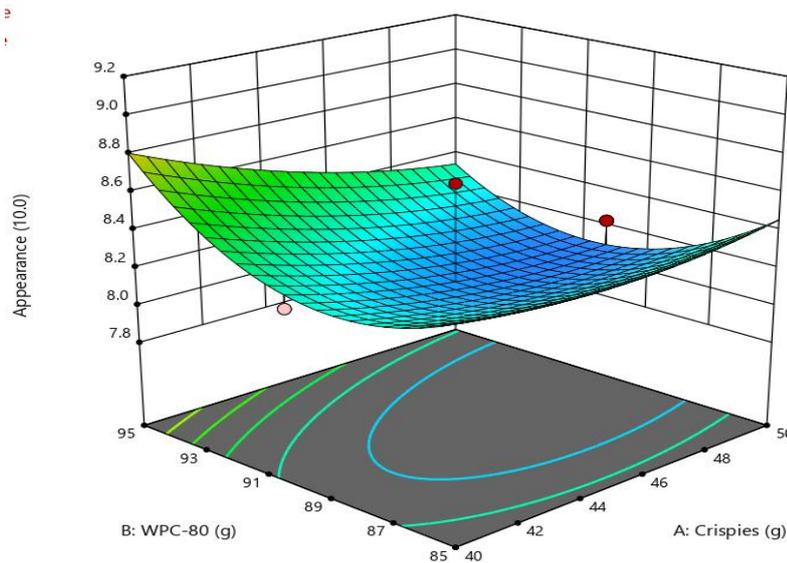
A - Crispies, B- WPC-80 and C - SPI

The algorithm calculated the appearance of Protein Energy Bars (P-E Bars) as judged on a Composite Score Card by plugging in the values of the components (Crispies, WPC-80 and SPI). The coefficients represent the relative importance of each component and their interactions on the overall look. The coefficients represent the size and direction of the impacts, whether positive or negative and how they interact with one another.

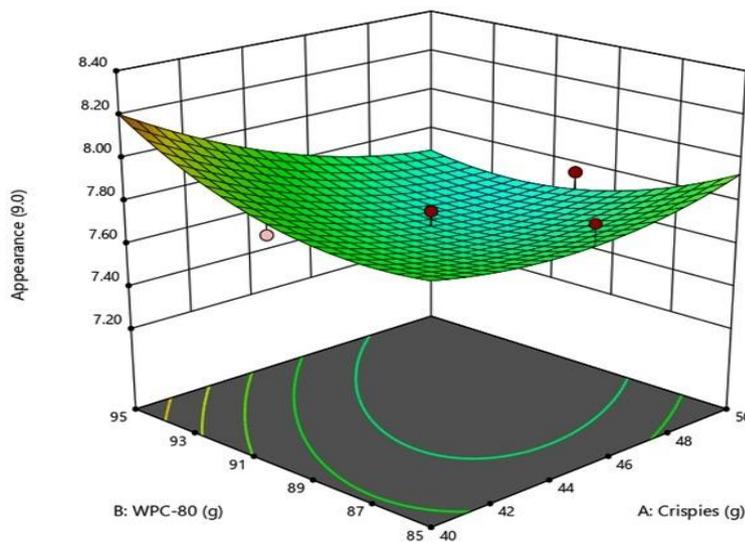
The regression equation (on a 9-PHS) suggests that A, C and the interaction between A-B, A-C and the quadratic effects of C had negative effects on the appearance score, while factors B, BC and the quadratic effects of A and B had positive effects on the appearance score. This implies that per cent WPC-80 had a positive impact on the appearance score. However, the size of the effects varies and some effects are relatively small compared to others. Moreover, the constant term, 7.69 represented the predicted appearance score when all the coded factors were set to zero.

The three-dimensional response surface plots provide a visual representation of these interaction effects, allowing for a better understanding of the relationship between the variables and the appearance scores. These three-dimensional response surface plots were generated using the regression model mentioned earlier, considering the experimental range for the three independent variables. Figures 4.2.1 to 4.2.6 illustrate the impact of variable interactions on the appearance scores of Protein-Energy Bars evaluated on a Composite Score Card and 9-Point Hedonic Scale. The analysis of the plots revealed findings regarding the interaction effects among the variables. Specifically, on a CSC the interaction between Crispies and WPC-80 (AB) as well as the interaction between Crispies and SPI (AC) demonstrated a decrease in the appearance score. Conversely, the interaction between WPC-80 and SPI (BC) exhibited a positive influence on the appearance score. This implies that when WPC-80 and SPI

were combined, the appearance of the Protein-Energy Bars was improved, leading to higher scores. Whereas on a 9-PHS the results showed that the interaction between Crispies-WPC-80 (AB) and Crispies-SPI (AC) led to a decrease in the appearance score, while the interaction between WPC-80-SPI (BC) resulted in an increase in the appearance score.



**Fig.4.2.1 Response Surface of Appearance Score (10) of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



**Fig.4.2.2 Response Surface of Appearance Score of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a 9-PHS**

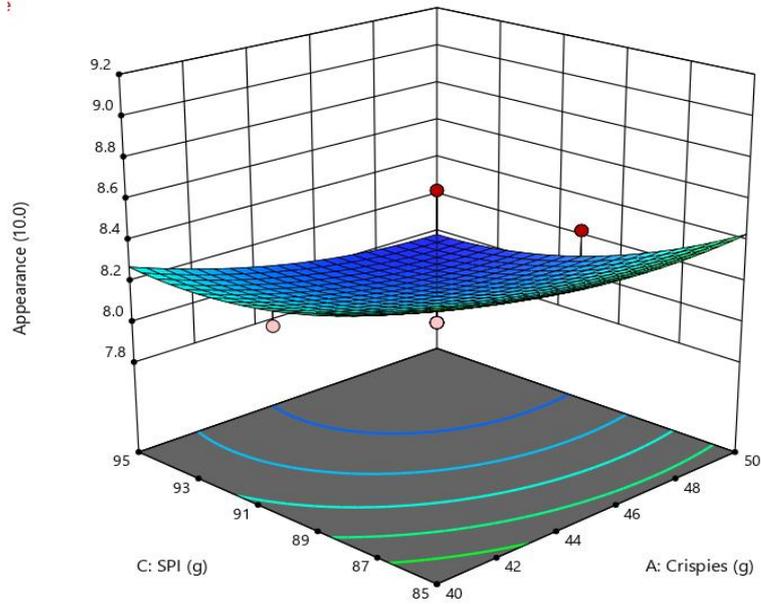


Fig.4.2.3 Response Surface of Appearance Score (10) of P-E Bars as influenced by level of Crispiers (A) and SPI (C) on a CSC

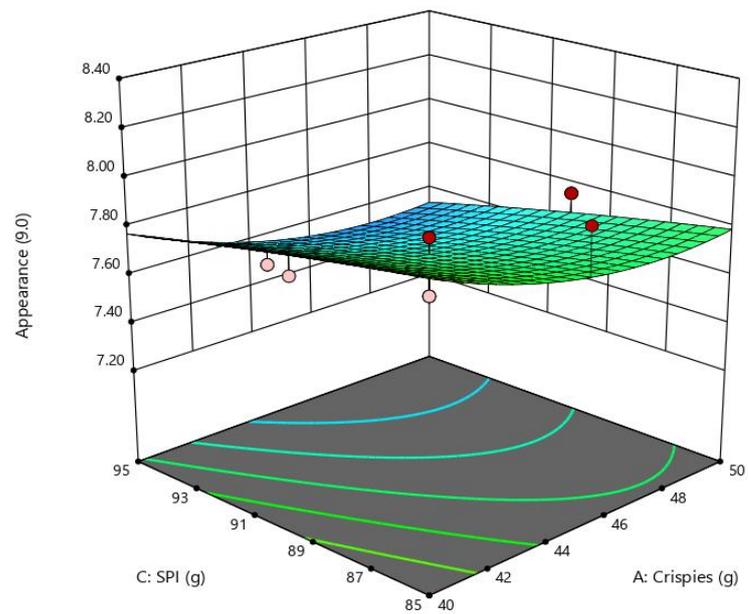
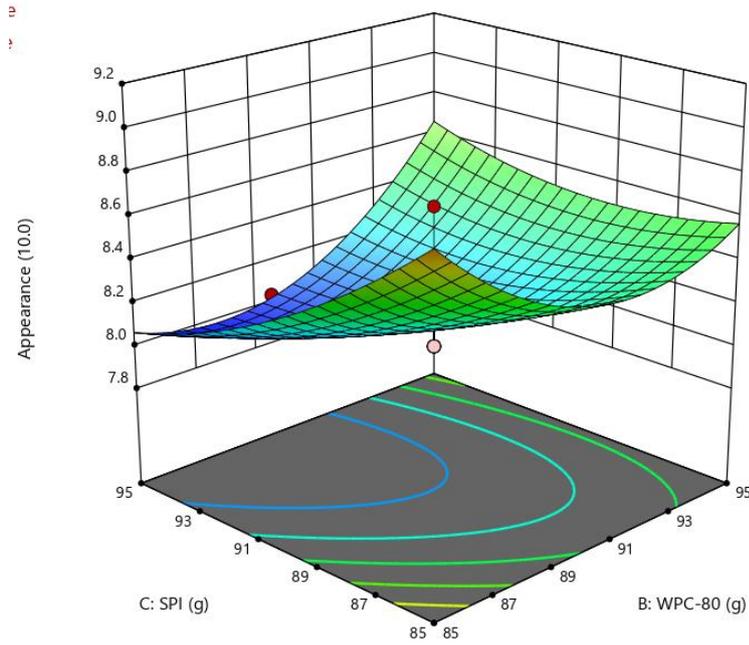
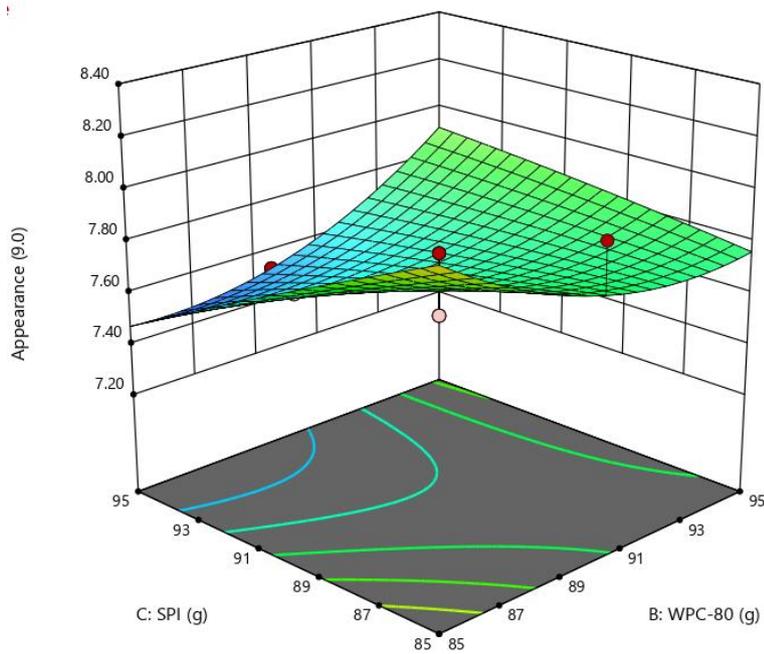


Fig.4.2.4 Response Surface of Appearance Score of P-E Bars as influenced by level of Crispiers (A) and SPI (C) on a 9-PHS



**Fig.4.2.5 Response Surface of Appearance Score (10) of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**



**Fig.4.2.6 Response Surface of Appearance Score of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a 9-PHS**

**4.2.2.1.2 Response Surface of Taste Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (15) and a 9-PHS**

The taste score of Protein-Energy Bars, which is widely regarded as a crucial aspect of product quality and consumer acceptability, was evaluated using a CSC on the maximum score of 15 and a 9-PHS and ranged from 12.1 to 13.7 and 7.42 to 8.15, as reported in table 4.2.2 and 4.2.3, respectively. Among the various formulations that were tested, the one with 8.1 per cent (50 g) Crispies, 13.7 per cent (85 g) WPC-80 and 13.7 per cent (85 g) SPI (Run number: 8) on a CSC and 6.5 per cent (40 g) Crispies, 15.3 per cent (95 g) WPC-80 and 13.7 per cent (85 g) SPI (Run number: 5) on a Hedonic Scale was rated the highest by the panellists. Whereas run numbers: 1, 3, 11, 13 and 20, comprising the formula of 7.3 per cent (45 g) Crispies, 14.5 per cent (90 g) WPC-80 and 14.5 per cent (90 g) SPI on CSC and 7.3 per cent (45 g) Crispies, 14.5 per cent (90 g) WPC-80 and 15.3 per cent (95 g) SPI (Run number: 6) on a 9-PHS received the lowest taste score. These findings suggest that the relative proportions of the different ingredients in the formulations had a significant impact on the taste profile of the P-E Bar.

Table 4.2.4 and 4.2.5 shows a high coefficient of determination ( $R^2$ ) value of 0.88 and 0.84 measured on CSC and 9-PHS, respectively, which indicated that the model could explain a large proportion of the variability in the data. The APV value of 8.13 (CSC) and 8.89 (9-PHS), considerably higher than the desirable minimum value of 4.00 for APV, indicated that the response was suitable for navigating the design. In addition, the significant Model F-value of 8.20 (CSC) and 5.93 (9-PHS) suggested that the model had a statistically significant effect on the response variable.

The findings from table 4.2.4 and 4.2.5 suggest that the on a 9-PHS, proportions of Crispies (A) and SPI (C) in the formulation of Protein-Energy Bars had a significant negative effect on the taste with the coefficient of - 0.105 and - 0.156 respectively at  $p < 0.05$ , while the proportion of WPC-80 (B) has a small negative effect that is not statistically significant (- 0.030). This implies that reducing the amount of Crispies and SPI in the formulation and potentially increasing the amount of WPC-80 may result in an improved taste of the bar. However, the findings also suggest that on a CSC, the proportion of Crispies and WPC-80 (- 0.147) was negatively statistically significant at a significance level of  $p < 0.1$  and SPI showed a negative non-significant (- 0.107) impact on the taste score on CSC.

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An interactive effect refers to the influence of the joint effects of two or more independent variables on the dependent variable. As indicated in table 4.2.4 and 4.2.5, considering the interceptive effect on the taste of the bars, the results showed that the interactive effect of Crispies-WPC-80 (AB) showed no statistically significant relationship with a coefficient of -0.056, which was not significant at the  $p < 0.05$  level on a 9-PHS but a significant negative relationship was found with a coefficient of -0.169 at the  $p < 0.1$  level on CSC. The effect of relationship between Crispies-SPI (AC) on a 9-PHS for taste was found to be non-significant with a coefficient of 0.043 and on a CSC, the relationship was negative but not statistically significant, with a coefficient of -0.048. Whereas the interceptive relationship between WPC-80-SPI (BC) a weak positive relationship was observed with a coefficient of 0.086 and 0.161 respectively on a 9-PHS and a CSC, respectively.

In the regression model presented in table 4.2.4 and 4.2.5, the quadratic term or squared factor represents the effect of the independent variables at the highest level used in product standardization. The tables showed that, while holding the effect of WPC-80 and SPI constant, the squared factor of Crispies ( $A^2$ ) had a small, negative non-significant effect on the taste of the bars, with a partial regression coefficient of -0.028 (9-PHS) and a non-significant effect with a partial regression coefficient of 0.111 (CSC). On the other hand, WPC-80 ( $B^2$ ) had a statistically significant positive effect on taste, with a partial coefficient of 0.735 and 0.223 ( $p < 0.05$ ), respectively on a 9-PHS and CSC. Additionally, a small, positive non-significant effect was observed on the taste of the bars at a partial coefficient of 0.067 (CSC) and 0.066 (9-PHS) for the squared factor of SPI ( $C^2$ ), at the given level of significance ( $p < 0.05$ ).

The multiple regression equations describing the effect of independent variable on the taste scores of the Protein-Energy Bars as affected by different factors in terms of coded factors are as follows:

### **On a Composite Score Card:**

Out of 15	=	$12.33 - 0.1472 A - 0.1473 B - 0.1076 C - 0.1690 AB - 0.0478 AC$ $+ 0.1614 BC + 0.1108 A^2 + 0.7350 B^2 + 0.0670 C^2$
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**On a 9-Point Hedonic Scale:**

Out of 9.0	=	+7.65 - 0.1045 A - 0.0301 B - 0.1563 C - 0.0557 AB + 0.0428 AC + 0.0856 BC - 0.0279 A <sup>2</sup> + 0.2229 B <sup>2</sup> + 0.0662 C <sup>2</sup>
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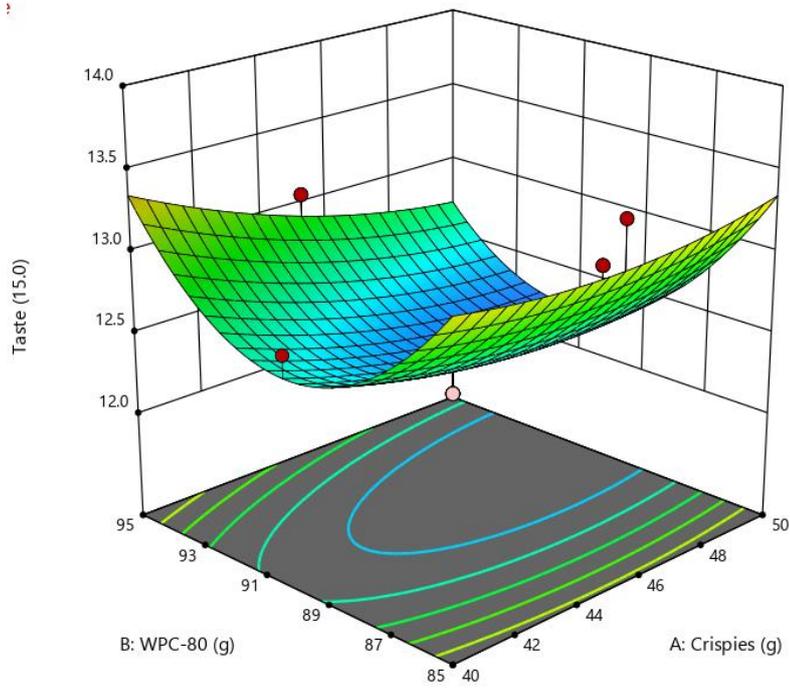
Where,

A - Crispies, B- WPC-80 and C - SPI

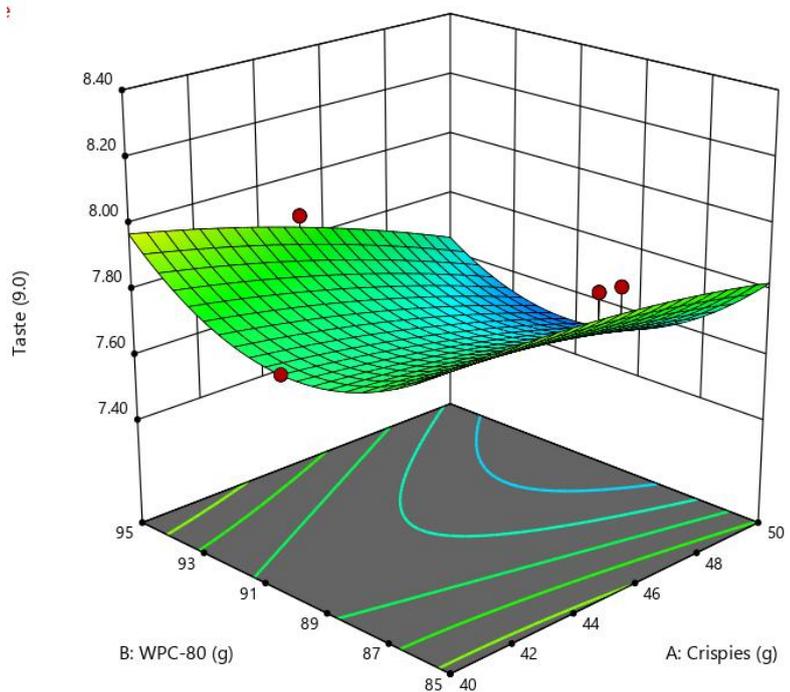
Based on the equation for the effect of variable on taste score on a CSC, the amount of Crispies, WPC-80 and SPI in the P-E Bars may have a variable influence on the taste score. Crispies and WPC-80 interactions, as well as Crispies and SPI interactions, have negative impacts on taste score, but WPC-80 and SPI interactions have a favourable effect. Furthermore, the connections between Crispies and taste score, as well as WPC-80 and SPI, may not be linear and may have quadratic effects.

According to the equation for the effect of independent variables on the taste of the P-E Bars as measured on a 9-PHS, there appears to be a significant impact on the taste score due to the interaction between Crispies and WPC-80, as well as the combinations of Crispies and SPI and WPC-80 and SPI. The model also indicated that the relationship between the amount of WPC-80 and SPI and the taste score may be quadratic, indicating the presence of an optimal amount of these ingredients for achieving the highest taste score.

The three-dimensional response surface plots in Figures 4.2.7 to 4.2.12 illustrate how the interaction among the independent variables influences the taste scores of Protein-Energy Bars, based on the model developed with the experimental data. The range of variation for each independent variable on both the evaluation scales were considered while generating the plots.



**Fig.4.2.7 Response Surface of Taste Score (15) of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



**Fig.4.2.8 Response Surface of Taste Score of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a 9-PHS**

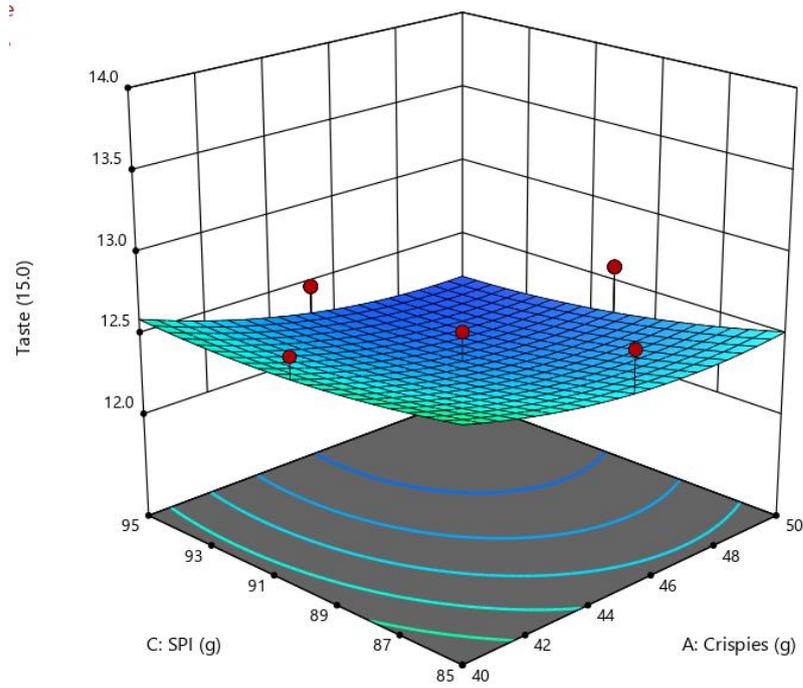


Fig.4.2.9 Response Surface of Taste Score (15) of P-E Bars as influenced by level of Crispiess (A) and SPI (C) on a CSC

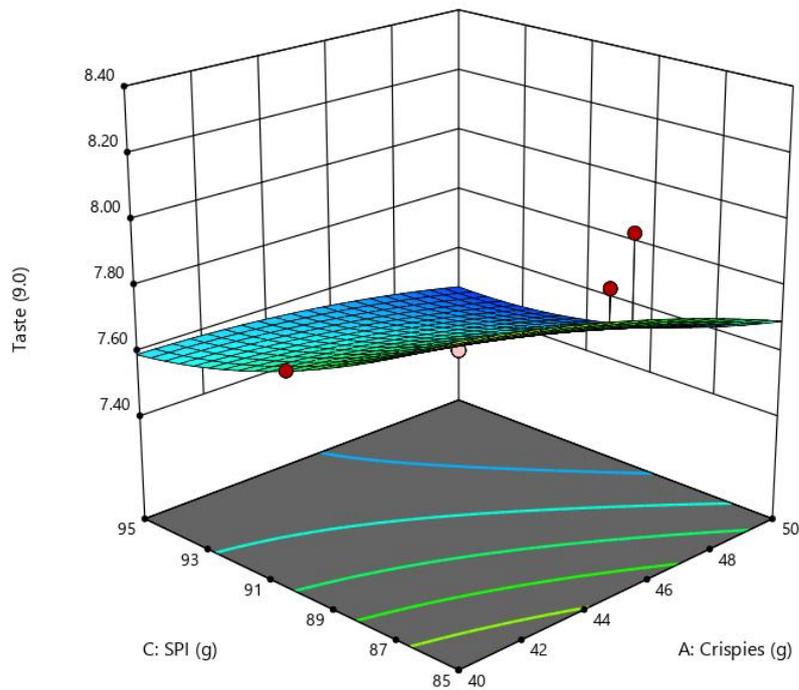
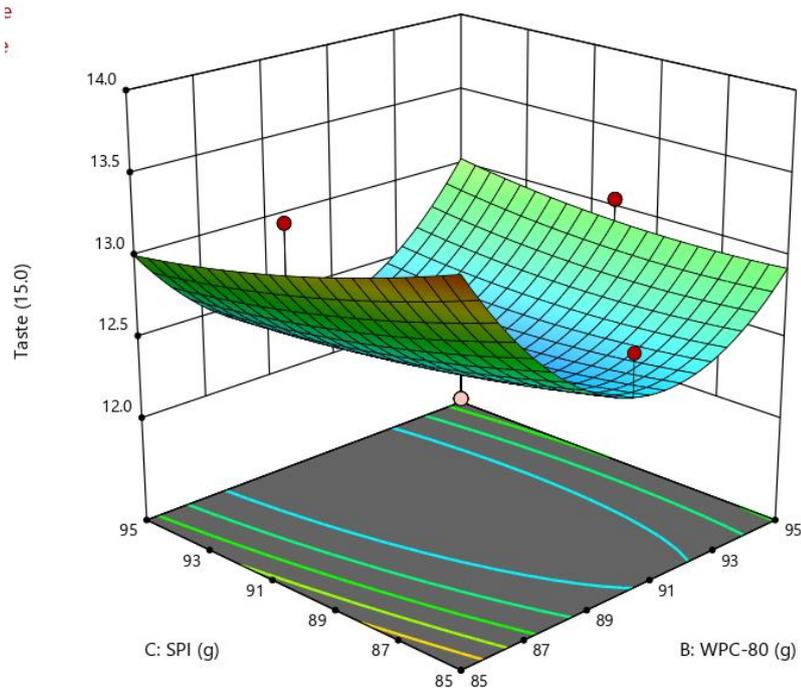
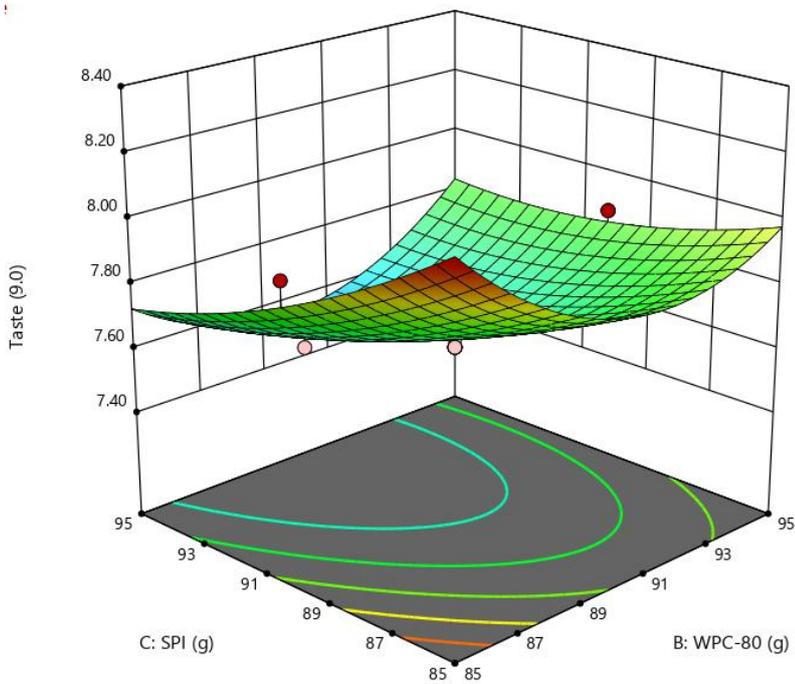


Fig.4.2.10 Response Surface of Taste Score of P-E Bars as influenced by level of Crispiess (A) and SPI (C) on a 9-PHS



**Fig.4.2.11 Response Surface of Taste Score (15) of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**



**Fig.4.2.12 Response Surface of Taste Score of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a 9-PHS**

**4.2.2.1.3 Response Surface of Flavor Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (10) and a 9-PHS.**

Flavor factors encompass a range of sensory experiences that are perceived by both the tongue and the nose, comprising the basic tastes of sweet, salty, sour and bitter, as well as the aromas detected by the nose. Therefore, flavor is a composite of both taste and aroma.

Table 4.2.2 and 4.2.3 display the flavor scores of P-E Bar, which is an important component influencing product quality and customer approval, as determined on a CSC with a maximum score of 10 and 9 points on a Hedonic Scale. The scores ranged from 8.1 to 8.7 and 7.48 to 8.09 for the various formulations tested respectively on a CSC and a 9-PHS. The formulation with 7.3 per cent (45 g) Crispies, 14.5 per cent (90 g) WPC-80 and 14.5 per cent (90 g) SPI (Run number: 1, 3,11,13 and 20) received the lowest flavor score on a CSC and the formula having 7.3 per cent (45 g) Crispies, 14.5 per cent (90 g) WPC-80 and 15.3 per cent (95 g) SPI (Run number: 6) received the lowest flavor score on a 9-PHS. On the other hand, the formulation with 8.1 per cent (50 g) Crispies, 13.7 per cent (85 g) WPC-80 and 13.7 per cent (85 g) SPI (Run number: 8) received the highest rating on a CSC and the formulation with 6.5 per cent (40 g) Crispies, 15.3 per cent (95 g) WPC-80 and 13.7 per cent (85 g) SPI (Run number: 5) received the highest rating on a 9-PHS from the panellists. These results suggest that the proportion of different components in the formulations has a significant influence on the flavor profile of the Protein-Energy Bars.

The data in table 4.2.4 and 4.2.5 suggests that the regression model had a high degree of accuracy in explaining the variability in the data, as indicated by the high coefficient of determination ( $R^2$ ) value of 0.84 (CSC) and 0.83 (9-PHS). The APV value, which measures the Signal-to-Noise Ratio, was found to be 8.82 (CSC) and 7.88(9-PHS), indicating that the model was highly precise and suitable for navigating the design. The significant Model F-value of 5.78 and 5.25 respectively for CSC and 9-PHS further suggests that the model had a statistically significant effect on the response variable, indicating that it was a reliable and valid predictor of the taste score of the Protein-Energy Bars.

## *Results and Discussion*

The values presented in table 4.2.4 and 4.2.5, at linear level, indicated that on a Composite Score Card, flavor score for Crispies (A) and SPI (C) revealed a coefficient of -0.079 and -0.079 respectively with a significance level of  $p < 0.1$  and with a coefficient of - 0.052, WPC-80 (B) had a non-significant effect. Whereas on a 9-Point Hedonic Scale the percentage of Crispies and SPI had a significant negative effect on the flavor of the Protein-Energy Bars, as indicated by their partial regression coefficients of -0.099 and -0.143, respectively and their significant p-values of  $p < 0.05$ . On the other hand, the partial regression coefficient of WPC-80 was not statistically significant at  $p < 0.05$  but suggested a small negative effect (-0.017) on the flavor of the bars. These findings suggested that decreasing the percentage of Crispies and SPI in the formulation may improve the flavor of the bars, while adjusting the percentage of WPC-80 may have a negligible effect on the flavor.

The interactive effects between the independent variables are revealed in table 4.2.4 and 4.2.5. The results suggest that on a Composite Score Card there was a non-significant interactive effect of Crispies-WPC-80 (AB) and Crispies-SPI (AC), where AB showed a negative non-significant at  $p < 0.05$  with the coefficient of - 0.025 and 0.032, respectively. The interactive effect of WPC-80- SPI (BC), with the coefficient of 0.097 was found to be significant ( $p < 0.05$ ). However, when measured on a 9-Point Hedonic Scale the scores suggest that there were no significant interactive effects between Crispies- WPC-80 (AB), Crispies- SPI (AC) and WPC-80- SPI (BC) on the flavor of the Protein-Energy Bars with the values of - 0.039, - 0.009 and 0.062, respectively, where AB and AC had a negative non significance at  $p < 0.05$ . This means that the AB and AC had no synergistic or antagonistic effect on the flavor of the bars. However, the partial regression coefficient for the interactive effect between WPC-80- SPI (BC) suggests that there may be a positive synergistic effect between these two ingredients on the flavor of the bars, but this effect is not statistically significant at  $p < 0.05$ .

According to the regression model presented in table 4.2.4 and 4.2.5, the quadratic term of Crispies ( $A^2$ ) and SPI ( $C^2$ ) had a non-significant effect on the flavor of the Protein-Energy Bars on both Scales, at  $p < 0.05$ , with partial regression coefficients of 0.071 (CSC) and 0.076 (9-PHS) respectively, indicating a positive partial regression. In addition, partial regression coefficients of -0.015 (CSC) for SPI and -0.018 (9-PHS) for Crispies indicate that both scores have a slight negative non-significant influence on the flavor profile. However, the partial regression coefficients of 0.272 (CSC) and 0.202 (9-PHS) indicated that the quadratic component of ( $B^2$ ) had a beneficial influence on the flavor profile of the Protein-Energy Bars.

Multiple regression equations generated to predict the flavor as affected by different factors in terms of coded factors are as follows:

**On a Composite Score Card:**

$$\text{Out of 10} = 8.21 - 0.0786 A - 0.0524 B - 0.0769 C - 0.0246 AB + 0.0322 AC + 0.0966 BC + 0.0711 A^2 + 0.2719 B^2 - 0.0148 C^2$$

**On a 9-Point Hedonic Scale:**

$$\text{Out of 9.0} = +7.64 - 0.0997 A - 0.0172 B - 0.1434 C - 0.0391 AB - 0.0088 AC + 0.0618 BC - 0.0184 A^2 + 0.2023 B^2 + 0.0757 C^2$$

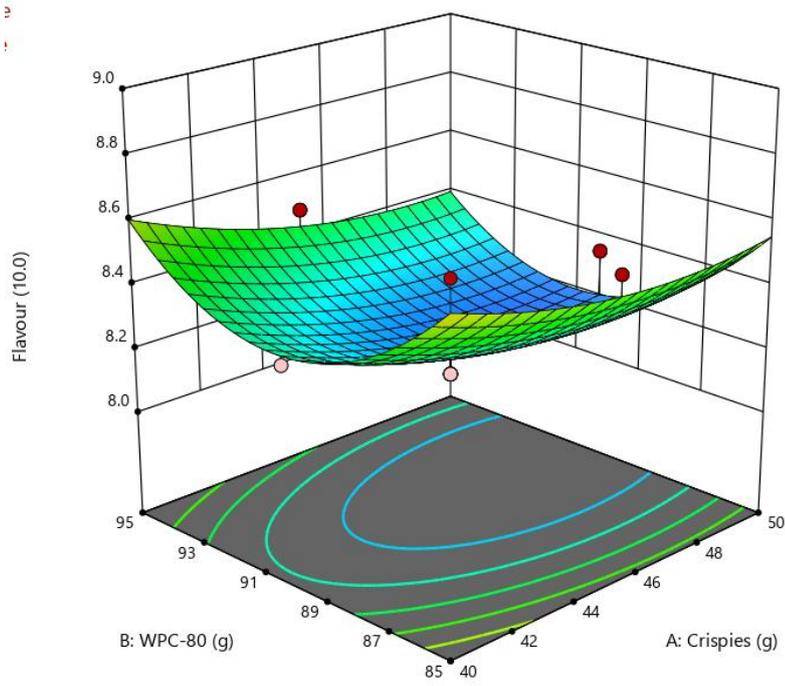
Where,

A - Crispies, B- WPC-80 and C- SPI

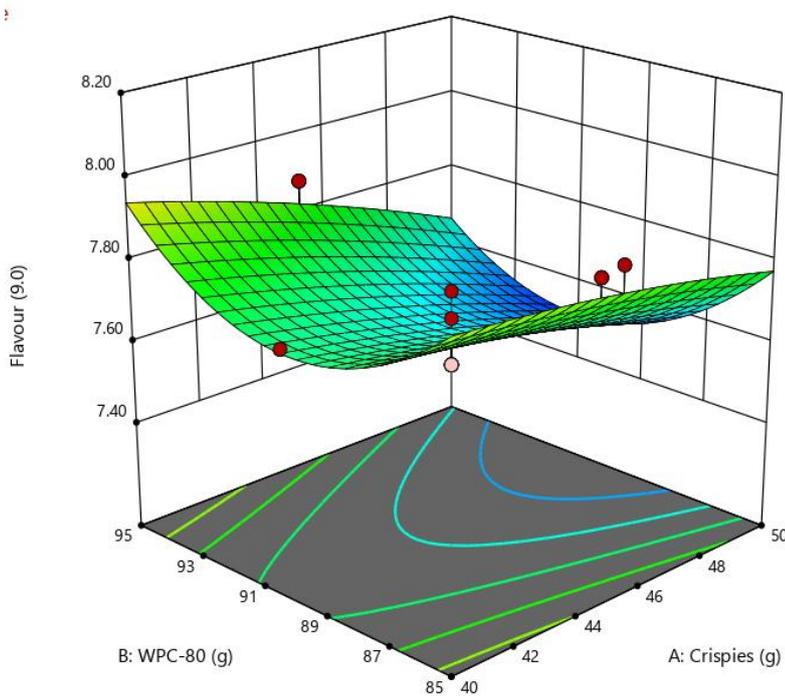
According to the regression equation for the flavor scores on the CSC, the quantity of Crispies, WPC-80 and SPI in the protein bars may impact the flavour score. Increasing the quantity of Crispies and WPC-80 may reduce the flavour score, however combining Crispies with SPI has a good impact. Furthermore, the link between Crispies and flavour, as well as WPC-80 and flavour, may not be linear and may display a positive quadratic impact.

The equation for the flavor scores on the 9-point hedonic scale (9-PHS) indicated a predicted flavor score of 7.64 when all independent variables were set to zero. The model also suggests that the interaction between Crispies and WPC-80, as well as the combination of WPC-80 and SPI, had significant effects on the flavor score. Additionally, the model indicated that the relationship between the amount of Crispies and the flavor score may not be linear and quadratic effects may play a role.

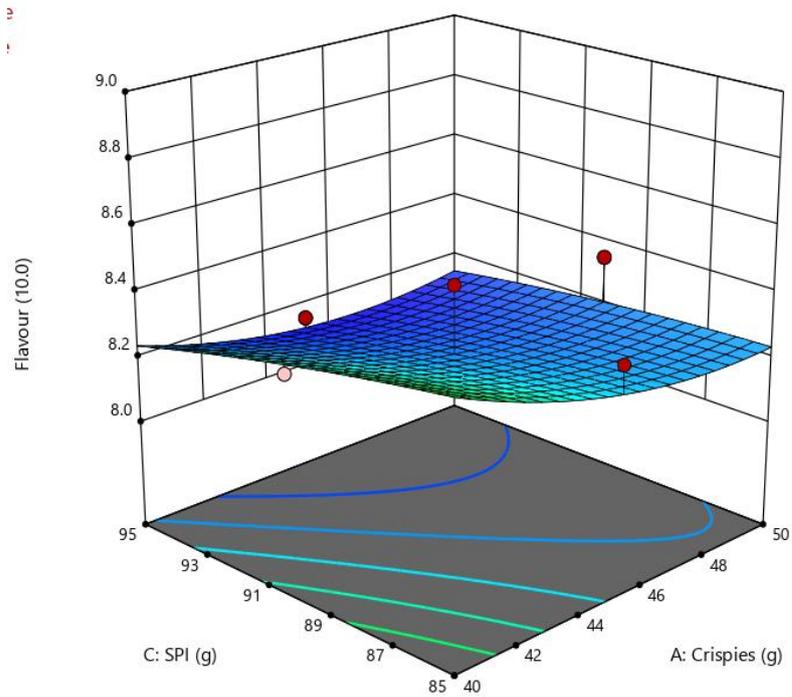
The three-dimensional response surface plots shown in Figures 4.2.13 to 4.2.18 represent the effects of the interaction between the independent variables on the flavor ratings of Protein-Energy Bars as calculated by the constructed model using experimental data using a CSC and a 9-PHS. The graphs consider the range of possibilities for each independent variable.



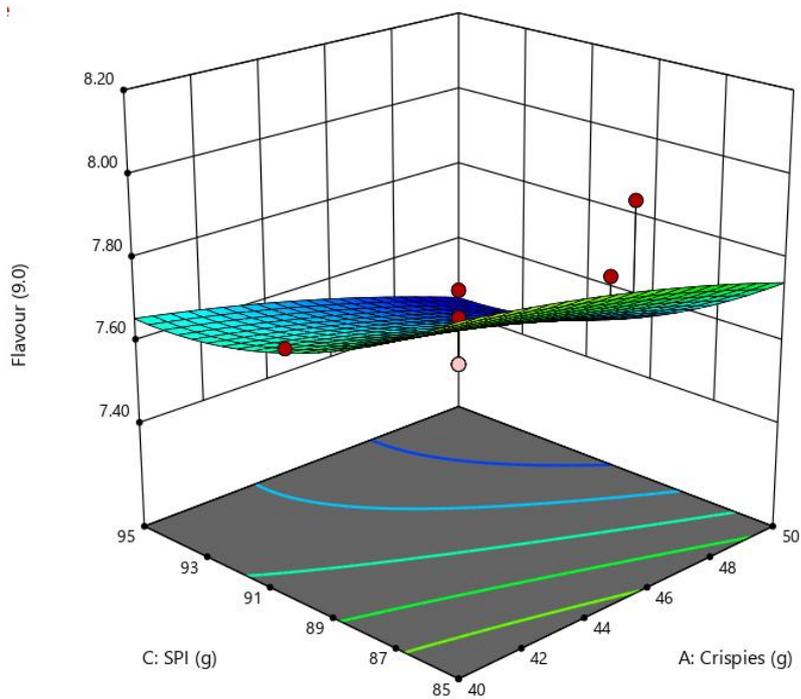
**Fig.4.2.13 Response Surface of Flavor (10) score of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



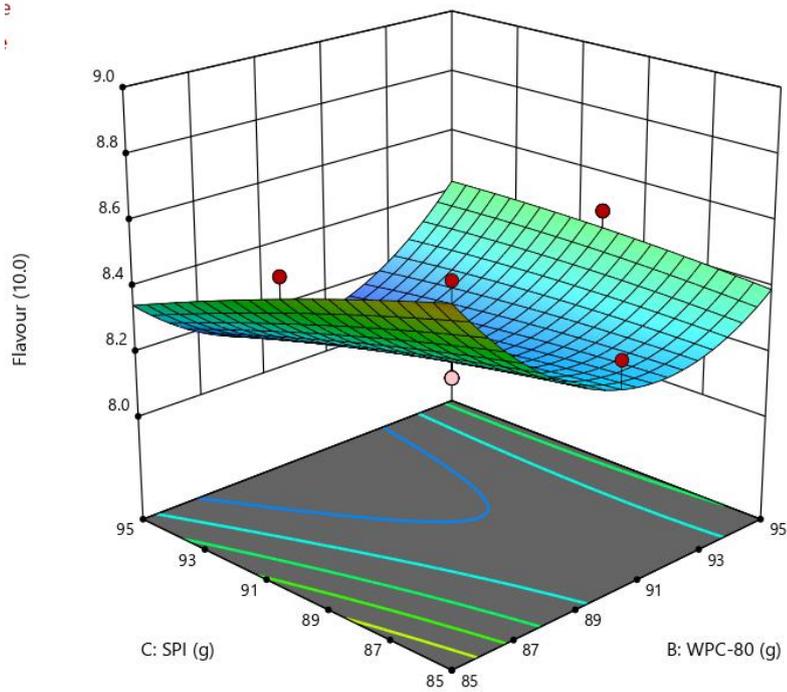
**Fig.4.2.14 Response Surface of Flavor Score of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a 9-PHS**



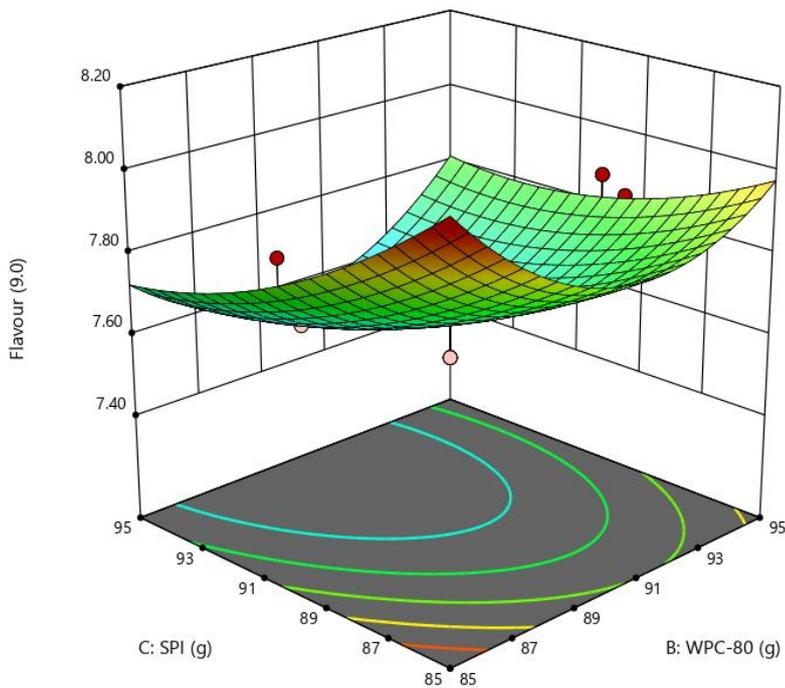
**Fig.4.2.15 Response Surface of Flavor (10) score of P-E Bars as influenced by level of Crispiess (A) and SPI (C) on a CSC**



**Fig.4.2.16 Response Surface of Flavor Score of P-E Bars as influenced by level of Crispiess (A) and SPI (C) on a 9-PHS**



**Fig.4.2.17 Response Surface of Flavor (10) score of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**



**Fig.4.2.18 Response Surface of Flavor Score of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a 9-PHS**

**4.2.2.1.4 Response Surface of Texture Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (20) and a 9-PHS.**

Texture refers to the physical properties of food that can be felt in the mouth, including its consistency, firmness, cohesiveness and other attributes that affect the way it feels when chewed, swallowed, or held in the mouth. A desirable texture is one that is easy to chew and swallow, not too dry or too moist and has a pleasant mouthfeel. Texture is an important aspect of protein bars as it greatly influences consumer acceptability and preference.

The texture score of Protein-Energy Bars shown in table 4.2.2 and 4.2.3 ranged from 18.1 to 15.5 on a CSC with a maximum score of 20 and the range on the 9-PHS was 6.58 to 8.18 for the various formulations tested. The formulation with 6.5 per cent (40 g) Crispies, 15.3 per cent (95 g) WPC-80 and 15.3 per cent (95 g) SPI (Run number: 19) received the highest texture score on both the scales, while Run No. 15, with the formulation having 8.1 per cent (50 g) Crispies, 15.3 per cent (95 g) WPC-80 and 13.7 per cent (85 g) SPI on a CSC with a maximum texture score of 20 received the least score. The formulation with 7.3 per cent (45 g) Crispies, 14.5 per cent (90 g) WPC-80 and 14.5 per cent (90 g) SPI (Run number: 1, 2, 11, 13, 20) received the lowest rating from the panellists on a 9-Point Hedonic Scale. These findings indicate that the proportion of various components in the formulations significantly affects the texture profile of Protein-Energy Bars.

The results presented in table 4.2.4 and 4.2.5 demonstrate that the regression model used to predict the texture score of Protein-Energy Bars was highly accurate, as evidenced by the high coefficient of determination ( $R^2$ ) value of 0.89 on both the scales used for evaluating the texture profile of the bars. This means that the model can explain 89 per cent of the variability in the data, which indicated a strong relationship between the independent and dependent variables. The APV value of 9.65 (CSC) and 8.65 (9-PHS) further suggests that the model was highly precise, meaning that it can effectively distinguish between signal and noise in the data. Additionally, the significant Model F-value of 9.05 and 9.02, respectively on a CSC and a 9-PHS indicated that the model had a statistically significant effect on the response variable, implying that it is a reliable and valid predictor of the texture score of the Protein-Energy Bars. Overall, these findings support the use of the regression model as a useful tool for predicting and optimizing the texture score of P-E Bar.

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According to table 4.2.4 and 4.2.5, the proportion of WPC-80 (B) had a small non-significant influence at the linear level, with a negative score on both scales and a linear coefficient of -0.088 and -0.061. Similarly, the linear association of SPI (C) with the score on CSC on the 9-PHS exhibited a negative non-significant effect on texturing with a coefficient of -0.149. However, at  $p < 0.05$ , there was a negative significance on the linear level of Crispies on a CSC (-0.344) and Crispies and SPI on a 9-PHS with linear coefficients of -0.213 and -0.179, respectively. In general, the data indicated that the textural properties of Protein-Energy B P-E Bars were heavily impacted by the component selection and proportion.

The interactive effects of the independent factors on the texture of the Protein-Energy Bars were investigated using the approach described in table 4.2.4 and 4.2.5. Interaction between Crispies-WPC-80 (AB) showed a statistically significant negative effect with a coefficient of - 0.280 at a significance level of  $p < 0.1$  on CSC and a statistically significant negative effect with a coefficient of - 0.217 at a significance level of  $p < 0.05$  on a 9-PHS, while keeping the other independent variables constant. The interaction between Crispies-SPI (AC) exhibited a non-significant effect on texture with a coefficient of 0.155 on a CSC and a negative non-significant effect on texture with a coefficient of -0.035 with the other independent variables held constant. On the other hand, the interaction between WPC-80-SPI (BC) demonstrated a strong significant positive effect on texture, as indicated by a coefficient of 0.636 (CSC) and 0.262 (9-PHS) at a significance level of  $p < 0.05$ , while the other independent variables remained constant. These findings suggest that the combination of WPC-80 and SPI, within the given experimental ranges, can have a notable impact on the texture profile of Protein-Energy Bars.

The impact of different combinations of independent factors on the texture of Protein-Energy Bars was examined using the methodology outlined in table 4.2.4 and 4.2.5. The interaction between Crispies-WPC-80 (AB) was found to have a statistically significant negative effect on CSC, with a coefficient of -0.280 at a significance level of  $p < 0.1$ . Similarly, it had a statistically significant negative effect on 9-PHS, with a coefficient of -0.217 at a significance level of  $p < 0.05$ , while holding the other independent variables constant. On the other hand, the interaction between Crispies-SPI (AC) did not show a significant effect on texture, with a coefficient of 0.155 on CSC and a non-significant negative effect with a coefficient of -0.035 on 9-PHS, when

## *Results and Discussion*

other independent variables were held constant. Conversely, the interaction between WPC-80-SPI (BC) demonstrated a strong and significant positive effect on texture. It was characterized by a coefficient of 0.636 (CSC) and 0.262 (9-PHS) at a significance level of  $p < 0.05$ , while keeping the other independent variables constant. These findings indicate that the combination of WPC-80 and SPI, within the specified experimental ranges, can have a significant impact on the texture profile of Protein-Energy Bars.

The quadratic terms of the independent variables in the regression model were examined using the method outlined in table 4.2.4 and 4.2.5. The quadratic term of Crispies ( $A^2$ ) on CSC (0.314) and 9-PHS (0.169), as well as SPI ( $C^2$ ) on CSC (0.139), exhibited a non-significant effect on the texture score at a significance level of  $p < 0.05$ , while holding the other independent variables constant. Conversely, the quadratic term of WPC-80 ( $B^2$ ) had a strong significant partial regression coefficient of 0.669 at  $p < 0.05$  on CSC and 0.328 at  $p < 0.1$  on 9-PHS, indicating its influence on the texture profile. Regarding the quadratic term of SPI ( $C^2$ ), it did not show a significant effect on the texture profile of the Protein-Energy Bars, as indicated by the coefficient of 0.139 at  $p < 0.05$ . However, SPI demonstrated a positive and significant effect at  $p < 0.05$  with a coefficient of 0.436.

The following multiple regression equation was created to predict the texture as impacted by distinct elements in terms of coded factors:

### **On a Composite Score Card:**

$$\text{Out of 20} = 16.09 - 0.3438 A - 0.0879 B - 0.1486 C - 0.2803 AB + 0.1553 AC + 0.6364 BC + 0.3141 A^2 + 0.6697 B^2 + 0.1398 C^2$$

### **On a 9-Point Hedonic Scale:**

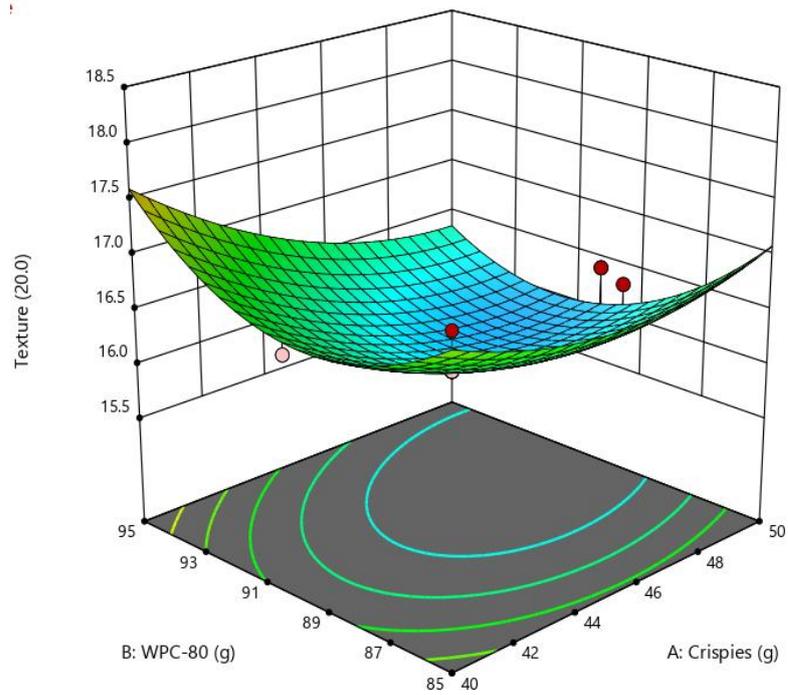
$$\text{Out of 9.0} = +6.77 - 0.2132 A - 0.0611 B - 0.1796 C - 0.2170 AB - 0.0352 AC + 0.2624 BC + 0.1686 A^2 + 0.3277 B^2 + 0.4357 C^2$$

Where,

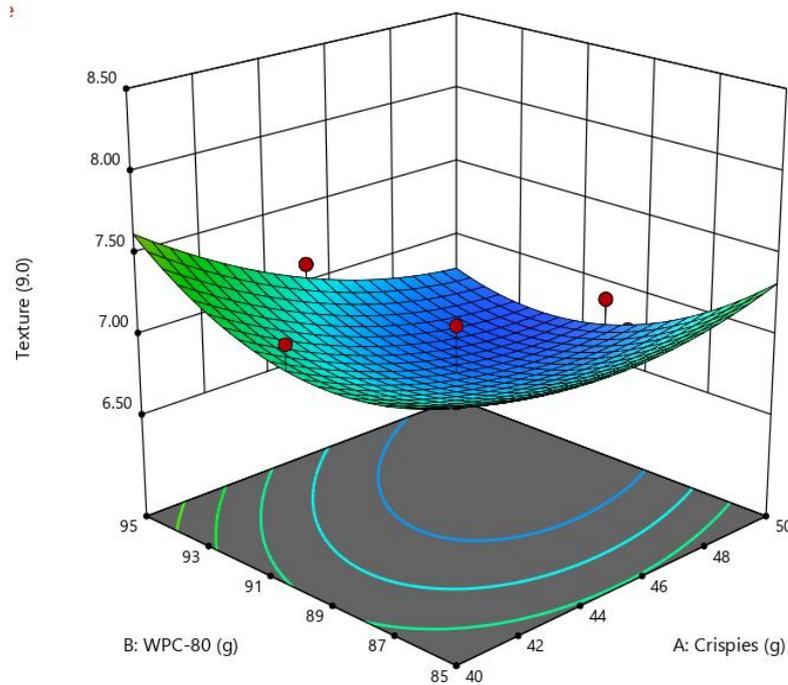
A - Crispies, B- WPC-80 and C - SPI

According to the equations' interpretation of these coefficients, the quantity of Crispies, WPC-80 and SPI in the protein bars may impact the texture score. As per the Composite Scoring Card, increasing the quantity of Crispies and WPC-80 may have a negative impact on the texture score, however combining Crispies and SPI, as well as WPC-80 and SPI, has a good impact. Furthermore, the connections between Crispies and texture score, as well as WPC-80 and texture score, may not be linear and may have positive quadratic effects. Multiple regression equation for the 9-Point Hedonic Scale depicted that, reducing the quantity of Crispies, WPC-80 and SPI may result in an improvement in the texture score of the protein energy bars. The model also indicated that the interaction of Crispies and WPC-80, as well as the combination of WPC-80 and SPI, has a substantial influence on texture score. Furthermore, the model suggests that the link between the quantity of Crispies, WPC-80 and SPI and the texture score is not linear and that quadratic effects may be present. When all the independent variables were set to zero, the constant term indicated the predicted texture score as 6.77.

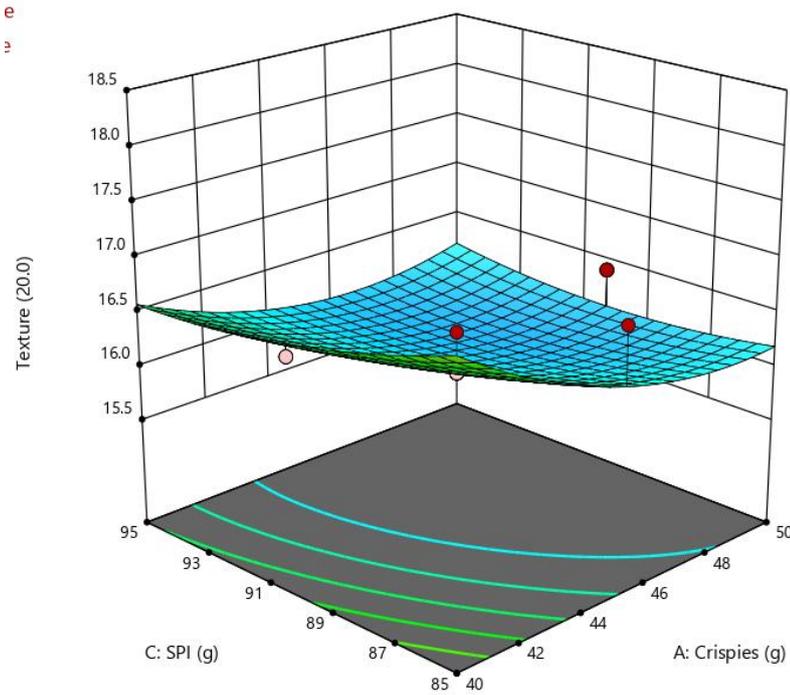
The three-dimensional response surface plots presented in Figures 4.2.19 to 4.2.24 illustrate the impact of variable interactions on the texture scores of Protein-Energy Bars. These plots were created using the established model and by considering the experimental range of the three independent variables.



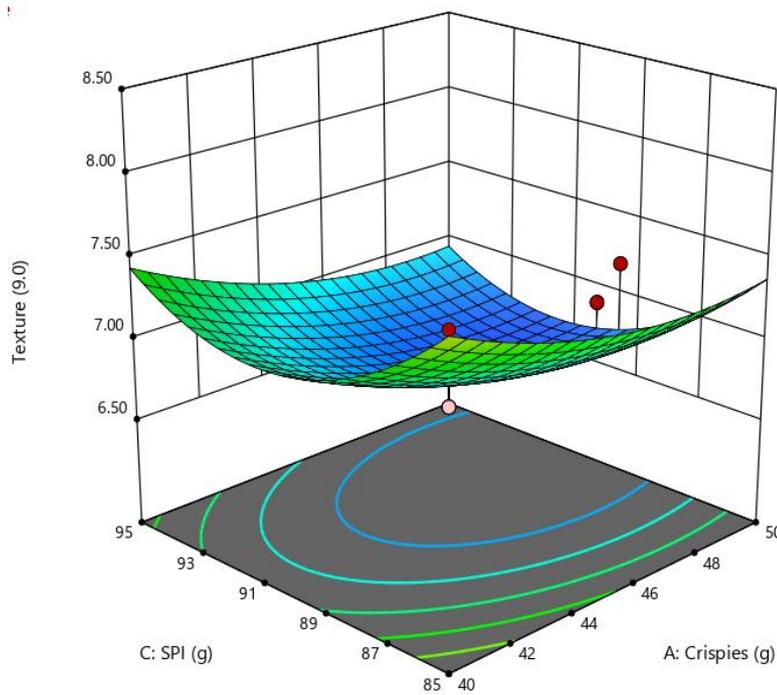
**Fig.4.2.19 Response Surface of Texture Score (20) of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



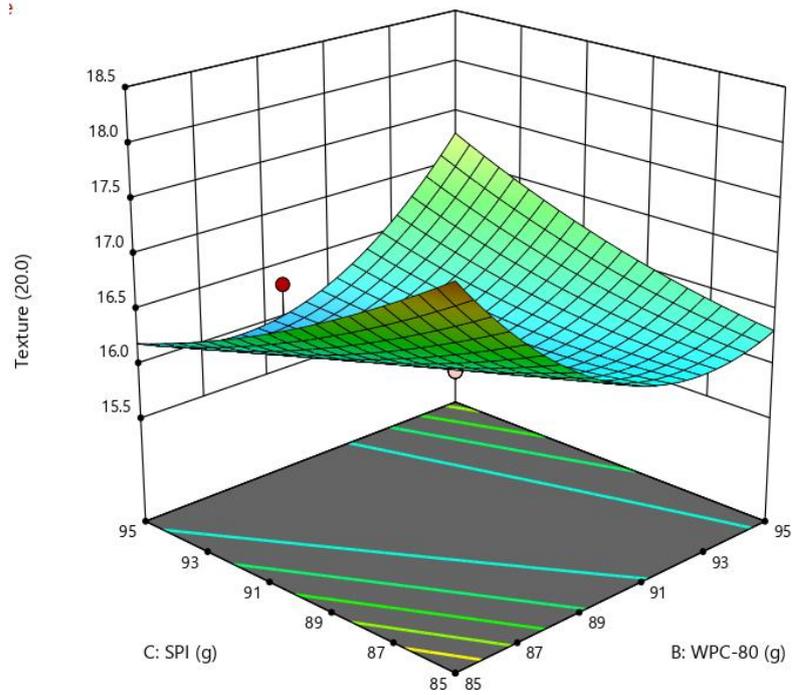
**Fig.4.2.20 Response surface of texture score of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a 9-PHS**



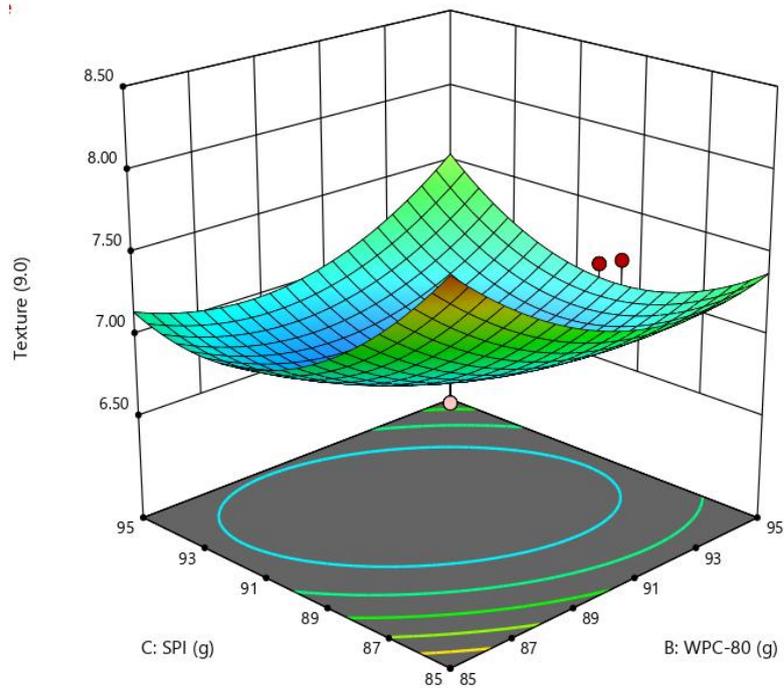
**Fig.4.2.21 Response Surface of Texture Score (20) of P-E Bars as influenced by level of Crispiess (A) and SPI (C) on a CSC**



**Fig.4.2.22 Response surface of texture score of P-E Bars as influenced by level of Crispiess (A) and SPI (C) on a 9-PHS**



**Fig.4.2.23 Response Surface of Texture Score (20) of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**



**Fig.4.2.24 Response Surface of Texture Score of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a 9-PHS**

**4.2.2.1.5 Response Surface of Serving Size Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (15) and a 9-PHS**

Serving size is significant in sensory assessment for standardization, portion control, sensory attribute perception, customer relevance, statistical analysis and directing product development. It assures the consistency, accuracy and meaningful interpretation of sensory data, resulting in better understanding and optimization of food items. Protein bar serving size is critical in managing the intake of necessary nutrients such as carbs, proteins, lipids and other vital components. It acts as a guide for people to efficiently regulate their portion sizes and manage their calorie intake.

The Protein-Energy Bars were assessed using a CSC with the maximum score of 15 and a 9-PHS and the portion size ratings varied from 13.6 to 14.4 on a CSC and 8.00 to 8.48 on a 9-PHS, as shown in table 4.2.2 and 4.2.3. Among the several formulae evaluated, the formula having 7.3 per cent (45g) Crispies, 14.5 per cent (90g) WPC-80 and 14.5 per cent (90g) SPI, (Run No. 1, 3, 11, 13 and 20) received the lowest scores on a CSC while the formula having 7.3 per cent (45g) Crispies, 15.3 per cent (95 g) WPC-80 and 13.7 per cent (85g) SPI received the highest scores on a CSC. On a 9-PHS, run no.12 obtained the lowest rating for serving size, with 8.1 per cent (50g) Crispies, 13.7 per cent (85g) WPC-80 and 15.3 per cent (95 g) SPI. The panellists gave the highest rating to Run no.7, which included 7.3 percent (45 g) Crispies, 14.5 percent (90 g) WPC-80 and 13.7 percent (85 g) SPI on a 9-PHS.

The analysis presented in table 4.2.4 and 4.2.5 reveals a high coefficient of determination ( $R^2$ ) value of 0.85 and 0.88, respectively on a CSC and a 9-PHS indicating that the regression model effectively captures the variability in the data for the serving size of the protein bars. Moreover, the APV of 8.29 (CSC) and 10.38 (9-PHS) surpasses the desired minimum threshold of 4.00, indicating that the model provided a reliable and precise estimation of the serving size. Additionally, the significant Model F-value of 6.54 (CSC) and 7.98 (9-PHS) signifies that the overall model had a statistically significant impact on the serving size of the protein bars. These findings support the suitability and accuracy of the model in understanding and predicting variations in the serving size of the bars.

## *Results and Discussion*

The results from table 4.2.4 indicated that the linear effects of Crispies (C), WPC-80 (B) and SPI (C) on the CSC did not show a significant effect on the serving size of the Protein-Energy Bars. The coefficients of -0.027 for Crispies, 0.052 for WPC-80 and -0.049 for SPI suggested that changes in these factors within the given experimental ranges did not have a statistically significant impact on the serving size. In other words, altering the amounts of Crispies, WPC-80, or SPI in the formulation did not result in notable changes in the perceived serving size of the Protein-Energy Bars, as evaluated by the CSC. On a 9-PHS as indicated in the table 4.2.5 decrease in the percentage of Crispies and SPI is associated with an increase in the serving size of the bars, as indicated by the negative coefficients of -0.056 and -0.114 respectively, with a significance level of  $p < 0.05$ . These findings suggest that higher proportions of Crispies and SPI in the formulation did not result into the acceptance of a higher serving sizes of the bars. The linear impact of WPC-80 on serving size, on the other hand, was not statistically significant at the specified level of significance ( $p < 0.05$ ). When all other factors are kept constant, the coefficient of 0.012 indicated that WPC-80 had little impact on serving size. As a result, as compared to Crispies and SPI, the percentage of WPC-80 may not have a significant influence on serving size.

The interactive effects refer to the combined influence of two or more independent variables (Crispies, WPC-80 and SPI) on the dependent variable (Serving Size) of the Protein-Energy Bars. Based on the values presented in table 4.2.4 and 4.2.5, the interactive effect of Crispies-WPC-80 (AB) was found to have a statistically significant negative impact on both the CSC and 9-PHS. The coefficient of -0.136 (CSC) and -0.081 (9-PHS) at  $p < 0.05$  indicated that when Crispies and WPC-80 are combined, there is a negative influence on the serving size ratings. Similarly, the interactive effect of Crispies-SPI (AC) was found to be statistically significant at a significance level of  $p < 0.05$ . It exhibited a negative effect on the serving size ratings on the 9-PHS, indicated by the coefficient of -0.070. However, when assessed on the CSC, the coefficient of -0.068 suggests a negative but non-significant effect. In the case of the interactive effect of WPC-80-SPI (BC), the coefficient of -1.27 suggests a negative but non-significant effect on the serving size scores as assessed on the CSC. However, on the 9-PHS, the coefficient of 0.037 indicated a positive but non-significant relationship at  $p < 0.05$ .

## *Results and Discussion*

In table 4.2.4 and 4.2.5, the quadratic terms or squared factors represent the squared values of the independent variables, indicating the effect of ingredients at the highest level used in product standardization. The quadratic term for Crispies ( $A^2$ ) was found to be significant with a coefficient of 0.209 ( $p < 0.05$ ) on the CSC (Composite Score Card), suggesting a positive effect on serving size. However, on the 9-PHS (9-Point Hedonic Scale), the coefficient of -0.029 indicated a non-significant negative effect. On the other hand, the quadratic term for WPC-80 ( $B^2$ ) was found to be non-significant both on the CSC (-0.037) and the 9-PHS (0.020), indicating that it did not have a significant impact on serving size according to the given statistical analysis. Regarding the quadratic term for SPI ( $C^2$ ), it was reported to be significant with a coefficient of 0.199 on the CSC and 0.127 on the 9-PHS, both at a significance level of  $p < 0.05$ .

The regression equations describing the effect of the independent variables on the Serving Size of the P-E Bars in terms of actual level of variables is given as:

### **On a Composite Score Card:**

$$\begin{aligned} \text{Out of 15} &= 13.69 - 0.0273 A + 0.0523 B - 0.0495 C - 0.1364 AB - 0.0682 AC \\ &+ 0.0000 BC + 0.2093 A^2 - 0.0369 B^2 + 0.1990 C^2 \end{aligned}$$

### **On a 9-Point Hedonic Scale:**

$$\begin{aligned} \text{Out of 9.0} &= +8.11 - 0.0561 A + 0.0118 B - 0.1143 C - 0.0808 AB - 0.0702 \\ &AC + 0.0373 BC - 0.0296 A^2 + 0.0204 B^2 + 0.1272 C^2 \end{aligned}$$

Where,

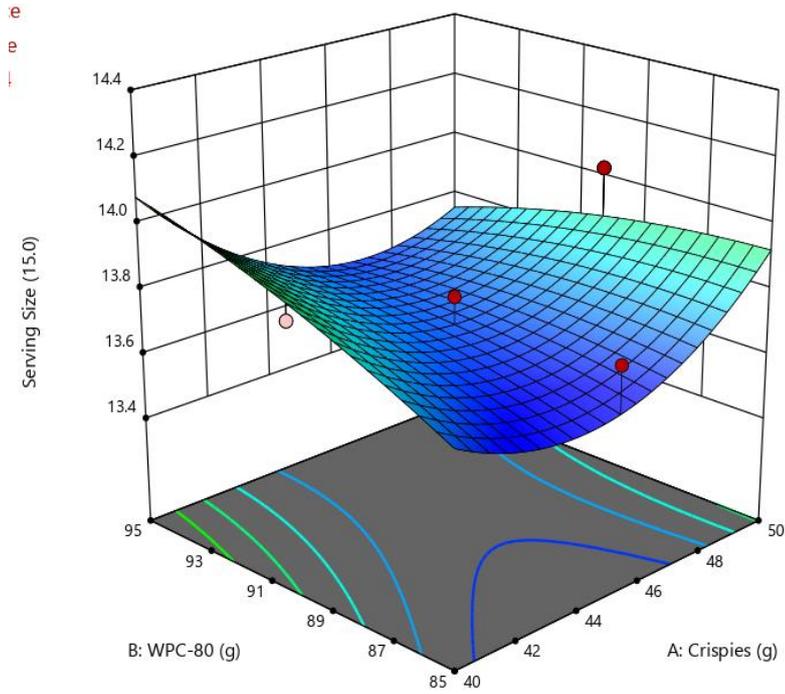
A - Crispies, B- WPC-80 and C - Soy Protein Isolate SPI

According to the regression equation for the CSC, the quantity of Crispies, WPC-80 and SPI in the protein bars had an impact on the serving size score. Increasing the quantity of WPC-80 and SPI may result in a minor gain in the serving size score, however Crispies and WPC-80, as well as Crispies and SPI, may have negative impacts. Also considered were the correlations between Crispies and the serving size score, as well as the quadratic impacts of Crispies and SPI.

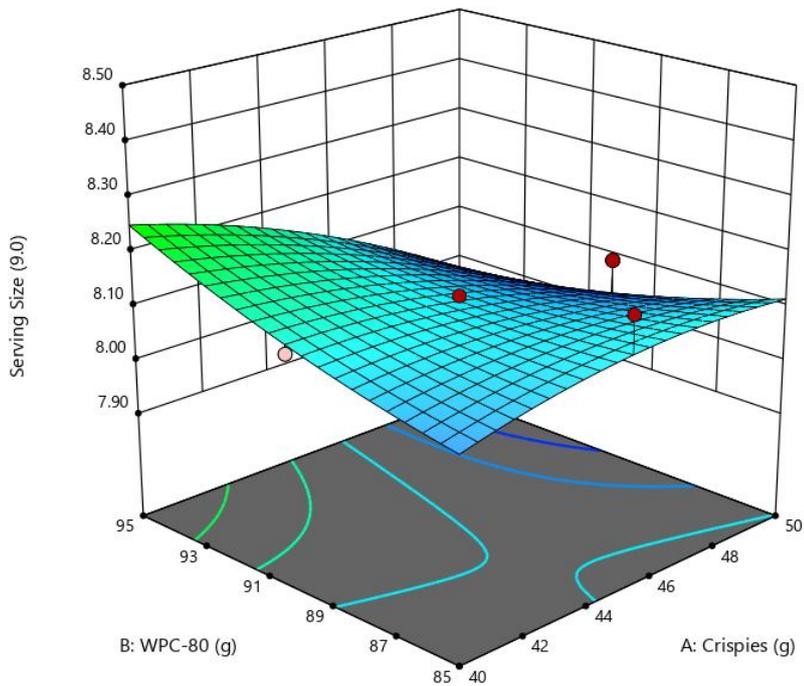
## *Results and Discussion*

For a 9-PHS, the constant term, 8.11 represents the expected serving size score when all the independent variables were set to zero. In summary, the model indicated that the quantity of Crispies and SPI in protein bars may have a negative impact on the serving size score. WPC-80, on the other hand, may have a minor favourable impact. The interplay of Crispies and WPC-80, as well as the combination of Crispies and SPI, may have an additional impact on the serving size score. Furthermore, the connections between Crispies and the serving size score, as well as WPC-80 and SPI, may not be linear and may display quadratic effects.

The three-dimensional response surface plots as presented in Figures 4.2.25 to 4.2.30 gave a useful insight into how various parameters and their interactions impact the Protein-Energy Bars serving size score. For a CSC scores the combination of Crispies and WPC-80 as well as Crispies and SPI had a negative effect on the serving size score. However, the combination of WPC-80 and SPI did not significantly impact the serving size score. Moreover, on a 9-PHS the three-dimensional response surface plots and regression model coefficients, the graphs revealed that the interaction between Crispies-WPC-80 and Crispies-SPI had a negative influence on the serving size score. In contrast to the previous interactions, the interaction between WPC-80 and SPI has a positive effect on the serving size score. Furthermore, the positive coefficients for  $A^2$ ,  $B^2$  and  $C^2$  indicate that increasing the quantity of Crispies, WPC-80 and SPI separately has a positive quadratic influence on the serving size score.



**Fig.4.2.25 Response Surface of Serving-Size Score (15) of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



**Fig.4.2.26 Response surface of Serving-Size score of P-E Bars as influenced by level of Crispies (A) and WPC-80 (B) on a 9-PHS**

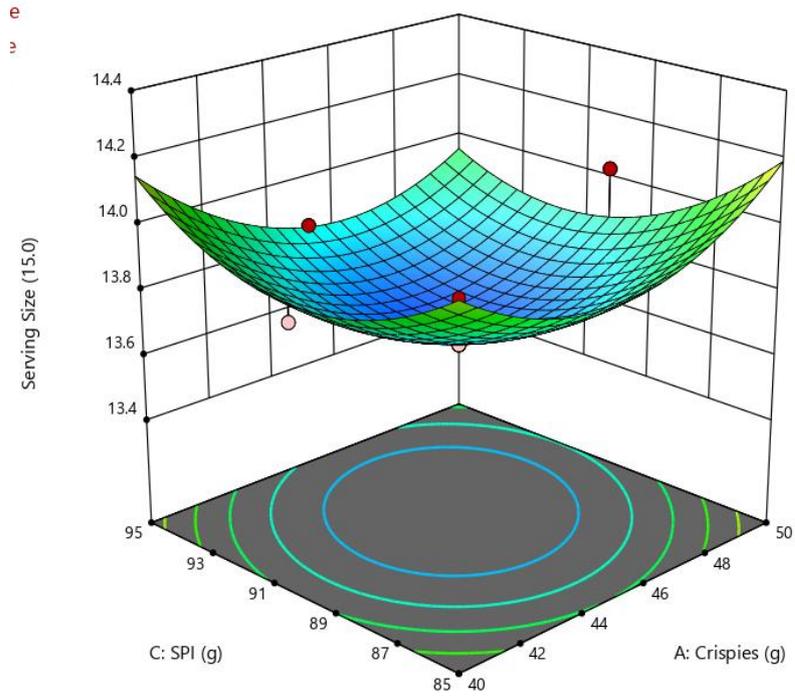


Fig.4.2.27 Response Surface of Serving-Size Score (15) of P-E Bars as influenced by level of Crispies (A) and SPI (C) on a CSC

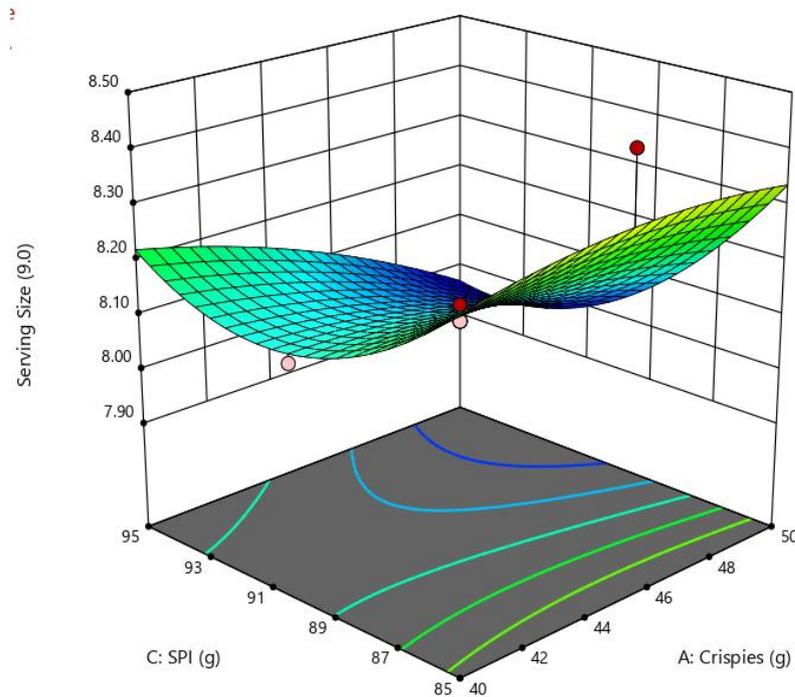
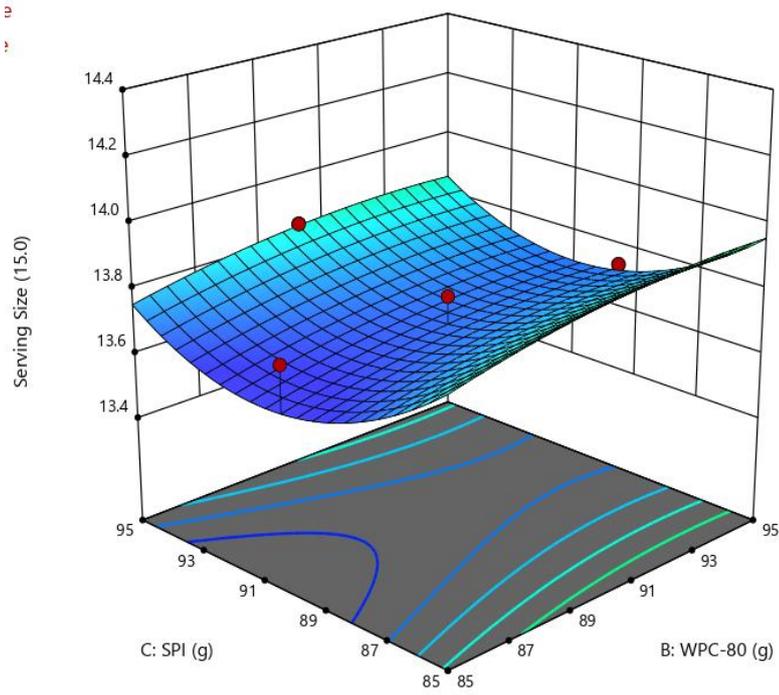
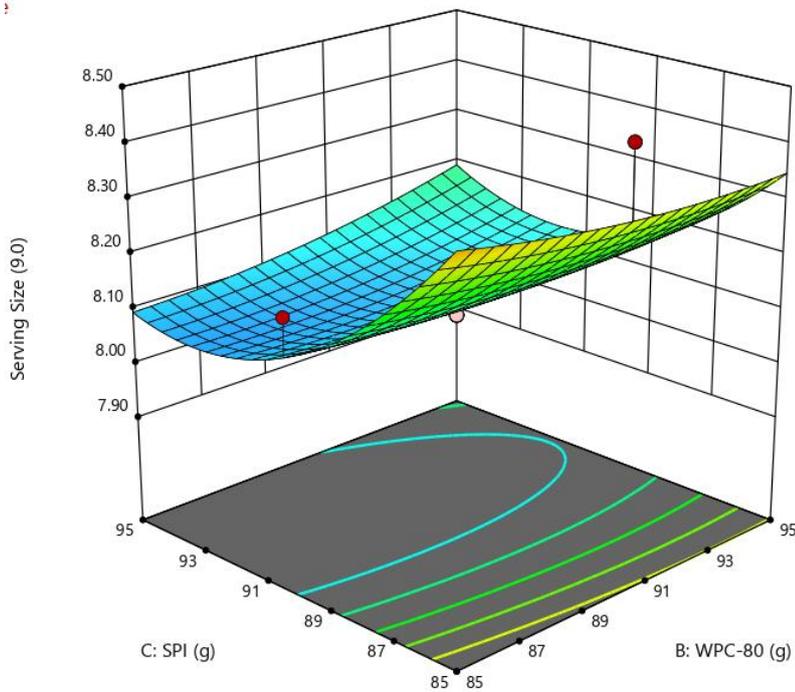


Fig.4.2.28 Response surface of Serving-Size score of P-E Bars as influenced by level of Crispies (A) and SPI (C) on a 9-PHS



**Fig.4.2.29 Response Surface of Serving-Size Score (15) of Protein-Energy Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**



**Fig.4.2.30 Response surface of Serving-Size score of Protein-Energy Bars as influenced by level of WPC-80 (B) and SPI (C) on a 9-PHS**

**4.2.2.1.6 Response Surface of Mouthfeel Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (10)**

Mouthfeel refers to the tactile and textural sensations experienced in the mouth when eating or drinking. It is a key quality in the sensory assessment of protein energy bars since it gives useful information regarding the texture, consistency and overall sensory experience of the product. Mouthfeel in the context of protein energy bars relates to the perceived smoothness, creaminess, grittiness, chewiness, stickiness and moisture level of the bar. It describes how the bar crumbles or breaks while biting, how it feels during chewing and how it coats the mouth throughout consumption.

The mouthfeel of the Protein-Energy Bars was assessed using a CSC with a maximum score of 10, with scores ranging from 7.9 to 8.9, as presented in table 4.2.2. Among the various formulations tested, the one with 7.3 per cent (45g) Crispies, 14.5 per cent (90g) WPC-80 and 15.3 per cent (95g) SPI (run number: 6) received the lowest scores for mouthfeel, according to the panel members' evaluations. Conversely, the formulations with 6.5 per cent (40g) Crispies, 13.7 per cent (85g) WPC-80 and 13.7 per cent (85g) SPI (run number: 10) and 6.5 per cent (40g) Crispies, 15.3 per cent (95g) WPC-80 and 15.3 per cent (95g) SPI (run number: 19) received the highest scores for mouthfeel in the P-E Bars' evaluation.

The coefficient of determination ( $R^2$ ) is a statistical measure that indicates the proportion of variability in the dependent variable that is accounted for by the regression model. In the case of the data presented in table 4.2.4 for the mouthfeel of the protein bars, the high  $R^2$  value of 0.84 suggested approximate 84 per cent of the variability in the mouthfeel can be explained by the independent variables included in the model. The Model F-Value is a measure of the overall significance of the regression model. The value of 5.95 suggests that the model had a statistically significant impact on the mouthfeel of the protein bars. This means that the independent variables included in the model collectively contribute to explaining the variation in the mouthfeel scores. The APV, also known as the Signal-to-Noise Ratio, provided an assessment of the precision and reliability of the model predictions. In this case, the APV of 8.01 exceeded the minimum threshold of 4.00. This indicated that the model provides a reliable and precise estimation of the mouthfeel of the protein bars, suggesting that the model can effectively predict the mouthfeel scores with a good level of accuracy.

## *Results and Discussion*

According to the results presented in table 4.2.4, the linear effects of Crispies (A) and SPI (C) on the mouthfeel of the Protein-Energy Bars were found to be statistically significant and negative. The linear regression coefficient for Crispies (A) was -0.152 and for SPI (C) it was -0.219, both at a significance level of  $p < 0.05$ . However, the linear effect of WPC-80 (B) on the mouthfeel of the Protein-Energy Bars was found to be non-significant, with a regression coefficient of -0.036. This means that the amount of WPC-80 in the formulation did not have a significant impact on the mouthfeel of the bars, as determined by the statistical analysis.

The values presented in table 4.2.4 indicate that the interactive effects of Crispies-WPC-80 (AB) and Crispies-SPI (AC) on the mouthfeel of the Protein-Energy Bars were found to be negative but non-significant at  $p < 0.05$ . The interactive effect of Crispies-WPC-80 (AB) had a coefficient of -0.091, while the interactive effect of Crispies-SPI (AC) had a coefficient of -0.057. However, the combined effect of WPC-80-SPI (BC) on mouthfeel, indicated by a partial regression coefficient of 0.155, was found to be significant at a significance level of  $p < 0.05$ . This suggests that the presence and amount of combination of WPC-SPI in the Protein Energy Bars had a significant independent effect on the mouthfeel, regardless of the other factors or interactions.

According to the findings in table 4.2.4, the quadratic terms of Crispies ( $A^2$ ) and SPI ( $C^2$ ) had no influence on the mouthfeel of the Protein-Energy Bars. Crispies ( $A^2$ ) quadratic term exhibited a negative non-significant impact with a value of -0.101 at a significance level of  $p < 0.05$ . Similarly, with a value of 0.043, the quadratic component of SPI ( $C^2$ ) exhibited a minor non-significant impact. The quadratic term of WPC-80 ( $B^2$ ), on the other hand, had a considerable influence on the mouthfeel of the Protein-Energy Bars. This implies that the squared value of WPC-80 at the maximum level employed in product standardization had a considerable impact on mouthfeel with a coefficient of 0.323 at a significance level of  $p < 0.05$ . The findings show that, while the quadratic terms of Crispies and SPI had no significant influence on mouthfeel, the quadratic term of WPC-80 had a substantial impact on the mouthfeel of the Protein-Energy Bars.

## *Results and Discussion*

The following multiple regression equation was created to predict Mouthfeel as impacted by distinct variables in terms of coded factors on a Composite Score Card:

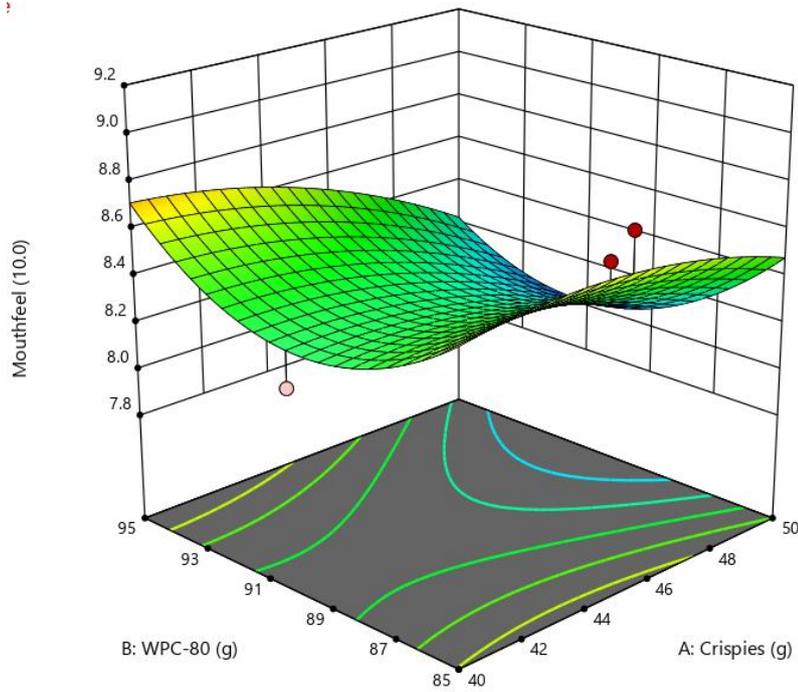
$$\text{Out of 10} = 8.29 - 0.1515 A - 0.0364 B - 0.2197 C - 0.0909 AB - 0.0568 AC + 0.1553 BC - 0.1012 A^2 + 0.3230 B^2 + 0.0427 C^2$$

Where,

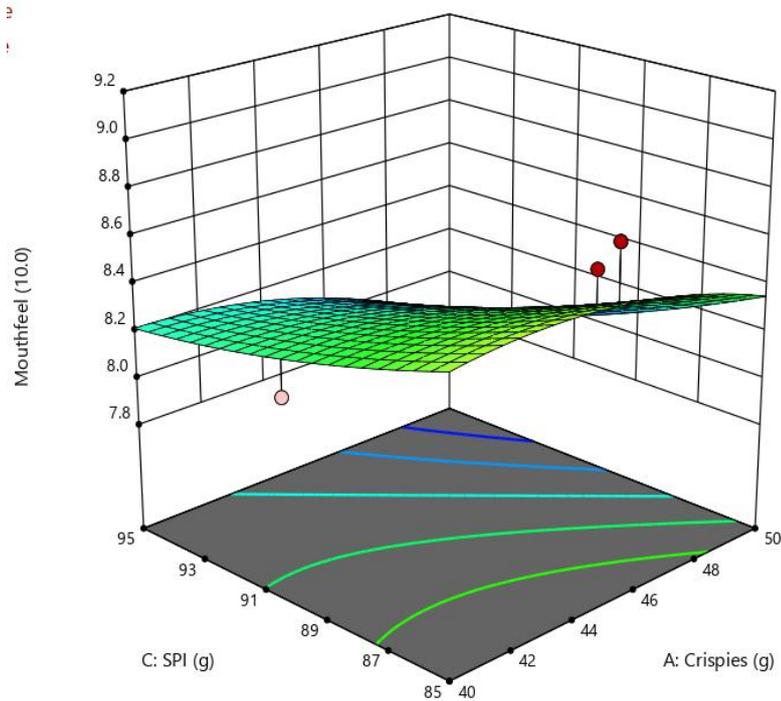
A - Crispies, B- WPC-80 and C - SPI

According to the regression model, the quantity of Crispies, WPC-80 and SPI in the protein bars may impact the mouthfeel score. The constant term (8.29) represents the expected mouthfeel score when all the independent variables are set to zero. Increasing the quantity of Crispies and WPC-80 may reduce the mouthfeel score, however increasing the amount of SPI may have a significant negative impact. The combination of Crispies and WPC-80, as well as Crispies and SPI, may have harmful consequences. The interplay between WPC-80 and SPI, on the other hand, has a favourable influence on the mouthfeel score. Furthermore, the correlations between Crispies and mouthfeel score, as well as the quadratic influence of WPC-80, should be considered.

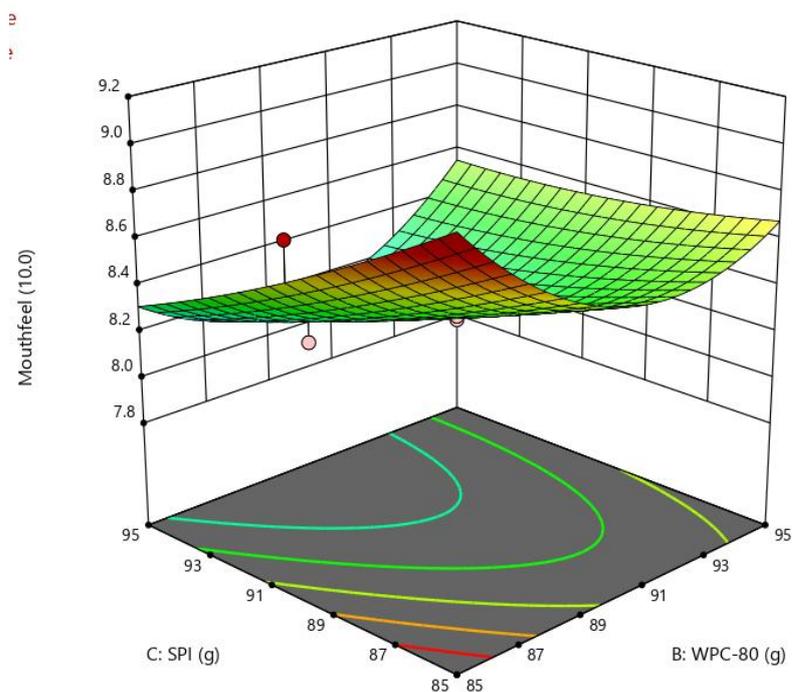
The three-dimensional response surface plots as presented in Figures 4.2.31 to 4.2.33 gave an insight into how various parameters and their interactions impact the Protein-Energy Bars serving size score. It was expressed by the graphs that the independent variables and their interactive effects did not have any positive influence on the mouthfeel scores of the bars. However, a positive effect was also seen on the interactive effect of WPC-80 and SPI on the mouthfeel scores as measured on CSC.



**Fig.4.2.31 Response Surface of Mouthfeel (10) of P-E Bar as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



**Fig.4.2.32 Response Surface of Mouthfeel (10) of Protein-Energy Bars as influenced by level of Crispies (A) and SPI (C) on a CSC**



**Fig.4.2.33 Response Surface of Mouthfeel (10) of Protein-Energy Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**

**4.2.2.1.7 Response Surface of Absence of Defects Score of P-E Bars as influenced by Crispies, WPC-80 and SPI on a CSC (10)**

The lack of defects is a critical factor in the sensory assessment of protein energy bars. It refers to the product's quality in terms of the absence or presence of any unpleasant or off-putting qualities or defects. In other words, it determines if the protein energy bars have any visible flaws or blemishes that may reduce their overall acceptance.

The Protein-Energy Bars were evaluated for their evaluation of defects (absence of defects) and the values were presented in the Experimental Design Matrix and Sensory Attributes (table 4.2.2). The sensory scores for absence of defects, rated on a Composite Score Card with a maximum score of 10, ranged from 8.3 to 9.0 as presented in Table 4.3. Among the various formulations evaluated based on the sensory scores, the bars formulated with 7.3 per cent (45g) Crispies, 14.5 per cent (90g) WPC-80 and 14.5 per cent (90g) SPI (run number: 1, 3, 11, 13 and 20), as well as the bars formulated with 8.1 per cent (50g) Crispies, 14.5 per cent (90g) WPC-80 and 14.5 per cent (90g) SPI

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(run number: 17), received the lowest scores for absence of defects. These formulations were perceived to have a likelihood of exhibiting flaws or imperfections. On the other hand, the bars formulated with 6.5 per cent (40g) Crispies, 15.3 per cent (95g) WPC-80 and 13.7 per cent (85g) SPI (run number: 5), 6.5 per cent (40g) Crispies, 13.7 per cent (85g) WPC-80 and 13.7 per cent (85g) SPI (run number: 10) and 6.5 per cent (40g) Crispies, 15.3 per cent (95g) WPC-80 and 15.3 per cent (95g) SPI (run number: 19) received the highest scores for absence of defects. These formulations were perceived to have a lower likelihood of exhibiting flaws or imperfections, indicating a higher quality in terms of absence of defects.

The coefficient of determination ( $R^2$ ) is a statistical metric that measures the amount of variation in the dependent variable that the regression model can explain. The AOD characteristic in table 4.2.4 revealed a significant association with the dependent variable, as evidenced by the high  $R^2$  value of 0.92 when assessed using the Composite Score Card by the Semi trained Panel (37). The Model F-Value of 13.48 supports the statistical significance of AOD's effect on the Product. Furthermore, the APV of 11.86 indicated that the model predictions are extremely accurate and reliable.

Based on the information presented in table 4.2.4, the independent variables Crispies (A), WPC-80 (B) and SPI (C) have a statistically significant negative influence on the AOD attribute at a linear level ( $p < 0.05$ ). Crispies and SPI have linear coefficients of -0.135 and -0.064, respectively. Both coefficients are negative, indicating that increasing Crispies or SPI leads to a drop in AOD. WPC-80, on the other hand, has a detrimental impact on AOD, although not statistically significant at the  $p < 0.05$  level. This shows that the observed relationship between WPC-80 and AOD might be attributable to chance and is not statistically significant.

The combined influence of two or more independent factors on the dependent variable is referred to as an interactive effect. It indicated that the relationship between the independent variables and the dependent variable is not simply cumulative but is influenced by variable interaction. The interaction effect between Crispies-WPC-80 (AB) was found to be negatively significant at the significance level of  $p < 0.05$ , with the coefficient of -0.106. This indicated that the relationship between Crispies and the dependent variable is not continuous over all WPC-80 levels. This interaction effect indicated that the combined impact of AB on the AOD is substantial. However, the value of -0.106 indicated that the interaction between Crispies and SPI has no

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statistically significant influence on the dependent variable. On the other hand, at the stated significance level ( $p < 0.05$ ), the interaction effect between WPC-80-SPI (BC) was shown to be statistically significant with a coefficient of 0.121. This summarizes that the interaction between WPC-80-SPI (BC) had a substantial effect on the dependent variable, indicating their combined influence influences on the attribute (AOD).

The squared value of an independent variable is represented by a quadratic term. The highest number of components employed in the context of product standardisation may have a different impact on the end-product than the linear effect alone. By using a quadratic component, any non-linear connection between the ingredient level and product standardisation might be captured. Table 4.2.4 shows that for Crispies ( $A^2$ ), the quadratic terms had a small non-significant effect on the flawlessness of the Protein-Energy Bars, with partial regression coefficient of 0.008 at  $p < 0.05$ . On the other hand, the partial regression coefficients of 0.153 and 0.201 for the quadratic terms of WPC-80 ( $B^2$ ) and SPI ( $C^2$ ), respectively, at  $p < 0.05$  indicate a good impact of the independent variables on the impeccability of the bars. These coefficients suggest that the quadratic terms of WPC-80 and SPI had a statistically significant positive influence on the Absence of Defects of the bars.

Multiple regression equation generated to predict the AOD as affected by different factors in terms of coded factors is as follows:

$$\text{Out of 10} = 8.38 - 0.1350 A - 0.0273 B - 0.0641 C - 0.1057 AB + 0.0155 AC + 0.1208 BC + 0.0079 A^2 + 0.1528 B^2 + 0.2005 C^2$$

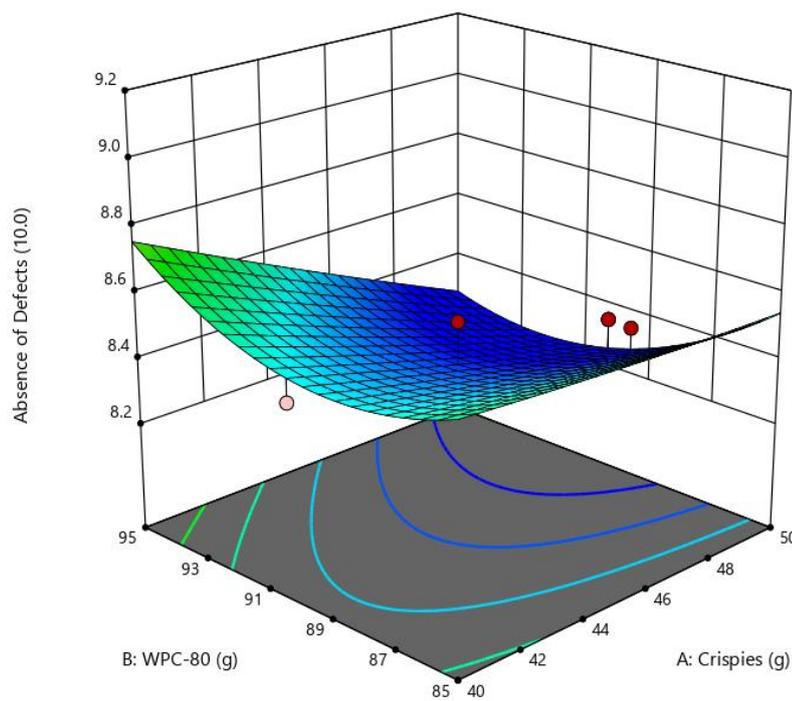
Where,

A - Crispies, B- WPC-80 and C - SPI

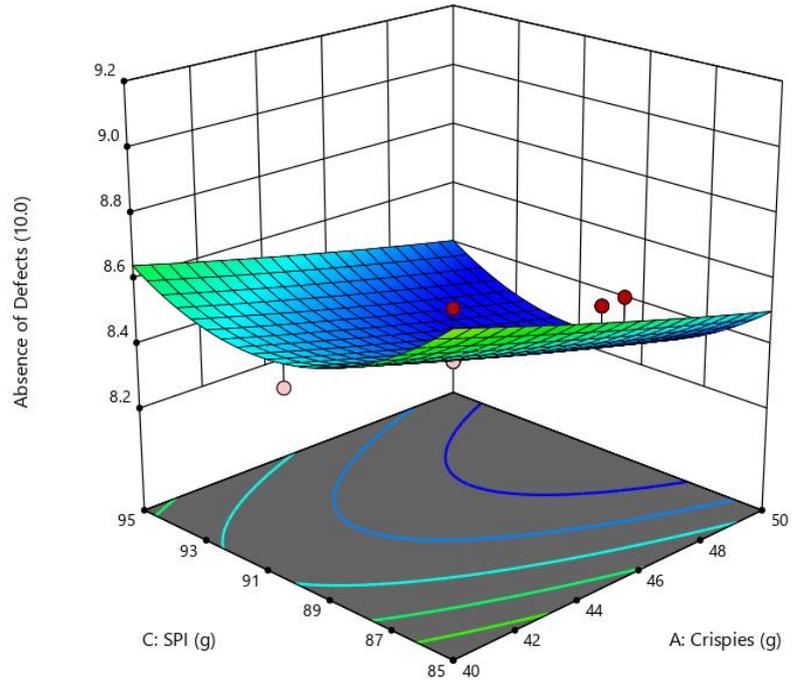
According to the regression equation, the quantity of Crispies, WPC-80 and SPI in the protein bars may affect the lack of faults score. The amount of Crispies, WPC-80 and SPI in the protein bars may impact the absence of defects score, according to the regression equation. The Protein-Energy Bars on a Composite Score Card are influenced by the numerous factors and their interactions. The interaction impact of Crispies-SPI, WPC-80-SPI and the quadratic term of Crispies and WPC-80 on the flawlessness of the bars was shown to have a favourable influence.

## Results and Discussion

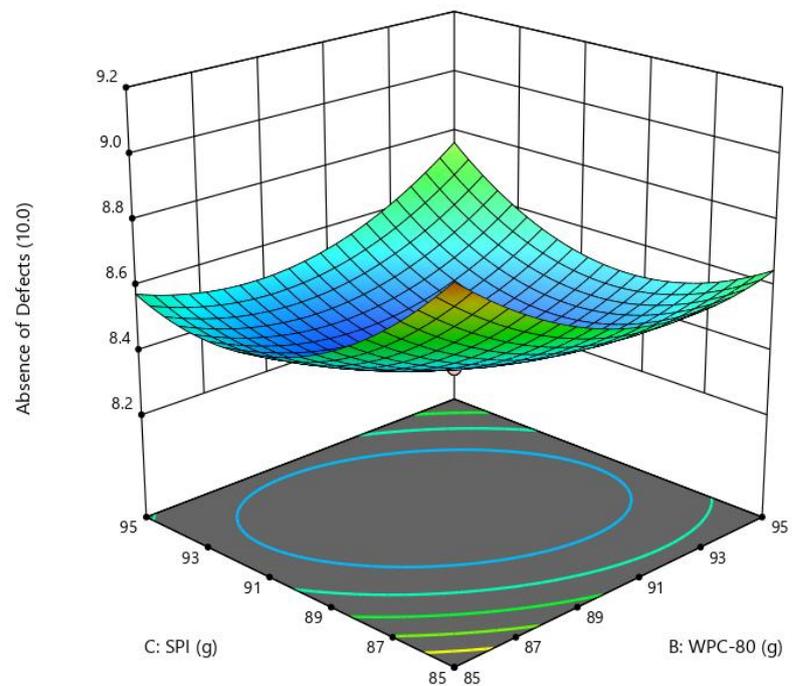
The three-dimensional response surface plots as presented in Figures 4.2.34 to 4.2.36 gave an insight into increasing the quantity of Crispies and WPC-80 may reduce the absence of flaws score, however increasing the amount of SPI may have a little negative impact. The combination of Crispies and WPC-80, as well as Crispies and SPI, may have harmful consequences. The combination between WPC-80 and SPI, on the other hand, has a favourable influence on the absence of defects score. Also considered are the correlations between Crispies and the lack of flaws score, as well as the quadratic influence of SPI.



**Fig.4.2.34 Response Surface of AOD (10) of P-E Bar as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



**Fig.4.2.35 Response Surface of AOD (10) of P-E Bar as influenced by level of Crispies (A) and SPI (C) on a CSC**



**Fig.4.2.36 Response Surface of AOD (10) of P-E Bar as influenced by level of WPC-80 (B) and SPI (C) on a CSC**

**4.2.2.1.8 Response Surface of Overall Score of P-E Bar as influenced by Crispies, WPC-80 and SPI on a CSC (10)**

Sensory assessment is examining several features or characteristics of a product, such as appearance, taste, aroma, flavor, texture and so on. Calculating an overall score provides for a simpler interpretation and summation of the sensory experience, delivering a single number that reflects the overall impression of the product. Overall scores take into consideration the combined influence of all sensory qualities, including both positive and negative features.

Protein-Energy Bars were evaluated on a CSC for overall rating with a maximum score of 10. The scores ranged from 8.0 to 8.4 for the different formulae (20) tested as shown in table 4.2.2. Among the different formulae tested the one having with 6.5 per cent (40g) Crispies, 15.3 per cent (95g) WPC-80 and 13.7 per cent (85g) SPI (run number: 5), scored the highest overall scores while, run number 15, which consisted of 8.1 per cent (50g) Crispies, 15.3 per cent (95g) WPC-80 and 13.7 per cent (85g) SPI and run number:17, which had 8.1 per cent (50g) Crispies, 14.5 per cent (90g) WPC-80 and 14.5 per cent (90g) SPI scored the lowest in terms of overall rating.

The coefficient of determination ( $R^2$ ) of 0.82 in table 4.2.4 suggested that the model was well suited to the data. The APV of 8.20, which was much more than the minimum desired value of 4.00, indicated that the response was an appropriate choice for navigating the design. Furthermore, the Model F-Value of 5.21 indicated that the model had a statistically significant influence on the P-E Bars' Overall rating.

The linear impact of Crispies (A) on the total scores of the Protein-Energy Bars was determined to be statistically significant and negative, with a coefficient of -0.142 at a significance level of  $p < 0.05$ , according to the results presented in table 4.2.4. WPC-80 (B) had a non-significant and negative linear impact, as evidenced by a coefficient of -0.027 (not statistically significant). The linear impact of SPI (C) was determined to be statistically significant at  $p < 0.1$ , with a coefficient of -0.090 indicating a negative effect. The findings show that Crispies had a substantial negative linear influence on the total Protein-Energy Bar ratings, while WPC-80 and SPI had non-significant but negative linear effects.

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The interactive effects refer to the influence of the joint effects of two or more independent variables on the dependent variable. The value shown in table 4.2.4 indicated a negative significance of the interactive effect between Crispies-WPC-80 (AB) and the overall scores of the Bars with the value of - 0.102 at  $p < 0.1$ . While the effect was found to be statistically non-significant with the value of 0.027 for Crispies-SPI (AC). The interactive effect of WPC-80-SPI (BC) was found to have a significance with the value of 0.098 at  $p < 0.1$ .

A quadratic term in a regression model indicates the squared value of an independent variable and depicts the influence of ingredients at the greatest level utilized in product standardization. Table 4.2.4 shows that the influence of the quadratic term of Crispies ( $A^2$ ) on the overall scores of the bars as measured by the Composite Score Card was statistically and negatively non-significant - 0.079. Furthermore, at a value of 0.131, the influence of the SPI's quadratic component ( $C^2$ ) was shown to be statistically insignificant. However, the influence of the quadratic component of WPC-80 ( $B^2$ ) on the overall rating of the bars was significant at  $p < 0.05$  with a value of 0.254.

Multiple regression equation generated to predict the overall score as affected by different factors in terms of coded factors is as follows:

$$\text{Out of 10} = 8.12 - 0.1424 A - 0.0273 B - 0.0905 C - 0.1023 AB + 0.0265 AC + 0.0985 BC - 0.0794 A^2 + 0.2539 B^2 + 0.1306 C^2$$

Where,

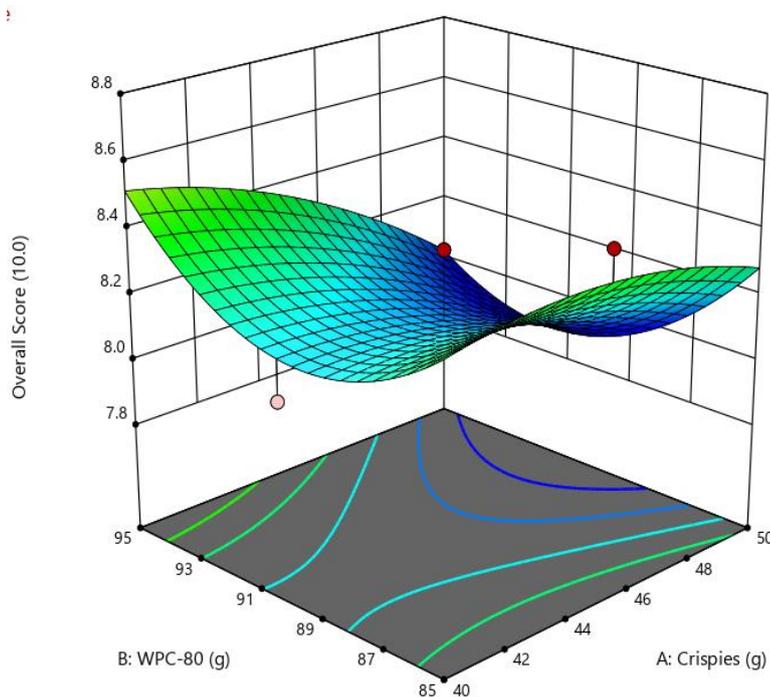
A - Crispies, B- WPC-80 and C - SPI

The regression equation suggested that the amount of Crispies, WPC-80 and SPI in the protein bars can influence the overall score on the composite score card. The interactive effect of Crispies-SPI implies that when both Crispies and SPI were present in the protein bars, their combined effect positively affects the overall score. This suggests that the interaction between Crispies and SPI enhanced the overall sensory experience, or other aspects measured by the composite score card. Similarly, the interactive effect of WPC-80-SPI indicated that when both WPC-80 and SPI were present in the protein bars, their combined effect had a positive influence on the overall score. This suggests that the interaction between WPC-80 and SPI also contributed positively to the overall

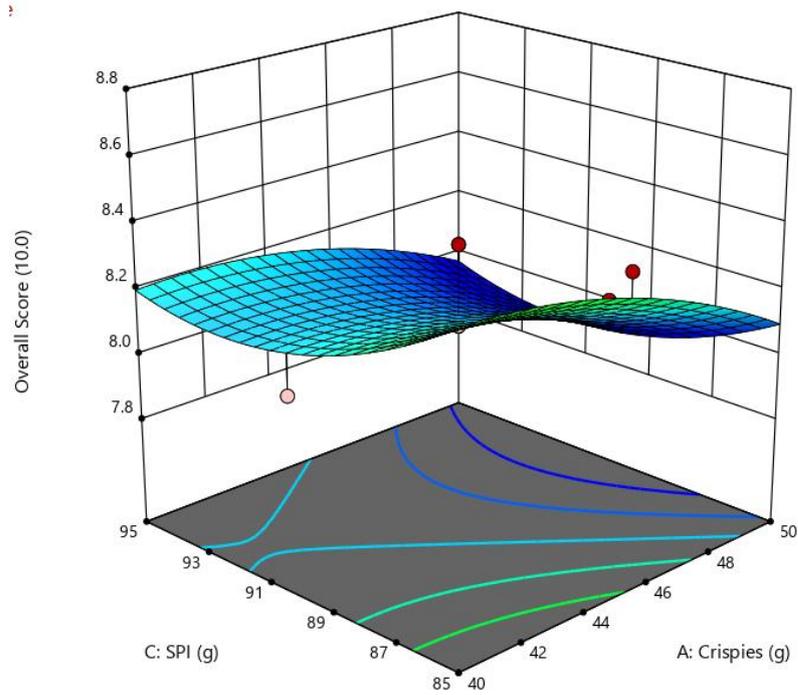
## Results and Discussion

quality or attributes. Additionally, the quadratic terms of WPC-80 and SPI in the equation suggest that there was a non-linear relationship between the amount of WPC-80 or SPI and the overall score. The positive influence of these quadratic terms implies that increasing the amount of WPC-80 or SPI beyond certain thresholds may enhance the overall scores of the protein energy bars.

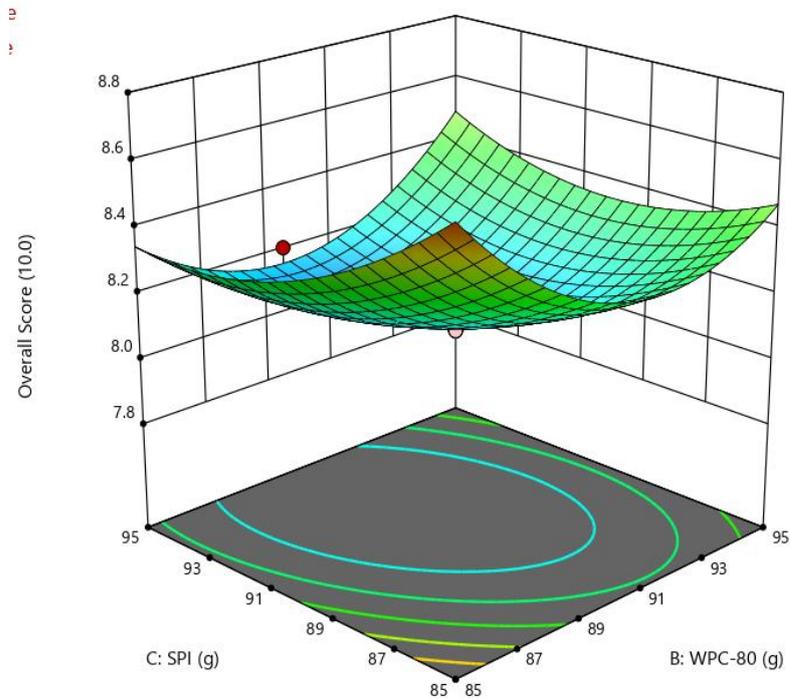
The three-dimensional response surface plots shown in Figures 4.2.37 to 4.2.39 provided significant insight into how different factors and their interactions affect the overall scores of P-E Bars. Increasing the number of Crispies, WPC-80 and SPI may have a detrimental impact on the total score. The combination of Crispies and WPC-80, as well as Crispies and SPI, may have harmful consequences. The relationship between WPC-80 and SPI, on the other hand, has a favourable influence on the total score. Furthermore, the correlations between Crispies and total score, as well as the quadratic influence of WPC-80, should be considered.



**Fig.4.2.37 Response Surface of Overall Score (10) of P-E Bar as influenced by level of Crispies (A) and WPC-80 (B) on a CSC**



**Fig.4.2.38 Response Surface of Overall Score (10) of P-E Bar as influenced by level of Crispies (A) and SPI (C) on a CSC**



**Fig.4.2.39 Response Surface of Overall Score (10) of P-E Bars as influenced by level of WPC-80 (B) and SPI (C) on a CSC**

**4.2.2.1 Optimization of Product Formulation for P-E Bars**

Based on the aforementioned findings, it can be stated that the quality of the P-E Bars is not contingent upon a single primary factor. Instead, all independent variables play a crucial role in defining the characteristics of the P-E Bars. Consequently, the subsequent step involved determining the optimal combination of independent variables capable of producing the expected characteristics of the final product, namely percent of Crispies (A), WPC-80 (B) and SPI (C). To achieve this, numerical optimization was conducted for the process parameters to obtain the optimal formula for the P-E Bars. For the simultaneous optimization of the different responses, Design Expert (8.0.3) software was utilized. Desired goals were selected for each factor and responses on a CSC scale (table 4.2.6) and on a 9-PHS (table 4.2.7).

**Table 4.2.6 Criteria chosen for process optimization of P-E Bars on a CSC**

<b>Sr. No.</b>	<b>Parameter</b>	<b>Units</b>	<b>Goal</b>	<b>Lower Limit</b>	<b>Upper Limit</b>	<b>Level of Importance</b>
<b>1</b>	A: Crispies	g	In range	40	50	4
<b>2</b>	B: WPC-80	g	In range	85	95	4
<b>3</b>	C: SPI	g	In range	85	95	4
<b>4</b>	Appearance	Out of 10	In range	7.97	9.08	3
<b>5</b>	Taste	Out of 15	In range	12.12	13.67	3
<b>6</b>	Flavour	Out of 10	In range	8.12	8.82	3
<b>7</b>	Texture	Out of 20	In range	15.55	18.09	3
<b>8</b>	Mouthfeel	Out of 10	In range	7.91	8.91	3
<b>9</b>	Serving size	Out of 15	In range	13.64	14.36	3
<b>10</b>	Absence of defects	Out of 10	In range	8.35	9.03	3
<b>11</b>	Overall score	Out of 10	In range	8.00	8.79	3

**Table 4.2.7 Criteria chosen for process optimization of P-E Bars on a 9-PHS**

Sr. No.	Parameter	Units	Goal	Lower Limit	Upper Limit	Level of Importance
1	A: Crispies	g	In range	40	50	4
2	B: WPC-80	g	In range	85	95	4
3	C: SPI	g	In range	85	95	4
4	Appearance	Out of 9	In range	7.39	8.30	3
5	Taste	Out of 9	In range	7.42	8.18	3
6	Flavor	Out of 9	In range	7.48	8.09	3
7	Texture	Out of 9	In range	6.58	8.18	3
8	Serving size	Out of 9	Maximize	8.00	8.48	3

The table 4.2.8 displays the optimal combination of independent variables, as recommended by the RSM analysis, for the P-E B. This combination achieves a maximum desirability score of 1. The final product was prepared by following the formulation recommended in table 4.2.8, in conjunction with other predetermined ingredient quantities listed in table 4.2.11.

Tables 4.2.9 and 4.2.10 displays the predicted Sensory properties of optimized P-E B from RSM analysis on a CSC and a 9-PHS respectively. As depicted in the tables, the actual results were obtained through seven replications. The predicted values of the selected criteria/responses, which were used for process optimization, were compared with the corresponding actual values. The findings confirmed that the chosen combination, as outlined at the beginning of the study, yielded the best results in terms of sensory responses. To validate the results statistically, a 't' test was conducted and the calculated 't-values' for all parameters are presented in the tables 4.2.9 and 4.2.10. Since the 't' test values were lower than the critical values from the table, it can be inferred that there were no significant ( $P > 0.05$ ) differences between the predicted and actual values of the responses indicated in tables 4.2.9 and 4.2.10.

**Table 4.2.8 Suggested solution from RSM analysis for P-E Bars**

Solution No.	Solutions			Desirability
	Crispies (g)	WPC-80 (g)	SPI (g)	
1	45	90	85	1

**Table 4.2.9 Comparison of predicted v/s actual values of responses used for process optimization of P-E Bars on a CSC**

Response	P Value	Predicted Value *	Actual Value @	Cal. t-Value#	Level of Significance
Appearance	0.15	8.40	8.49	1.65	NS
Taste	0.46	12.50	12.25	0.79	NS
Flavour	0.11	8.30	8.09	1.89	NS
Texture	0.40	16.40	16.14	0.89	NS
Mouthfeel	0.24	8.50	8.36	1.28	NS
Serving size	0.16	13.90	14.33	1.61	NS
Absence of defects	0.26	8.60	8.72	1.25	NS
Overall score	0.23	8.30	8.46	1.34	NS
Grand total	0.64	85.10	84.86	0.49	NS

\* Predicted values of Design Expert 8.0.3 package  
 @ Actual values are average of seven trials for optimized product  
 # t-values found non-significant at 5 per cent level of significance  
 NS = Non Significant  
 Tabulated t-value = 2.447 (cal. t-value less than tabulated value)

**Table 4.2.10 Comparison of Predicted v/s Actual Values of Responses used for Process Optimization of P-E Bars on a 9-PHS**

<b>Response</b>	<b>P Value</b>	<b>Predicted Value *</b>	<b>Actual Value @</b>	<b>Cal. t-Value#</b>	<b>Level of Significance</b>
<b>Appearance</b>	0.87	7.80	7.81	0.18	NS
<b>Taste</b>	0.99	7.87	8.00	0.02	NS
<b>Flavor</b>	0.22	7.85	7.90	1.36	NS
<b>Texture</b>	0.11	7.38	7.62	1.87	NS
<b>Serving size</b>	0.39	8.35	8.27	0.93	NS
<p><b>* Predicted values of Design Expert 8.0.3 package</b>  <b>@ Actual values are average of seven trials for optimized product</b>  <b># t-values found non-significant at 5 per cent level of significance</b>  <b>NS = Non-Significant</b>  <b>Tabulated t-value = 2.447 (cal. t-value less than tabulated value)</b></p>					

Thus, the optimized formulation for the preparation of Protein-Energy Bars, which achieved maximum sensory scores as analyzed on a Composite Score card and a 9-Point Hedonic Scale, is presented in table 4.2.11. The bars produced using this final optimized formula were subsequently subjected to laboratory analysis.

**Table 4.2.11 Optimized formulation for preparation of P-E Bars**

<b>Sr. No</b>	<b>Component</b>	<b>Proportion (%)</b>
1.	Crispies	7.3
2.	WPC-80	14.5
3.	SPI	13.7
4.	Peanut #	7.3
5.	Chocolate chips	12.9
6.	Sugar	12.9
7.	Ghee	9.7
8.	Malt	9.7
9.	Butter	4.8
10.	Liquid glucose	4
11.	Date powder	0.8
12.	Sesame seeds	0.8
13.	Raisin	0.8
14.	Soy lecithin	0.5
15.	Chia seeds	0.3
<b># Peanuts were added by difference in formula</b>		

**Hypotheses Tested Phase II**

- Based on the findings of phase II, the null hypotheses (Ho) proposed at the start of the investigation is rejected.
- The following alternative hypothesis (H1) are acceptable.
- *There is a significant relationship between the ingredients of the Protein Energy Bar and its sensory attributes, suggesting that adjusting ingredient proportions leads to noticeable improvements in sensory characteristics.*

### **Result Highlights: Phase II**

- **Raw Material Processing:**
  - *The protein content of the ingredients ranged from 23% to 89%, with the highest protein content found in the isolate and concentrate.*
- **Optimization Process Using RSM:**
  - *Design Expert Software (RSM) facilitated the optimization of the Protein-Energy Bar formula, suggesting 20 different experimental runs.*
  - *Based on these suggestions, 20 bars were prepared, each with varying proportions of Crispies, WPC-80 and SPI.*
- **Sensory Evaluation:**
  - *A panel of 37 judges evaluated all 20 bars for sensory characteristics using a CSC and a 9-PHS.*
  - *The analysis revealed that the quadratic model provided a well-fitted representation of the sensory parameters, supported by a large  $R^2$  value approaching 1.00.*
- **Optimization and Validation:**
  - *The APV for all sensory scores exceeded 4.0, indicating the model's suitability for guiding the design.*
  - *The 't' test results indicated no significant difference ( $p > 0.05$ ) between the predicted and actual values of the responses, further affirming the model's accuracy.*
  - *The suggested solution from RSM analysis for the P-E Bars was 7.3% Crispies, 14.5% WPC-80 and 13.7% SPI.*

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

Protein-energy bars provide a convenient and nutrient-rich snacking choice for health-conscious individuals, with a wide range of flavours, formulations and functional ingredients. Yet, the consistency in quality among these bars can vary widely, influenced by factors such as organoleptical properties, physico-chemical composition, texture, microbial safety, shelf-life and production costs. Hence, conducting a comprehensive analysis of these factors is crucial to ensure the production of high-quality protein-energy bars that meet consumer expectations and regulatory standards.

Shelf life, the duration a food maintains acceptable quality, is influenced by factors like formulation, processing, packaging, storage and distribution. Controlled environments, with elevated factors like temperature, are used to accelerate deterioration rates for estimating true shelf life. Accelerated shelf-life testing (ASLT) expedites this process, crucial for new product development. In the study, P-E Bars (70 g unit weight) were stored at 35°C and 70 per cent humidity for 70 days. Samples were analyzed every seven days for chemical composition, texture, sensory attributes and microbiological quality.

#### **4.3 Characterization and Pricing**

The development and production of protein-energy bars require both characterisation and pricing. Characterization refers to the process of understanding and describing the properties and attributes of a product. This includes its chemical, physical, textural, microbial and sensory characteristics. In the context of protein-energy bars, characterization involved analysing factors such as proximate principles, physico-chemical characteristics, texture, sensory properties and shelf-life stability. While price and profitability are determined by costs, characterization ensures that the product satisfies quality and safety criteria. A competitive product's creation requires careful consideration of both quality and affordability. Investigating affordable, underutilised food sources with high nutritional content is necessary to meet this goal (Nadeem et al. 2012).

**4.3.1 Proximate Composition of the P-E Bars**

The proximate composition of the P-E Bar developed using an optimized formula to achieve maximum sensory scores was analyzed to determine its nutritional profile. The results are presented in table 4.3.1, which shows the moisture content, total calorie value and percentages of protein, carbohydrates, crude fat, crude fiber, ash and nitrogen for both 100 g and 70 g servings since most of the bars in the survey had a serving size of 70 g. Moreover, the serving size of 70 was appreciated with high sensory scores by the sensory panel as mentioned in the previous phase. The values were expressed as mean  $\pm$  SD for a 100 g serving size, while the values for a 70 g serving size were obtained through calculation from the formula.

**Table 4.3.1.1 Proximate Chemical Composition and total calorie value of P-E Bars**

Serving Size	Moisture (%)	Total Calorie Value (Kcal)	Protein (%)	Carbohydrate (%)	Crude Fat (%)	Crude Fiber (%)	Ash (%)	Nitrogen (%)
100 g*	6.33 $\pm$ 0.07	505 $\pm$ 0.00	35.81 $\pm$ 0.06	47.64 $\pm$ 0.00	17.78 $\pm$ 0.01	5.90 $\pm$ 0.01	2.29 $\pm$ 0.18	5.18 $\pm$ 0.04
70 g	4.43	354	25.07	33.35	12.45	4.13	1.60	3.63
* Each observation is a mean $\pm$ SD of three replication of the experiment (n=3)								

As shown in the table 4.3.1, the moisture content of the P-E Bar was found to be 6.33  $\pm$  0.07 per cent for a 100 g serving and 4.43 per cent for a 70 g serving. This indicates that the P-E Bar has a relatively low moisture content, which is desirable for shelf stability and texture.

Table 4.3.1 illustrates the total calorie value of the P-E Bar, which was determined to be 505 Kcal for a 100 g serving and 354 Kcal for a 70 g serving. For a physically active individual, this can contribute to meeting their energy needs, especially if they are engaged in intense physical activity. The protein content of the P-E Bar was found to

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be  $35.81 \pm 0.06$  per cent for a 100 g serving and 25.07 per cent for a 70 g serving making the product falling under a high protein food category. The carbohydrate content of the P-E Bar was determined to be  $47.64 \pm 0.00$  per cent for a 100 g serving and 33.35 per cent for a 70 g serving. The crude fat content of the P-E Bar was found to be  $17.78 \pm 0.01$  per cent for a 100 g serving and 12.45 per cent for a 70 g serving.

As indicated in table 4.3.1 the crude fiber content of the P-E Bar was determined to be  $5.90 \pm 0.01$  per cent for a 100 g serving and 4.13 per cent for a 70 g serving. The ash content of the P-E Bar was found to be  $2.29 \pm 0.18$  per cent for a 100 g serving and 1.60 per cent for a 70 g serving. The nitrogen content of the P-E Bar was determined to be  $5.18 \pm 0.04$  per cent for a 100 g serving and 3.63 per cent for a 70 g serving. Nitrogen is essential for the formation of amino acids, the building blocks of proteins, which are vital for growth, repair and maintenance of tissues in the body (Phillips et al. 2012).

In a study by Mridula et al. (2013), an omega-3 rich energy bar containing flaxseeds was found to have 11.5 per cent fat, 11.86 per cent protein, 12.41 per cent ash and 1.65 per cent carbohydrates, with carbohydrates making up 60.4 per cent of the total composition. In his dissertation on gluten, soy, milk and nut-free bars, Altoaimi (2015) reported that the bars contained 14.62 per cent moisture, 0.32 per cent fat, 9.16 per cent protein and 74.0 per cent carbohydrates.

Ho et al. (2016) reported that an "energy" snack bar made with local Malaysian ingredients had an average composition of 13.23 per cent moisture, 22.39 per cent fat, 6.36 per cent protein, 1.13 per cent ash and 56.89 per cent carbohydrates, with an energy content of 454.51 Kcal per 100 g. Giri and Mridula (2016) found that an energy bar made with potato exudates contained 12.32 per cent moisture, 1.65 per cent fat, 8.38 per cent protein, 1.62 per cent ash and 73.67 per cent carbohydrates, with an energy content of 343.03 Kcal per 100 g. Chitkara et al. (2017) reported that a polyherbal energy bar made with stevia, banana, cocoa butter and oats had 27.50 per cent moisture, 17.46 per cent fat, 5.65 per cent protein, 1.55 per cent ash and 17 per cent carbohydrates, with an energy content of 332 Kcal per 100 g. Jetavat et al. (2020) found that a milk solids and cereal-based energy bar contained 7.37 per cent moisture, 24.82 per cent fat, 11.46 per cent protein, 1.78 per cent ash and 54.57 per cent carbohydrates, with an energy content of 525 Kcal per 100 g..

The chemical composition and total calorie value of energy bars are influenced by the types of ingredients used in their formulation, as evidenced by various studies. According to Bourekoua et al. (2023), a product can be classified as an energy bar if it contains more than 280 Kcal per 100g and provides at least 20 per cent of the recommended daily protein requirements per 100g for labelling as a high-protein or protein-rich product under the Food Safety and Standards Amendment Regulations (Advertising and Claims) (FSSAI, 2019) (Ayatti et al.2021). In the present study, the proximate chemical composition of the P-E Bars, characterized by low moisture, high protein and high calorie content derived from carbohydrates and fats, aligns with the development of high protein-energy bars with longer shelf life.

### **4.3.2 Chemical Characteristics of P-E Bars**

The protein-energy bars were analyzed for their chemical properties, including Acid Value, Peroxide Value, Free Fatty Acid (FFA) and Water Activity, to assess its quality indicators. These parameters are crucial for determining the freshness, stability and overall quality of the bars. The results are presented table 4.3.2.1.

The Acid Value measures the amount of FFA present, which can indicate the level of lipid oxidation and rancidity. The Peroxide Value provides a measure of the extent to which hydro peroxides are formed during fat oxidation. FFA is a crucial quality indicator for edible oils and fats. Rancidity, characterized by unpleasant odors and flavours, can occur in fats due to two main processes: hydrolytic and oxidative. The FFA content measures the quantity of unbound fatty acids, which can contribute to rancidity and off-flavours. This process is accelerated by the presence of oxygen and is further hastened by factors such as heat, light, moisture and specific metal catalysts. Oxidative rancidity primarily results from the oxidation of oleic acid (Pomeranz, 2013). The table 4.3.2.1 indicates the mean Acid Value as 0.63, peroxide values to be 0.60 mEq of O<sub>2</sub>/kg fat and FFA of the P-E Bars as 0.32 per cent oleic acid which is relatively low, thus desirable for maintaining product quality. The Water Activity measures the amount of available water for microbial growth, with higher values indicating a higher risk of spoilage. As shown in the table 4.3.2.1, a lower water activity level (0.46 a<sub>w</sub>) indicates a lower risk of microbial spoilage, which is desirable for maintaining product safety and shelf life.

**Table 4.3.2.1 Chemical Characteristics of P-E Bars**

<b>Acid Value*</b>	<b>Peroxide Value*</b> <b>(mEq of O<sub>2</sub>/kg fat)</b>	<b>Free Fatty Acid*</b> <b>(% Oleic Acid)</b>	<b>Water Activity*</b> <b>(a<sub>w</sub>)</b>
<b>0.63 ± 0.04</b>	0.60 ± 0.04	0.32 ± 0.03	0.46 ± 0.02
<b>* Each observation is a mean± SD of three replication of the experiment (n=3)</b>			

These results were in line with the studies conducted by Aramouni and Abu-Ghoush (2011) which reported a water activity range of 0.506 to 0.688 for no-bake wheat-soy snack bars. Garcia et al. (2012) reported a water activity value of 0.55 for cereal bars prepared with roasted rice bran. Padmashree et al. (2012) prepared a protein-rich composite cereal bar and reported values of free fatty acids and peroxide value as 1.9 per cent oleic acid and 0.9 meq of O<sub>2</sub>/Kg fat, respectively. Padmashree et al. (2013) prepared a Flaxoat Nutty Bar and reported values of free fatty acids and peroxide value as 1.24 per cent oleic acid and 6.99 meq of O<sub>2</sub>/Kg fat, respectively, with a water activity range of 0.330 to 0.730. Rawat and Darappa (2015) prepared a baked energy bar, a baked energy bar with 50 per cent fiber-rich ingredient mixture and a baked energy bar with 50 per cent protein-rich ingredient mixture, reporting values of FFAs and Peroxide values as 4.82 per cent oleic acid and 4.9 meq of O<sub>2</sub>/Kg fat, respectively. The results suggest that the protein-energy bars have low levels of free fatty acids and lipid oxidation, which is indicative of good quality and freshness. The low Water Activity also suggests a lower risk of microbial spoilage.

#### **4.3.2.1 Changes in the Chemical Characteristics during storage**

Protein Energy Bars (P-E bars) have chemical characteristics that are susceptible to considerable storage-related changes. These changes can affect the product's quality, safety and shelf life. The P-E Bars were subjected to an Accelerated Shelf-Life Condition for 70 days at 35 ± 2°C and 70 per cent RH. The data in table 4.3.2.2 shows a significant ( $p < 0.05$ ) increase in the P-E Bars' chemical parameters during storage. It is evident that at day 70 (ASLT), the peroxide value increased from 0.60 mEq of O<sub>2</sub>/kg fat on day 0 to 2.17 mEq of O<sub>2</sub>/kg fat. This suggests that oxidation is occurring on the

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P-E bars while they are being stored. However, during 70 days of storage in an altered condition, the peroxide value up to 2.17 mEq of O<sub>2</sub>/KG fat was determined to be below the acceptable limits (<10 meq/kg), as recommended by FSSAI (2019). Higher free fatty acid level suggests more fatty acid breakdown, which can cause rancidity and off-flavors. Free fatty acid concentration increased from 0.32 percent Oleic Acid at day 0 to 1.61 percent at day 70. This suggests, P-E bars experience fatty acid degradation during storage which is considerably low. Acid value increased from 0.63 on day 0 to 3.19 at day 70. This shows that P-E bars enhance free fatty acids during storage. Appropriate packing and storage conditions can reduce Protein Energy Bar free fatty acid levels during storage. Conducting water activity studies is essential for evaluating the stability and microbiological growth potential of food items. Water activity may greatly impact product safety, shelf life and quality. Table 4.3.2.2 shows that Protein Energy Bars' water activity increased from 0.46 on day 0 to 0.60 over 70 days of storage. Significant variations in water activity were observed at the given periods ( $p < 0.05$ ). This suggests that formulation affect water activity storage stability. The small increase in water activity may have been caused by humidity variations (Padmashree et al., 2018). Water activity in high protein nutrition bars increased from 0.48 to 0.50 after 6 weeks of storage, according to Banach et al. (2016). Environmental humidity and storage circumstances may have increased water activity in study bars over time.

After 70 days of ambient storage, Rawat and Darappa (2015) found that the baked energy bar samples' initial peroxide value and free fatty acids rose from 6.13 meq of O<sub>2</sub> /Kg fat and 5.26 percent oleic acid to 7.45 meq and 8.60 percent, respectively. Padmashree et al. (2018) found that the original peroxide value, free fatty acids and water activity of choco-quinoa nutri bars in metallized polyester packaging increased from 5.31 meq of O<sub>2</sub> /Kg fat, 1.32 percent oleic acid and 0.330 to 12.45 meq, 3.21 percent and 0.532 after nine months of ambient storage.

Table 4.3.2.2 Influence of Storage on the Chemical properties of P-E Bars

Days#	Peroxide Value (mEq of O <sub>2</sub> /kg fat)		Free Fatty Acid (% Oleic Acid)		Acid Value		Water Activity (a <sub>w</sub> )	
	Mean ± SD	F - Value	Mean ± SD	F - Value	Mean ± SD	F - Value	Mean ± SD	F - Value
0	0.60 ± 0.04	480.785*	0.32 ± 0.03	167.05*	0.63 ± 0.04	177.93*	0.46 ± 0.02	25.34*
07	1.09 ± 0.02		0.43 ± 0.05		0.86 ± 0.04		0.50 ± 0.01	
14	1.31 ± 0.02		0.62 ± 0.04		1.24 ± 0.03		0.50 ± 0.00	
21	1.52 ± 0.04		0.63 ± 0.05		1.26 ± 0.01		0.52 ± 0.01	
28	1.56 ± 0.03		0.65 ± 0.04		1.31 ± 0.03		0.52 ± 0.00	
35	1.60 ± 0.02		0.80 ± 0.03		1.56 ± 0.08		0.53 ± 0.02	
42	1.61 ± 0.00		0.92 ± 0.04		1.83 ± 0.04		0.54 ± 0.01	
49	1.72 ± 0.01		0.94 ± 0.03		1.88 ± 0.04		0.55 ± 0.01	
56	1.76 ± 0.02		1.17 ± 0.10		2.03 ± 0.05		0.57 ± 0.01	
63	1.82 ± 0.04		1.47 ± 0.03		2.92 ± 0.01		0.59 ± 0.01	
70	2.17 ± 0.04		1.61 ± 0.02		3.19 ± 0.24		0.60 ± 0.01	

\*p < 0.05, Each observation is a mean± SD of three replication of the experiment (n=3), # ASLT

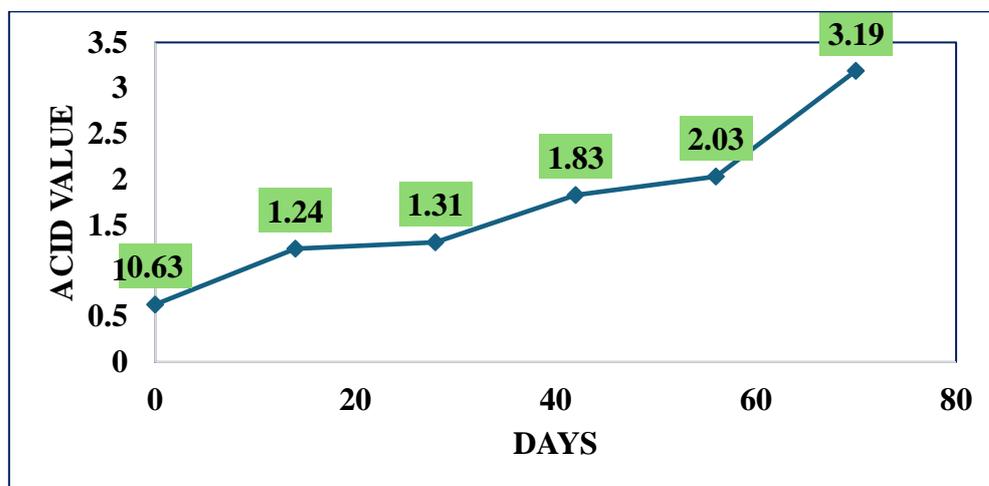


Figure 4.3.1 Influence of storage on the Acid Value of Protein-Energy Bars

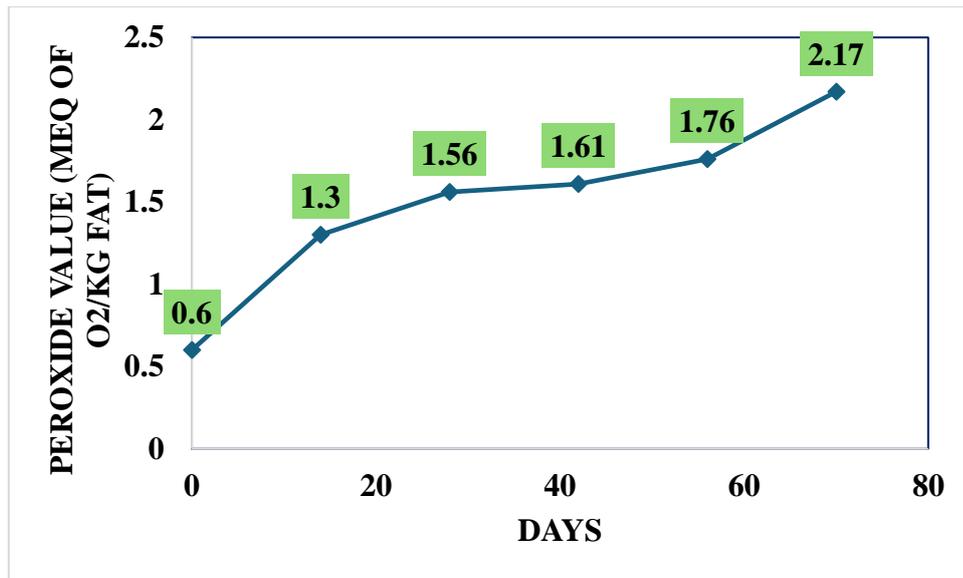


Figure 4.3.2 Influence of storage on the Peroxide Value (mEq of O<sub>2</sub>/kg fat) of P-E Bars

Figures 4.2.40 and 4.2.41 illustrate how storage affects the Acid Value and the Peroxide Value (mEq of O<sub>2</sub>/kg fat) respectively of Protein-Energy Bars.

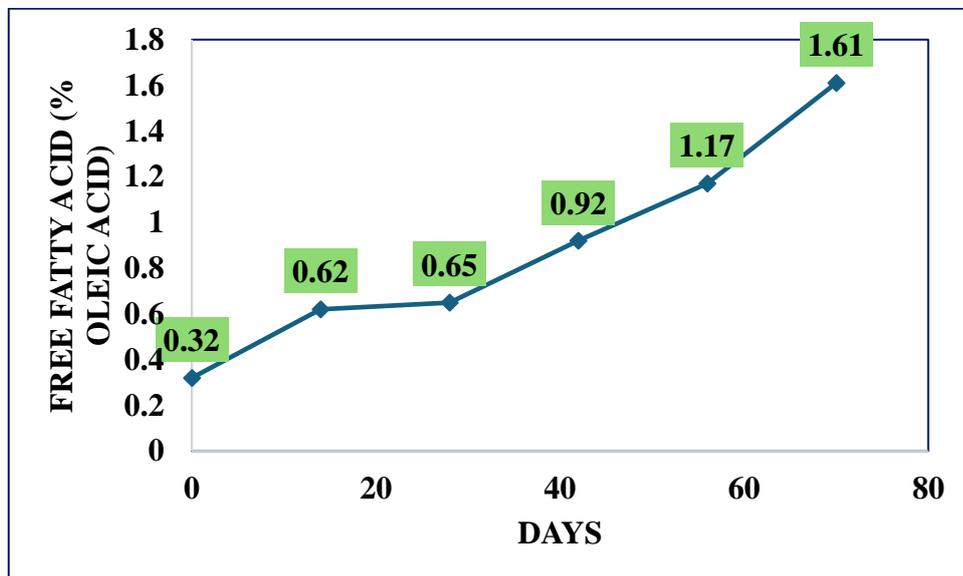
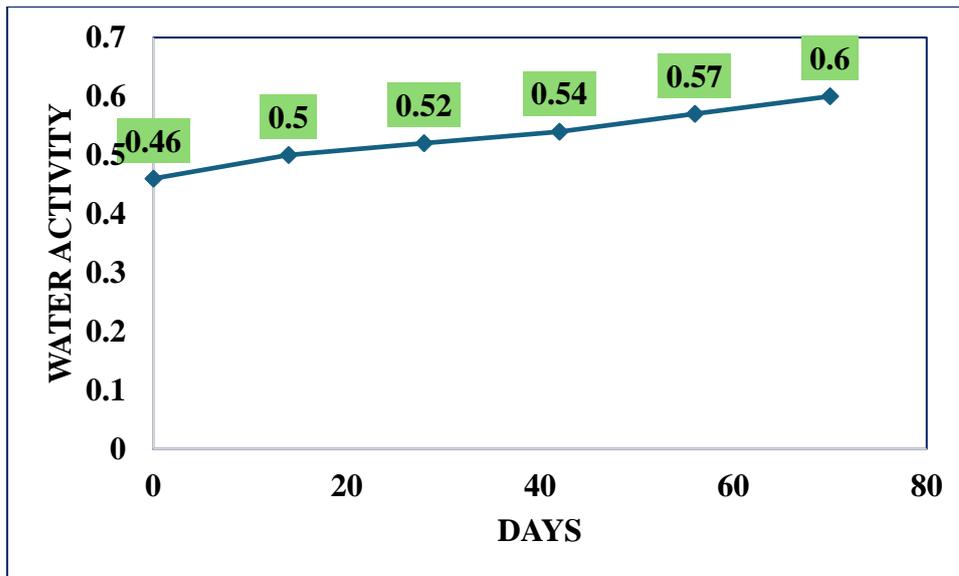


Figure 4.3.3 Influence of storage on the Free Fatty Acid (% Oleic Acid) of P-E Bars



**Figure 4.3.4 Influence of storage on the Water Activity ( $a_w$ ) of P-E Bars**

Figures 4.2.41 to 4.2.42 depict the impact of storage on the Free Fatty Acid (% Oleic Acid) and the Water Activity ( $a_w$ ) respectively of Protein-Energy Bars.

#### 4.3.3 Texture analysis and influence on storage of P-E Bars

Texture analysis is an important tool for evaluating the quality of protein-energy bars and it can provide valuable insights into how storage conditions can impact their physical attributes. The texture of a protein-energy bar is defined by its physical characteristics, including hardness, fracturability and cohesiveness. These properties might vary over time since storage circumstances can affect the physico-chemical makeup of the components.

The hardness of high-protein bars can be assessed using instrumental methods, such as measuring the force required to compress the bar between the consumer's thumb and forefinger or the force needed to bite the bar with the molars. Fracturability is a measure of how easily a sample disintegrates during compression. The hardness of high-protein bars is often due to the high concentration of proteins, which can undergo processes like Maillard reactions, water migration, protein aggregation, or sugar crystallization during storage, leading to hardening (Małecki et al. 2020).

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In the study bars, measuring fracturability offers insights into the product's brittleness or crispness, which can significantly influence the sensory experience of consuming the bar. For crispy or brittle bars, the fracturability typically ranges from 0.5 mm to 2 mm or even higher. In contrast, soft bars generally have a fracturability ranging from 5 mm to 10 mm or beyond. It's important to note that both hardness and fracturability are inversely related to each other (Foegeding et al. 2011).

The texture of the bars was evaluated following the method outlined by Nadeem et al. (2012) with some modifications. A 3-Point Bending Rig (HDP/3PB) equipped with a 50 kg load cell on a TA - HDi texture analyzer (manufactured by Stable Micro Systems, Surrey, UK) was utilized to assess the textural quality, specifically hardness and fracturability, of the energy bar samples. The bars were subjected to bending to determine the structural characteristics present inside or on the surface. Hardness was measured by plotting force (N) versus time (sec), with the maximum force (N) serving as an index of hardness for the bend test.

As indicated in the table 4.3.3.1, the protein energy bars had a fracturability of  $22.10 \pm 2.30$  mm and a hardness of  $23.67 \pm 1.15$  N, according to the textural study. This demonstrated the delicate texture of the bars. Furthermore, the fracturability value, which was more than 10.0 mm for soft bars, indicated that the bars were relatively soft.

**Table 4.3.3.1 Textural Attributes of P-E Bars**

<b>Hardness (N)</b>	<b>Fracturability (mm)</b>
<b><math>23.67 \pm 1.15</math></b>	<b><math>22.10 \pm 2.30</math></b>
<b>Each observation is a mean <math>\pm</math> SD of three replication of the experiment (n=3)</b>	

These results provided insights into the physical properties of the protein energy bars, which could impact their sensory attributes and overall consumer acceptance. These properties of the bars could be due to the role of major ingredients such as Crispies, WPC-80 and SPI added in varying proportions.

**4.3.3.1 Changes in the Textural Characteristics during storage of P-E Bars**

Monitoring the textural properties of protein-energy bars during storage is crucial for researchers to understand how the bars' texture changes over time. This is important because changes in texture can impact the overall quality and consumer acceptance of the final product.

**Table 4.3.3.2 Influence of Storage on the Textural Attributes of P-E Bars**

Days#	Hardness (N)		Fracturability (mm)	
	Mean ± SD	F - Value	Mean ± SD	F - Value
0	23.23 ± 1.15	465.99*	22.10 ± 2.30	74.07*
07	23.51 ± 0.58		18.27 ± 1.55	
14	24.67 ± 2.89		13.69 ± 2.58	
21	37.02 ± 2.65		4.51 ± 0.86	
28	57.35 ± 1.53		3.67 ± 2.02	
35	63.11 ± 1.00		3.41 ± 2.41	
42	74.42 ± 3.79		2.47 ± 0.60	
49	80.33 ± 3.21		1.63 ± 0.03	
56	90.00 ± 3.61		1.58 ± 0.04	
63	103.29 ± 4.16		1.54 ± 0.09	
70	116.87 ± 1.53		0.30 ± 0.27	
*p < 0.05, Each observation is a mean± SD of three replication of the experiment (n=3), # ASLT				

Texture is the primary sensory experience resulting from the physical interaction between food and the body. Traditionally, texture analysis is conducted through sensory tests. However, in this study, the Texture Analyzer was employed to evaluate the hardness and fracturability of Protein Energy Bars (P-E bars) over a 70-day storage period in accelerated condition. Hardness is quantified in Newtons (N), while fracturability is measured in millimetres (mm).

## ***Results and Discussion***

The table 4.3.2.2 shows that the P-E bars' hardness increased significantly ( $p < 0.05$ ) over the course of the storage period, going from 23.23 N on day 0 to 116.87 N on day 70. This suggests that throughout time, the bars hardened and were more resilient to deformation. At 70 days, the hardness of 116.87 N falls into the range of bars that are considered moderately hard. The P-E bars' fracturability dropped significantly ( $p < 0.05$ ) during the course of the storage period, going from 22.10 mm on day 0 to 0.30 mm on day 70 as shown in the table 4.3.2.2. This suggests that as time went on, the bars' propensity to fracture or break decreased.

This demonstrates that a formulation has a major impact on the product's storage stability in relation to fracturability. The reduced fracturability might be due to an increase in hardness during storage. According to the study by McMahon et al. (2009), after 37 days of ambient storage, the high protein nutrition bar's initial hardness value rose from 3.4 N to 15 N. As per the study by Pallavi et al. (2015), after 90 days of ambient storage (27 °C), the fruit and nut cereal bar's initial hardness value rose from 180 N to 240 N. In the study by Padmashree et al. (2018), after nine months of ambient storage (37 °C), the fracturability of the Choco Quinoa NutriBar within metallized polyester packaging fell from 1.764 mm to 1.468 mm and its initial hardness value increased from 43.71 N to 87.60 N. The P-E Bars in the study showed increasing trends in the similar manner.

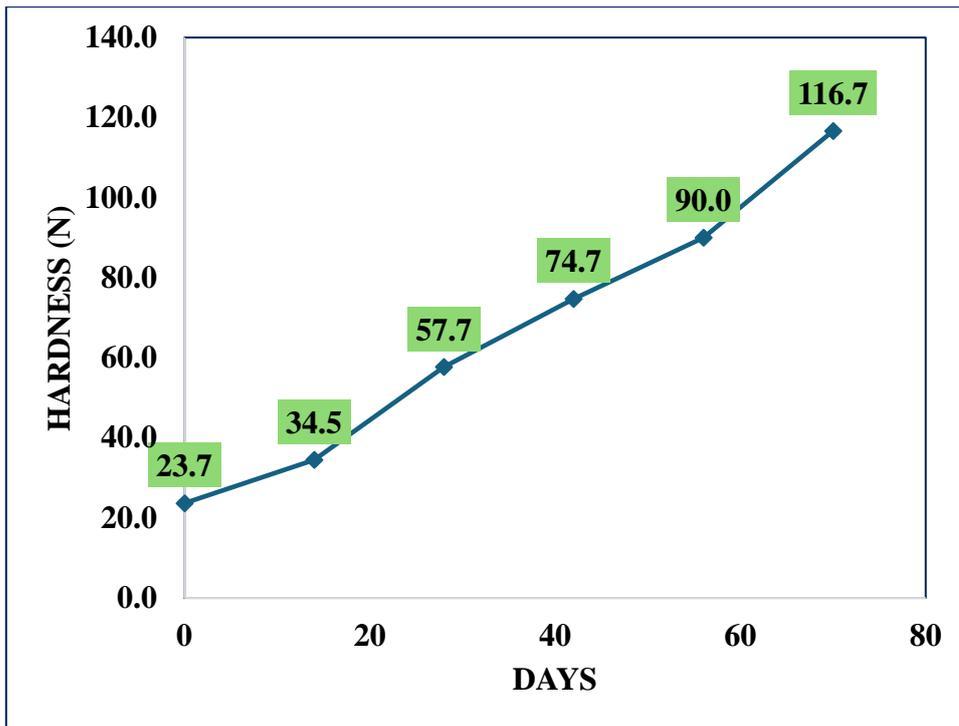


Figure 4.3.5 Influence of storage on the Hardness (N) of P-E Bars

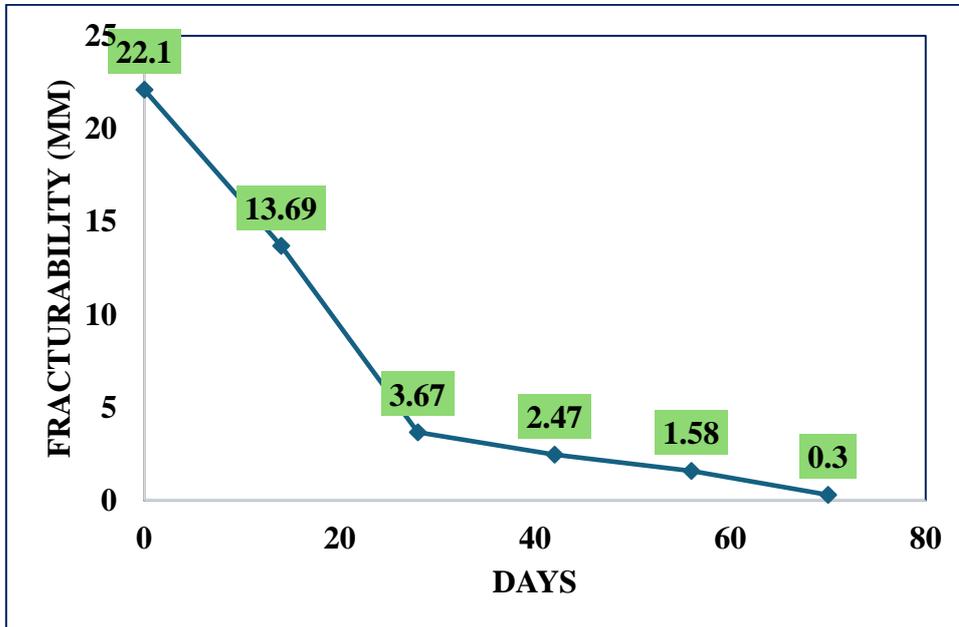


Figure 4.3.6 Influence of storage on the Fracturability (mm) of P-E Bars

#### **4.3.4 Organoleptic analysis and influence on storage of P-E Bars**

Organoleptic analysis involves the sensory assessment of food items, including their appearance, taste, flavour, texture, mouthfeel, serving size and general acceptability. This analysis is essential for comprehending customer perceptions of a product and its potential evolution, particularly during storage.

Food bars' sensory qualities may alter with storage. Due to extreme temperatures, humidity, moisture levels, production procedures and packing, bars may get stale, lose texture, or develop disagreeable flavours. Consistent organoleptic analysis enables companies track variances and make modifications to maintain product quality. The product quality study shows how protein energy bars may alter during storage and how this may affect consumer perception. This information may be utilised to create storage settings that reduce bad effects and extend product life and attractiveness.

The Protein Energy Bar underwent sensory evaluation by a panel of 18 semi-trained judges, consisting of teachers and doctoral students from the Department of Foods and Nutrition. The table 4.3.4.1 presents the scores for sensory characteristics of Protein-Energy Bar assessed using a composite score card. The attributes evaluated include Appearance, Taste, Flavor, Texture, Mouthfeel, Serving Size and Absence of Defects. Each attribute has a maximum score assigned to it a mentioned in the table 4.3.4.1.

As per the data mentioned in the table 4.3.4.1, the Protein-Energy Bar was well-received in terms of all sensory qualities. It received a favourable rating for its visual attractiveness, with an average score of  $8.4 \pm 0.7$ . Their taste was well-received, with an average score of  $12.5 \pm 1.0$ . The flavour was positively assessed with a mean score of  $8.3 \pm 0.5$ . The bar was rated highly for its texture, with an average score of  $16.4 \pm 0.8$ . The mouthfeel was found to be favourable with an average score of  $8.5 \pm 0.5$ . The bar had a satisfactory rating for portion size, with an average score of  $13.9 \pm 0.6$ . The product's mean score of  $8.6 \pm 0.5$  indicates that it was defect-free. The total score ( $85.1 \pm 0.7$ ) indicates that the bar was well-received by the panel.

Table 4.3.4.2 displays the ratings for the sensory attributes of Protein-Energy Bar evaluated on a 9-point hedonic scale. The aspects assessed including appearance, taste, flavour, texture, mouthfeel, serving size and overall acceptability.

**Table 4.3.4.1 Sensory Evaluation of P-E Bars by Semi Trained Panel: CSC (N=18)**

<b>Score For Sensory Characteristics of Protein-Energy Bars</b>									
<b>Attributes</b>	<b>Appearance</b>	<b>Taste</b>	<b>Flavor</b>	<b>Texture</b>	<b>Mouthfeel</b>	<b>Serving Size</b>	<b>Absence of Defects</b>	<b>Overall Score</b>	<b>Grand Total</b>
Maximum Score	10	15	10	20	10	15	10	10	100
Mean ± SD	8.4 ± 0.7	12.5 ± 1.0	8.3 ± 0.5	16.4 ± 0.8	8.5 ± 0.5	13.9 ± 0.6	8.6 ± 0.5	8.3 ± 0.3	85.1 ± 0.7
<b>Each observation is a mean ± SD of three replicate experiments by 18 semi trained panel members</b>									

**Table 4.3.4.2 Sensory Evaluation of P-E Bars by Semi Trained Panel: 9-PHS (N=18)**

<b>Score For Sensory Characteristics of Protein-Energy Bars (Maximum Score= 9)</b>						
<b>Attributes</b>	<b>Appearance</b>	<b>Taste</b>	<b>Flavor</b>	<b>Texture</b>	<b>Serving Size</b>	<b>Overall Acceptability</b>
Mean ± SD	7.80 ± 0.5	7.87 ± 0.3	7.85 ± 0.4	7.38 ± 0.5	8.35 ± 0.5	7.85 ± 0.3
<b>Each observation is a mean ± SD of three replicate experiments by 18 semi trained panel members</b>						

The results displayed in table 4.3.4.2 aligned closely with the composite rating scale. The bar garnered favourable scores for its visual attractiveness, with an average appearance score of  $7.80 \pm 0.5$ . It received a favourable taste rating with a mean tasting score of  $7.87 \pm 0.3$ . The taste received a mean score of  $7.85 \pm 0.4$ , indicating that the bar was well-received in terms of flavour. The mean texture score of  $7.38 \pm 0.5$  indicates that it obtained a satisfactory grade for its texture. The mean score for serving size was  $8.35 \pm 0.5$ , indicating that the bar was rated well for portion size. The mean score for overall acceptability is  $7.85 \pm 0.3$ , suggesting that the panel found the bar to be well-received.

Prior sensory research on snack bars from different categories also had similar results. Padmashree et al. (2012) developed a protein-rich composite cereal bar and evaluated its sensory attributes. The evaluations for colour, aroma, taste, texture and overall acceptability were 7.7, 7.6, 7.8, 7.7 and 7.9, respectively. Mridula and colleagues (2013) created an energy bar rich in omega-3 fatty acids that satisfied quality criteria. The sensory assessment scores for the energy bar were 7.2 for colour and appearance, 7.5 for texture, 7.4 for odour, 7.8 for flavour and 7.7 for overall acceptability. In 2016, Giri and Mridula created an energy bar using potato extrudates and evaluated sensory aspects such as colour and appearance, odour, mouthfeel, flavour, taste, sensory texture and overall acceptability. The numbers are 7.32, 7.68, 7.45 and 7.55, in that order.

### **4.3.4.1 Changes in the Organoleptic Characteristics during storage of P-E Bars**

During storage, the appearance of a product may change due to factors such as color changes, which can be caused by oxidation or enzymatic browning. The aroma of a product can also change over time, as volatile compounds may evaporate or react with other compounds in the product. Similarly, the taste and texture of a product can change due to factors such as moisture loss, which can lead to a dry or stale texture, or microbial growth, which can lead to off-flavours or odours. The sensory characteristics of Protein-Energy Bars packed in coated Brown Kraft Paper of 70 gsm, with dimensions of 80 mm width and 155 mm height and stored at cabinet temperature ( $35 \pm 2^\circ\text{C}$ ) and RH 70 per cent, are detailed in table 4.3.4.3. The sensory characteristics include appearance, taste, flavor, texture, mouthfeel, serving size, absence of defects and overall score, each rated on a scale of 10, 15 or 20.

**Table 4.3.4.3 Influence of Storage on Sensory Attributes- CSC of P-E Bars**

	<b>Storage Period (Days#)</b>										
	<b>0</b>	<b>7</b>	<b>14</b>	<b>21</b>	<b>28</b>	<b>35</b>	<b>42</b>	<b>49</b>	<b>56</b>	<b>63</b>	<b>70</b>
	<b>Appearance (10)</b>										
Mean ±	8.11 ±	8.17 ±	8.11 ±	8.06 ±	8.06 ±	7.94 ±	7.83 ±	7.78 ±	7.61 ±	7.39 ±	7.22 ±
SD	0.32	0.38	0.32	0.42	0.42	0.24	0.51	0.55	0.78	0.78	0.73
F - Value	<b>6.445*</b>										
	<b>Taste (15)</b>										
Mean ±	12.5 ±	11.89 ±	11.50 ±	10.5 ±	9.83 ±	9.83 ±	9.00 ±	8.83 ±	8.99 ±	7.56 ±	7.44 ±
SD	0.99	0.47	0.62	1.15	1.20	1.43	0.77	0.79	0.91	0.92	0.78
F - Value	<b>58.856*</b>										
	<b>Flavor (10)</b>										
Mean ±	8.28 ±	8.22 ±	7.94 ±	7.78 ±	7.00 ±	6.56 ±	6.44 ±	6.11 ±	5.89 ±	5.44 ±	5.22 ±
SD	0.46	0.43	0.54	0.65	0.91	0.92	0.78	0.68	0.58	0.51	0.43
F - Value	<b>52.681*</b>										
	<b>Texture (20)</b>										
Mean ±	16.44 ±	15.94 ±	15.72 ±	15.00 ±	14.67 ±	14.11 ±	13.72 ±	13.22 ±	12.56 ±	11.83 ±	11.61 ±
SD	0.86	0.94	1.07	0.91	0.84	0.68	0.96	1.00	1.04	1.04	0.92
F - Value	<b>55.757*</b>										
	<b>Storage Period (days)</b>										
	<b>Mouthfeel (10)</b>										
Mean ±	8.44 ±	8.17 ±	8.00 ±	7.83 ±	7.67 ±	7.17 ±	7.00 ±	6.72 ±	6.28 ±	6.11 ±	5.94 ±
SD	0.51	0.38	0.49	0.62	0.49	0.62	0.77	0.67	0.67	0.32	0.24
F - Value	<b>45.907*</b>										

*Results and Discussion*

	<b>Serving Size (15)</b>										
Mean ±	13.94 ±	12.94 ±	12.72 ±	12.56 ±	12.11 ±	11.89 ±	11.67 ±	11.44 ±	11.22 ±	11.06 ±	10.89 ±
SD	0.64	0.73	0.75	0.78	0.90	0.90	0.97	0.86	0.65	0.54	0.68
F - Value	<b>26.081*</b>										
	<b>Absence of Defects (10)</b>										
Mean ±	8.67 ±	8.39 ±	8.17 ±	8.11 ±	7.94 ±	7.83 ±	7.44 ±	7.17 ±	6.94 ±	6.56 ±	6.22 ±
SD	0.59	0.50	0.71	0.58	0.64	0.38	0.51	0.79	0.73	1.10	1.00
F - Value	<b>21.669*</b>										
	<b>Overall Score (10)</b>										
Mean ±	8.11 ±	8.09 ±	8.07 ±	8.06 ±	8.06 ±	7.94 ±	7.83 ±	7.78 ±	7.61 ±	7.39 ±	7.22 ±
SD	0.32	0.38	0.32	0.42	0.42	0.24	0.51	0.55	0.78	0.78	0.73
F - Value	<b>6.445*</b>										
<b>*p &lt; 0.05, Each observation is a mean ± SD of three replicate experiments by 18 semi trained panel members #ASLT</b>											

**Table 4.3.4.4 Influence of Storage on Sensory Attributes- 9-PHS of P-E Bars**

	Storage Period (Days#)										
	0	7	14	21	28	35	42	49	56	63	70
	<b>Appearance</b>										
Mean ±	7.83 ±	7.67 ±	7.39 ±	7.00 ±	6.83 ±	6.39 ±	6.28 ±	6.17 ±	6.06 ±	5.83 ±	5.67 ±
SD	0.51	0.49	0.70	0.59	0.62	0.70	0.83	0.71	0.64	0.71	0.77
F - Value	<b>22.532*</b>										
	<b>Taste</b>										
Mean ±	7.89 ±	7.72 ±	7.56 ±	7.28 ±	7.33 ±	7.06 ±	7.00 ±	7.06 ±	6.50 ±	6.17 ±	5.44 ±
SD	0.32	0.46	0.78	1.02	0.84	1.00	0.97	0.94	1.25	1.15	0.78
F - Value	<b>11.410*</b>										
	<b>Flavor</b>										
Mean ±	7.83 ±	7.67 ±	7.17 ±	7.00 ±	6.83 ±	6.56 ±	6.44 ±	6.00 ±	5.78 ±	5.61 ±	5.33 ±
SD	0.38	0.49	0.71	0.91	0.99	0.86	0.71	0.69	0.65	0.50	0.77
F - Value	<b>23.989*</b>										
	<b>Texture</b>										
Mean ±	7.39 ±	7.17 ±	6.94 ±	6.89 ±	6.56 ±	6.67 ±	6.50 ±	6.39 ±	6.17 ±	5.83 ±	5.00 ±
SD	0.50	0.38	0.64	0.58	0.78	0.49	0.51	0.50	0.62	0.38	0.69
F - Value	<b>24.980*</b>										
	<b>Storage Period (days)</b>										
	<b>Serving Size</b>										
Mean ±	8.33 ±	8.33 ±	8.30 ±	8.17 ±	8.11 ±	8.00 ±	7.78 ±	7.56 ±	7.50 ±	7.44 ±	7.28 ±
SD	0.49	0.49	0.50	0.51	0.47	0.69	0.43	0.62	0.62	0.78	0.90
F - Value	<b>7.983*</b>										
<b>*p &lt; 0.05, Each observation is a mean ± SD of three replicate experiments by 18 semi trained panel members, #ASLT</b>											

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The visual appeal scores of the P-E Bars decreased from  $8.11 \pm 0.32$  and  $7.83 \pm 0.51$  on day zero to  $7.22 \pm 0.73$  and  $5.67 \pm 0.77$  after 70 days of storage at cabinet temperature ( $35 \pm 2^\circ\text{C}$ ) and RH 70, under accelerated condition, as indicated in tables 4.3.4.3 and 4.3.4.4 using a Composite Score Card (maximum 10) and a 9-PHS. The variations in the bars' appearance scores over the storage period were significant ( $p < 0.05$ ). This demonstrates a notable impact of altering the formulation on the storage stability of the product in terms of visual attributes. On a CSC, when the average score at the conclusion of the storage period exceeded 70 per cent, the bars were considered visually appealing.

The taste scores of the P-E Bars decreased from  $12.5 \pm 0.99$  (day 0) to  $7.44 \pm 0.78$  (day 70) with a maximum score of 15. On the 9-PHS the score declined from  $7.89 \pm 0.32$  to  $5.44 \pm 0.78$  within the storage period as mentioned on the tables 4.3.4.3 and 4.3.4.4. These changes in taste scores were found to be statistically significant at a p-value of less than 0.05, indicating that they were not likely due to random chance. However, on a 9-PHS the changes were within the scale of liked moderately to be liked slightly till 56<sup>th</sup> day of storage.

The flavour ratings of the P-E Bars declined from  $8.28 \pm 0.46$  on day 0 to  $5.22 \pm 0.43$  on day 70, with the highest possible score of 10. The 9-PHS score decreased from  $7.83 \pm 0.38$  to  $5.33 \pm 0.77$  over the storage period as seen in tables 4.3.4.3 and 4.3.4.4. The alterations in flavour ratings were determined to be statistically significant with a p-value of less than 0.05, suggesting that they were unlikely to be a result of random chance. On a 9-point hedonic scale, the variations in likability ranged from moderately liked to somewhat be liked until the 56<sup>th</sup> day of storage.

The mean texture score of the P-E Bars decreased from  $16.44 \pm 0.86$  to  $11.61 \pm 0.92$  from day 0 to day 70 on the CSC with the maximum possible score of 20. Similarly, the changes on a 9-PHS (9-Point Hedonic Scale) also show a decline from the mean score of  $7.39 \pm 0.50$  to  $5.00 \pm 0.69$ . This indicates a significant decline in the texture quality of the bars over time when stored at the specified condition. These findings were statistically significant at  $p < 0.05$  (tables 4.3.4.3 and 4.3.4.4). These attributes can be studied closely with the changes in the scores of the texture as measured on a Texture Profile Analyser and described in the table 4.3.3.1. the texture was found to be increasing significantly harder as the period of storage increases.

## *Results and Discussion*

As shown in the tables 4.3.4.3 and 4.3.4.4 mouthfeel of the product shows some decline in the perception over the period of storage. The data shows decline as measured on a CSC (maximum score of 10) from  $8.44 \pm 0.51$  on the day 0 to  $5.94 \pm 0.24$ . The data was significant at  $p < 0.05$ . However, on 70<sup>th</sup> day the values were yet a little below 60 percent. Serving size holds an important criterion for a standardized product here as the bar falls into the high protein category. It is important to consider serving size as an important factor for the delivery of the mentioned nutrients in one serving. Despite the statistically significant decline in values on both CSC and 9-PHS, the product remained 73 per cent acceptable on the 70<sup>th</sup> day of storage, indicating a favorable overall outcome. The values are presented in the table 4.3.4.3. On a 9-PHS the mean values were found to be significantly declining from  $8.33 \pm 0.49$  to  $7.28 \pm 0.90$  on the 0 day and 70<sup>th</sup> day respectively. On the 70<sup>th</sup> day the bars as measured on a 9-PHS was within the range on liked very much to liked moderately as can be seen in table 4.3.4.4.

The bars showed some changes in the overall sensory score as measured on the CSC with a maximum score of 10. The values (Mean  $\pm$  SD) ranged from  $8.11 \pm 0.32$  on the 0<sup>th</sup> day to  $7.22 \pm 0.73$  on 70<sup>th</sup> day as can be seen from the table 4.3.4.3.

Based on sensory evaluation, it was determined that Protein-Energy Bars, when packed in coated Brown Kraft Paper of 70 gsm and sealed in pouches, were acceptable for consumption up to 63 days of storage at  $35 \pm 2^\circ\text{C}$ , 70 RH under accelerated condition. In 2016, Giri and Mridula discovered that the first ratings for several qualities of energy bars made with potato extrudates were as follows: appearance and colour 7.32, odour 7.45, mouthfeel 7.32, flavour 7.68, taste 7.45, sensory texture 7.55 and overall acceptability. The scores declined to 7.23, 7.40, 7.29, 7.35, 7.21 and 7.24 after 90 days of storage at room temperature ( $25^\circ\text{C}$ ).

Sobana (2017) found that composite sports bars' appearance, colour, flavour, texture and taste averaged 8.0, 8.2, 8.7 and 8.0. After 90 days at  $37^\circ\text{C}$ , scores dropped to 3.7, 2.3, 1.9, 3.9 and 1.4. Padmashree et al. (2018) discovered that choco-quinoa nutri bars with metallized polyester packaging scored 8.07, 8.10, 8.20, 8.09 and 8.17 for colour, odour, taste, texture and overall approval. After 9 months at  $37^\circ\text{C}$ , the scores dropped to 7.32, 7.23, 7.32, 6.30 and 6.60.

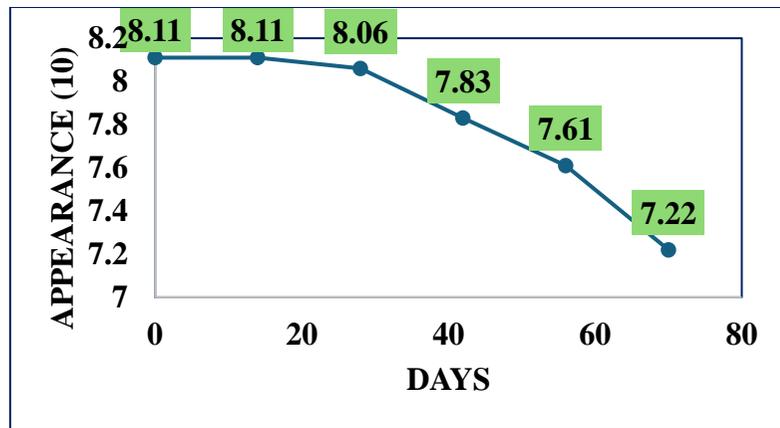


Figure 4.3.7 Influence of Storage on Appearance- CSC

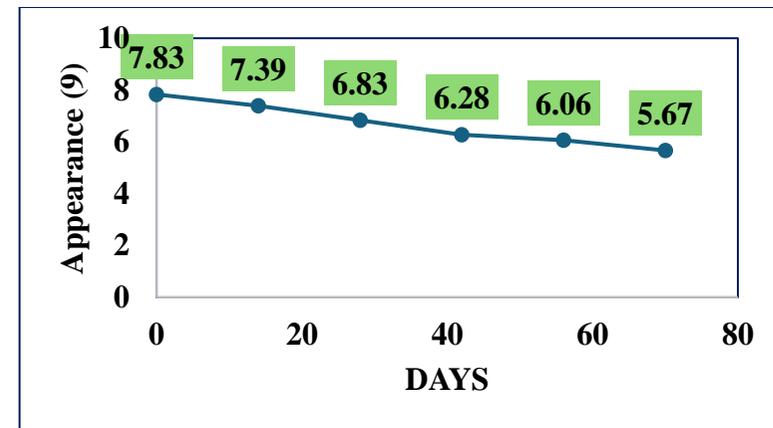


Figure 4.3.8 Influence of Storage on Appearance- 9-PHS

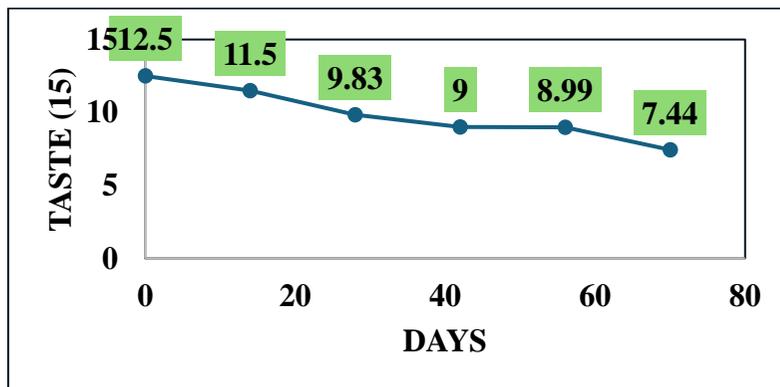


Figure 4.3.9 Influence of Storage on Taste- CSC

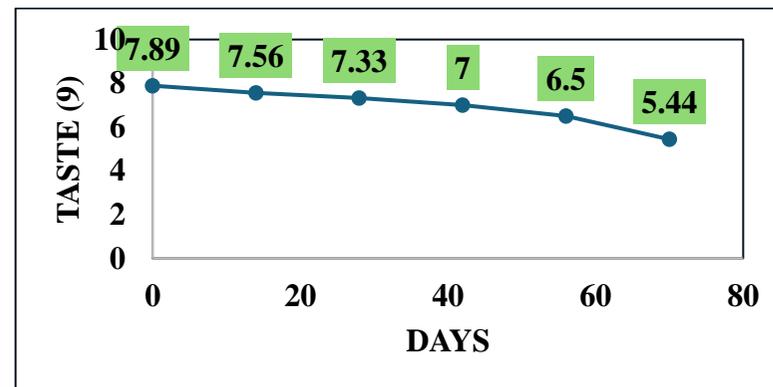


Figure 4.3.10 Influence of Storage on Taste- 9-PHS

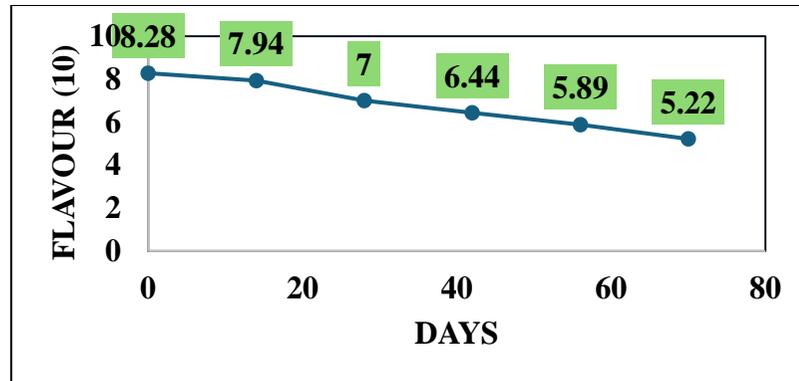


Figure 4.3.11 Influence of Storage on Flavour- CSC

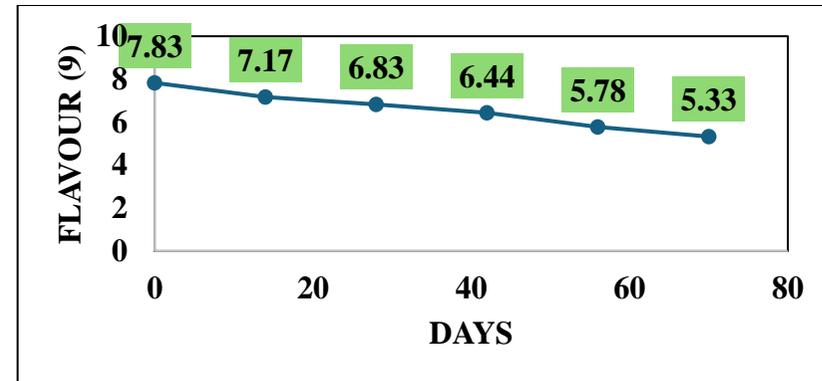


Figure 4.3.12 Influence of Storage on Flavour - 9-PHS

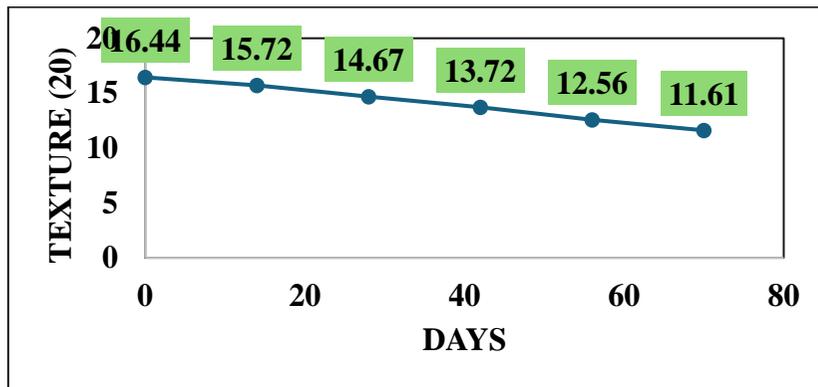


Figure 4.3.13 Influence of Storage on Texture- CSC

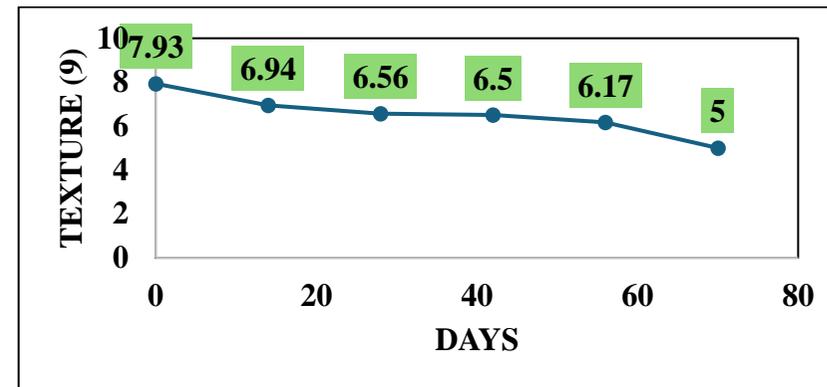


Figure 4.3.14 Influence of Storage on Texture - 9-PHS

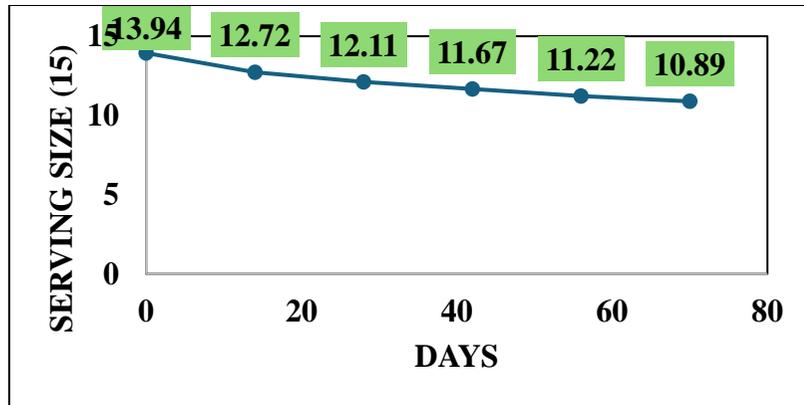


Figure 4.3.15 Influence of Storage on Serving Size- CSC

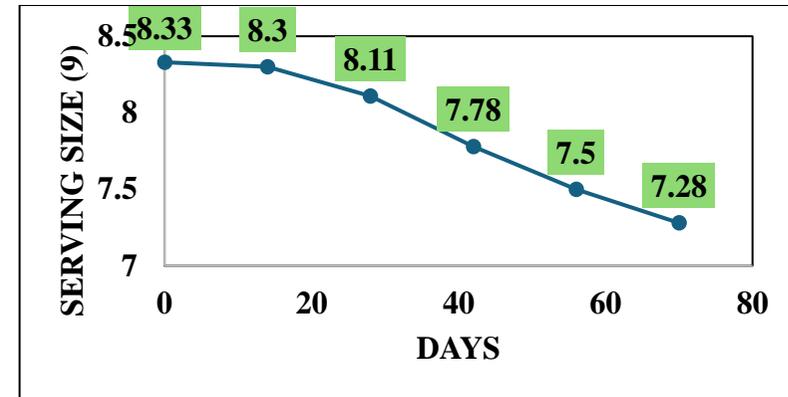


Figure 4.3.16 Influence of Storage on Serving Size - 9-PHS

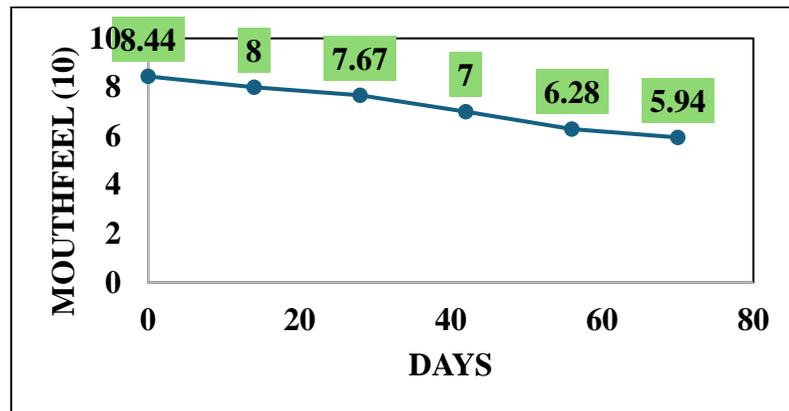


Figure 4.3.17 Influence of Storage on Mouthfeel - CSC

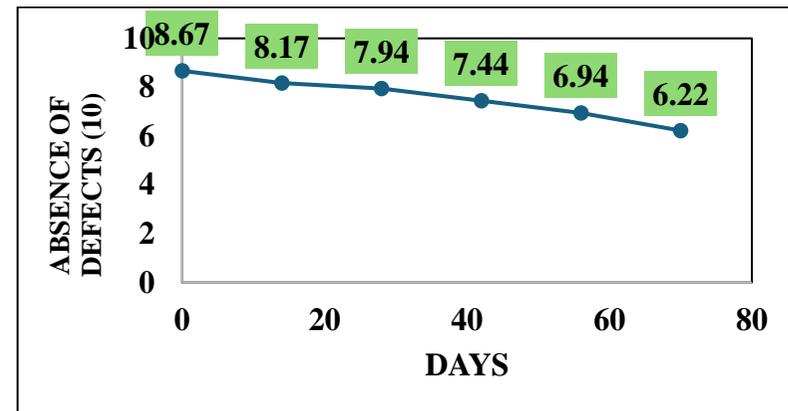
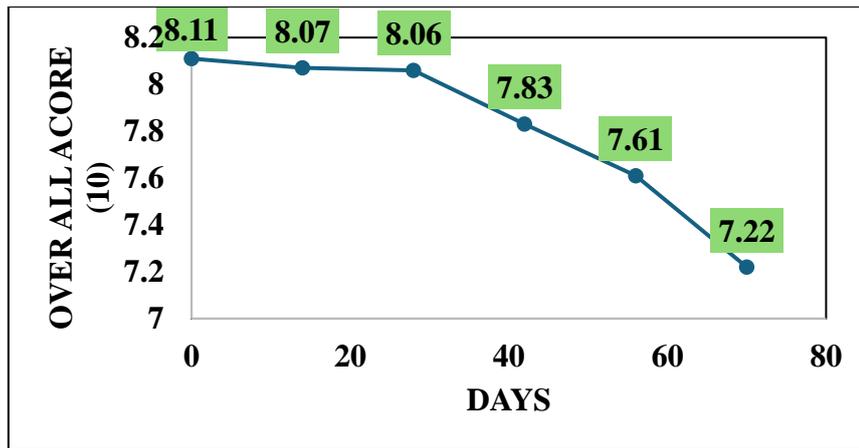


Figure 4.3.18 Influence of Storage on Absence of Defects - CSC



**Figure 4.3.19 Influence of Storage on Overall Acceptability - CSC**



**Figure 4.3.20 Sensory Evaluation test conducted by the Sensory Evaluation Panel**

Despite a decrease in scores over time, the ratings for various attributes on both the Composite Score Card and the 9-Point Hedonic Scale remain notably high, indicating favorable perceptions of appearance, flavor, texture, serving size, absence of defects and overall acceptance throughout the evaluation period. This suggests consistent positive feedback regarding the quality and acceptability of the product.

Despite these changes, the bars maintained favorable scores for visual attractiveness, taste, flavor, texture, serving size and overall acceptability. However, the overall sensory score decreased from  $8.11 \pm 0.32$  on day 0 to  $7.22 \pm 0.73$  on day 70. Considering the empirical formula where one month storage under accelerated conditions equals 2.9 months under laboratory storage conditions (Sharifah et al., 2010), it is suggested that the shelf life of the bars under normal laboratory conditions would be approximately 5.8 months.

**4.3.5 Microbial Quality and influence on storage**

The Protein Energy Bars were analyzed for Total Bacterial Count (TBC), Total Coliform and yeast and mould count. The TBC count of the fresh sample was  $1.5 \pm 0.083 \log_{10} \text{ cfu/g}$ , as shown in table 4.3.5.1. With a water activity of  $0.46 \pm 0.02 a_w$  (table 4.3.2.1) and a moisture content of  $6.33 \pm 0.07$  percent (table 4.3.1.1), they fall under the category of low moisture foods, which are not usually subjected to microbial spoilage.

**Table 4.3.5.1 Microbial Count of P-E Bars**

<b>Total Bacterial Count*</b> <b>(log<sub>10</sub> Cfu/g)</b>	<b>Total Coliform*</b> <b>(log<sub>10</sub> Cfu/g)</b>	<b>Yeast and Mould*</b> <b>(log<sub>10</sub> Cfu/g)</b>
$1.5 \pm 0.083$	Nil	Absent
Each observation is a mean $\pm$ SD of three replicate experiments by 18 semi trained panel members		

**4.3.5.1 Total Bacterial Count**

Total Bacterial Count (TBC) is a comprehensive assessment of the total microbiological condition of the product post-production and during its storage duration. TBC provides information on the microbiological quality of Protein-Energy Bars during storage. Table 4.3.5.2 demonstrates how the standard plate count of stored samples is affected by the duration of storage at  $15 \pm 2^\circ\text{C}$ . The Total Bacterial Count of the P-E Bar grew from  $1.34 \pm 0.02$  on day zero to  $2.50 \pm 0.02$  after 70 days of storage at a cabinet temperature of  $35 \pm 2^\circ\text{C}$ , RH of 70 under accelerated condition. It was anticipated since microorganisms, such as bacteria, moulds and yeasts, cannot thrive in water with an activity level below 0.70. The water activity the sample remained below 0.7 during storage. Farajzadeh and Golmakani (2011) noted that the standard plate count of an energy bar rose steadily from 2.64 to 3.00  $\log_{10} \text{ cfu/g}$  after being kept for 6 months at room temperature. Padmashree et al. (2012) found that the standard plate count of a protein-rich composite cereal bar grew steadily from 1.07 to 2.48  $\log_{10} \text{ cfu/g}$  after being kept for 9 months at room temperature.

#### **4.3.5.2 Total Coliform**

Coliforms are gram-negative rods that are motile and ferment lactose, producing gas. They typically form smooth, non-mucoid colonies on solid media. However, there are non-lactose fermenting strains of *E. coli* and some strains produce mucoid colonies. Throughout the storage study (six months), *E. coli* was not detected in the study bars. This was also observed in the study conducted by Farajzadeh and Golmakani (2011), who found that *E. coli* was not detected in energy bars during 6 months of storage at ambient temperature. Similarly, Padmashree et al. (2012) reported that *E. coli* was not detected in protein-rich composite cereal bars during 9 months of storage at ambient temperature. Silva et al. (2013) also reported that *E. coli* was not detected in cassava flour-based food bars during 210 days of storage at ambient temperature.

#### **4.3.5.3 Yeast and Mold**

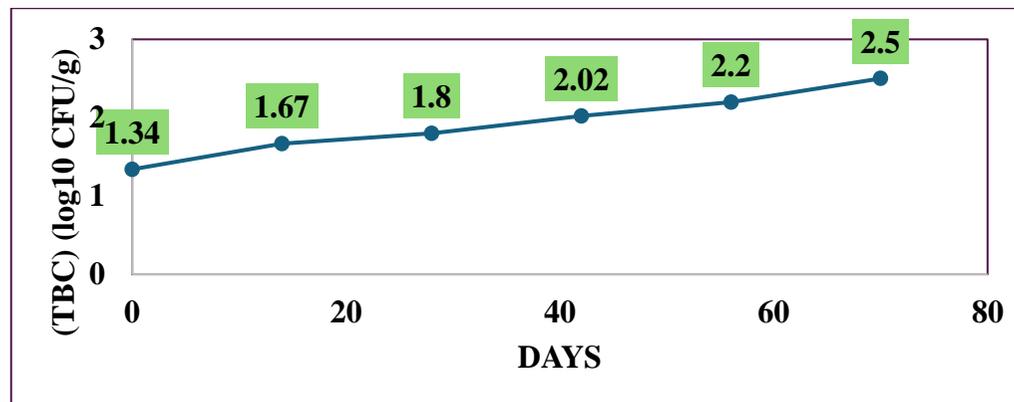
Yeast and molds are undesirable microorganisms that, when present in high quantities, can reduce the shelf life of a product. However, no yeast and mold were detected in the study bar during the storage testing (six months).

Farajzadeh and Golmakani (2011) also found no presence of yeast and mold in an energy bar stored for 6 months at room temperature. Similarly, Padmashree et al. (2012) found no presence of yeast and mold in a protein-rich composite cereal bar stored for 9 months at room temperature. In a study by Silva et al. (2013), yeast and mold were not found in cassava flour-based snack bars after being stored for 210 days at room temperature.

The absence of yeast and mold counts in this investigation suggests high-quality raw materials, sanitary manufacturing processes and the lack of airborne contamination.

**Table 4.3.5.2 Influence of Storage Period on Total Bacteria Count of P-E Bars**

Parameter Analysed	Storage Period (days)										
	0	7	14	21	28	35	42	49	56	63	70
<b>Total Bacterial Count (TBC) (log<sub>10</sub> CFU/g)</b> <b>(MEAN ± SD)</b>	1.34 ± 0.02	1.42 ± 0.02	1.67 ± 0.01	1.76 ± 0.02	1.80 ± 0.02	1.95 ± 0.02	2.02 ± 0.06	2.11 ± 0.06	2.20 ± 0.04	2.39 ± 0.04	2.50 ± 0.02



**Figure 4.3.21 Influence of Storage on Total Bacteria Count of P-E Bars**

#### **4.3.6 Cost Calculation for Production of Standardized P-E Bars**

The cost analysis for producing Protein-Energy Bars (P-E Bars) using a standardized process is outlined below. To estimate the feasibility of manufacturing the P-E Bar, an examination of technical and economic factors was conducted. The cost analysis was performed using 10 kgs (kg) of raw materials, yielding 10 kg of finished product. An attempt was made to determine the production cost of P-E Bars by considering raw ingredients, utility costs and overhead charges.

##### **4.3.6.1 Raw Material Cost**

Table 4.3.6.1 displays the raw material cost for producing a single batch (10 kg) of P-E Bars. The total cost of raw materials (during the phase, 2022-2023) for the preparation was 4136 rupees every 10-kg batch.

##### **4.3.6.2 Cost of Utilities and Overhead Expenses**

For the purpose of determining the cost of utilities, the appendix provides a breakdown of the specific heat, heat energy, gas need, heat and electricity that are required for the manufacturing of the bars. This information is necessary for the calculation of the cost of utilities. The utility and overhead costs that are a direct result of the pay of personnel working in a factory that manufactures P-E Bars are highlighted in table 4.3.6.2.

##### **4.3.6.3 Packaging and Labeling Cost**

The packaging and labeling expenses for P-E Bars are detailed in table 4.3.6.2. Included in the cost of packing is the cost of the material used for packaging, which is laminated brown Kraft paper of 70 gsm thickness, dimensions of 80 millimetres in width and 155 millimetres in height and a mechanism for sealing. The cost of labelling encompasses the expenses incurred in the process of developing and printing labels for the packaging.

**Table 4.3.6.1 Raw material cost for preparing one batch (10 kg) of P-E Bars**

<b>Sr. No.</b>	<b>Ingredients</b>	<b>Quantity of ingredient per batch (g)</b>	<b>Quantity of ingredient per batch (%)</b>	<b>Ingredient rate per batch * (rupees)</b>
1.	Crispies	726	7.3	72.58
2.	WPC-80	1452	14.5	2104.84
3.	SPI	1371	13.7	747.18
4.	Peanut	726	7.3	55.16
5.	Chocolate chips	1290	12.9	193.55
6.	Sugar	1290	12.9	58.06
7.	Ghee	968	9.7	483.87
8.	Malt	968	9.7	81.29
9.	Butter	484	4.8	273.39
10	Liquid glucose	403	4	24.19
11	Date powder	81	0.8	16.13
12	Sesame seeds	81	0.8	4.52
13	Raisin	81	0.8	4.84
14	Soy lecithin	48	0.5	3.82
15	Chia seeds	32	0.3	12.58
Raw material cost for 10 kg of P-E Bars				4136

\* Ingredient rates are based on the duration of the phase.

**Table 4.3.6.2 Cost of production for P-E Bars**

<b>Sr. No</b>	<b>Particular</b>	<b>Quantity Used</b>	<b>Rate (rupees)</b>	<b>Total Cost (rupees) Per Batch of 10 Kg</b>
<b>1</b>	Raw Material Cost (rupees) <sup>#</sup>	4136.00		
<b>2</b>	<b>Utilities Cost (rupees)</b>			
	a) Electricity\$	13.67 unit	7.6/ unit	103.89 rupees
	b) Heat Energy Cost	1.38 kg	46.50 /Kg	64.17 rupees
	c) Packaging Cost	143 pouches	1.5 rupees /unit	214.5 rupees
	d) Labeling Cost	143 pouches	1.5 rupees / unit	214.5 rupees
<b>3</b>	Overhead Cost	10% of (1) and (2)		468.56 rupees
Total Cost for one batch of P-E Bars (10kg) (1+2+3)				5201.62 rupees
Cost per 1 P-E Bar (70g)				36.41 rupees

#As shown in table 4.3.6.1, \$ Appendix (XXVI)

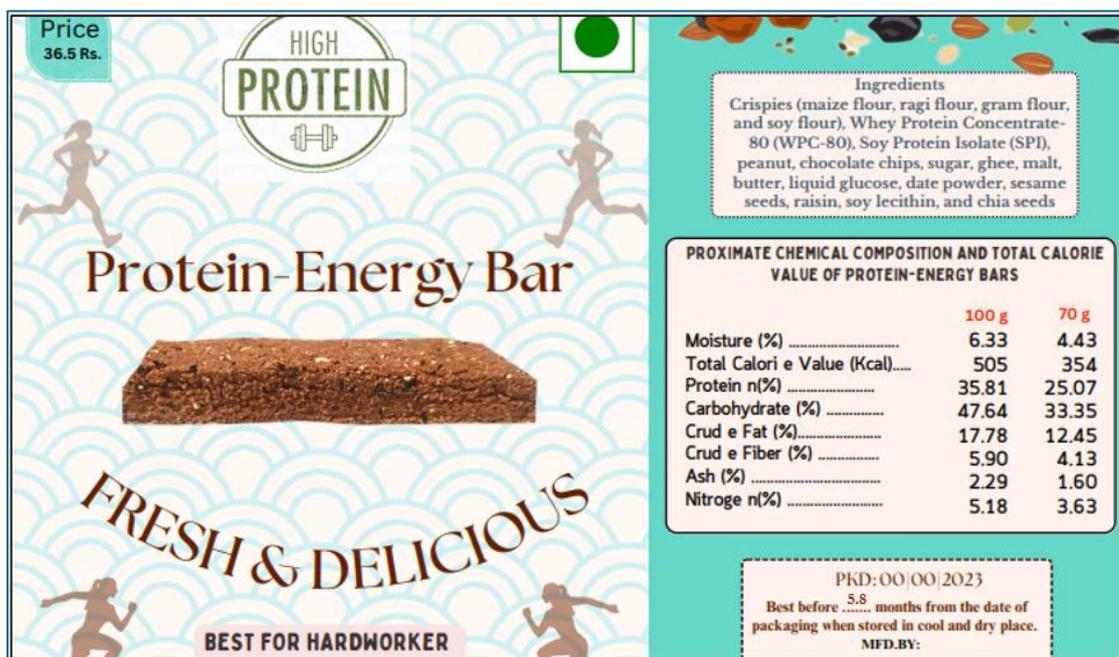
**4.3.6.4 Final Cost**

Total expense of producing P-E Bars for a 10-kg batch is detailed in table 4.3.6.2. For large-scale manufacture of P-E Bars, costs can be optimized by efficiently minimising overhead and utility expenses.

Dar et al. (2023) found that the overall cost of their snack bar was Rupees 69.65 per unit. Compared to other snack bars on the market that usually begin at Rupees 130 per 40 to 50g bar, this pricing was quite favourable. The P-E Bar analysis shows that a 70g bar costing rupees 36.41 could represent a cost-effective option for those looking for a protein-rich snack.

**4.3.6.5 Product Labeling**

Protein energy bars are favoured by athletes, fitness enthusiasts and others looking for a handy and nutritious snack. Labelling these bars is crucial to provide consumers with information about the product's components, nutritional value, pricing, expiration date and vegetarian suitability. Figure 4.3.21 shows the nutritional information for P-E Bars, including values per 100 g and per serving size (70 g). The figure displays the ingredient information and best before date based on the shelf life determined in this phase of the study.



**Figure 4.3.2.2 Product Label**

**Hypotheses Tested Phase III**

- Based on the findings of phase III, all the null hypotheses (H0) proposed at the start of the investigation are rejected.
- The following alternative hypothesis (H1) are acceptable.
  - *Varying levels of milk and pulse protein will significantly affect the quality of the protein bars.*
  - *The developed protein-energy bar will possess commercial value.*
  - *The Protein-Energy Bars will receive high acceptability scores on a Composite Score Card and a 9-Point Hedonic Scale as assessed by the semi-trained panel.*
  - *The texture of the P-E Bars will show acceptable scores in terms of hardness and fracturability on the instrumental analysis.*
  - *The shelf life of the standardized product will be within the acceptable range.*

**Result Highlights: Phase III**

- *The Protein-Energy Bar included 505 kcal per 100 g, with 47.64per cent carbs, 35.81per cent protein, 17.78per cent crude fat, 5.90per cent crude fibre and 5.18per cent nitrogen.*
- *Free fatty acid, peroxide value and acid value were 0.32per cent oleic acid, 0.60 mEq of O<sub>2</sub>/kg fat and 0.63 and 0.46 aw, respectively.*
- *The Total Bacteria Count (TBC) was determined to be 1.5 log<sub>10</sub> CFU/g.*
- *The designed bar, with a water activity of 0.46 0.02 aw, falls under the category of low moisture food. This type of food is often resistant to microbial decomposition when stored correctly for an extended period. As a result, no yeast, mould, or total coliforms were detected in the product sample.*
- *High acceptance was seen in the sensory examination, with a mean liking score above 7 on a 9-Point Hedonic Scale, demonstrating positive sensory qualities among 18 panel members.*
- *The cost of the final bar was 36.41 Indian Rupees per 70 g.*

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

**4.4 Acceptability Trials Involving Athletes, Coaches and Fitness Trainers.**

In the development process, acceptability trials play a pivotal role in assessing the reception and preferences of physically active individuals towards a new product, service, or intervention aimed at enhancing athletic performance, fitness, or overall health (Géci, et al. 2020). This phase involved conducting acceptability trials using a semi-structured questionnaire covering demographics, snack preferences, propensity towards healthy bars, satisfaction with current bars, exercise habits, perception of food bars and sensitivity to cost. A 9-point hedonic scale was employed to evaluate the protein energy bar's palatability and overall appeal. The study included 120 participants engaged in regular physical activity, drawn from athletes at the Department of Physical Education, University Pavilion, The Maharaja Sayajirao University of Baroda and fitness trainers from various Vadodara gymnasiums. Through interaction with end-users, the study aimed to ensure that the final product aligns with their requirements, preferences and expectations.

The survey was divided into four segments, each categorised under the following headings.

- 4.4.1 Assessment of general information and fitness habits of the test subjects
- 4.4.2 The individuals' preferences for snacks and their previous experience
- 4.4.3 Inquiry on the satisfaction and identification of factors that influence the choice
- 4.4.4 Post-consumption assessment and feedback of the subjects
- 4.4.5 Organoleptic evaluation using a 9- PHS

**4.4.1 Assessment of General Information and Fitness Habits of the Test Subjects**

This phase involved gathering demographic data and insights into the fitness habits of the test subjects. Information such as age, gender and regularity of exercise or gym attendance was collected to provide a foundational understanding of the study population's characteristics and exercise regularity. The study comprised 120 persons who engaged in regular physical activity, with a majority (84.17per cent) belonging to the age range of 18-25 years, while the rest of the participants were 26 years old or

## Results and Discussion

older (As shown in figure 4.4.1.1). The gender ratio, as depicted from figure 4.1.1.2 was around 60:40, with a higher proportion of males. The demographic distribution indicates a primarily young and active population, with a slightly higher representation of males.

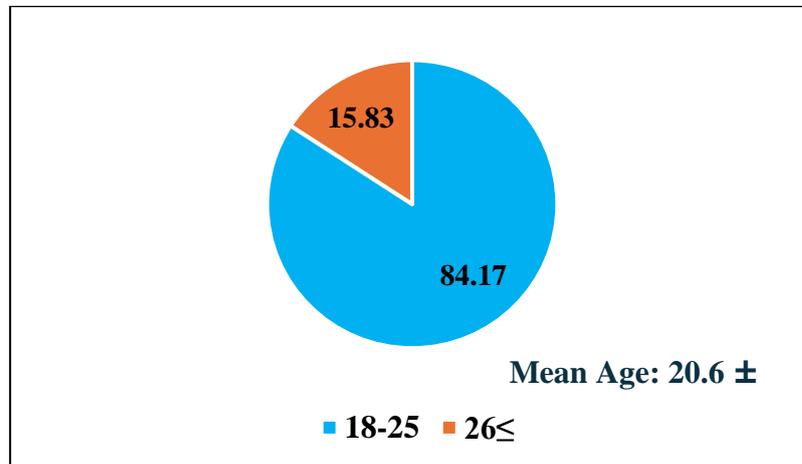


Figure 4.4.1.1 Age of the respondents (N=120, %)

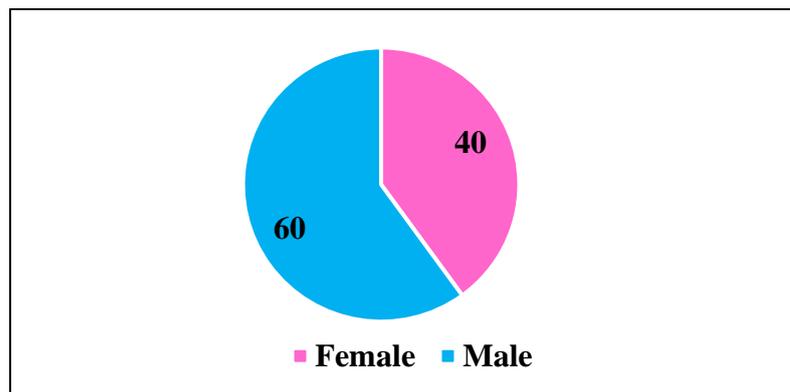


Figure 4.4.1.2 Gender of the Subjects (N=120, %)

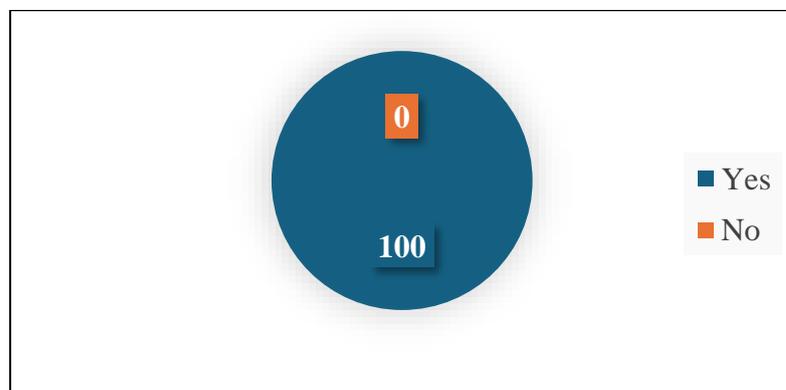


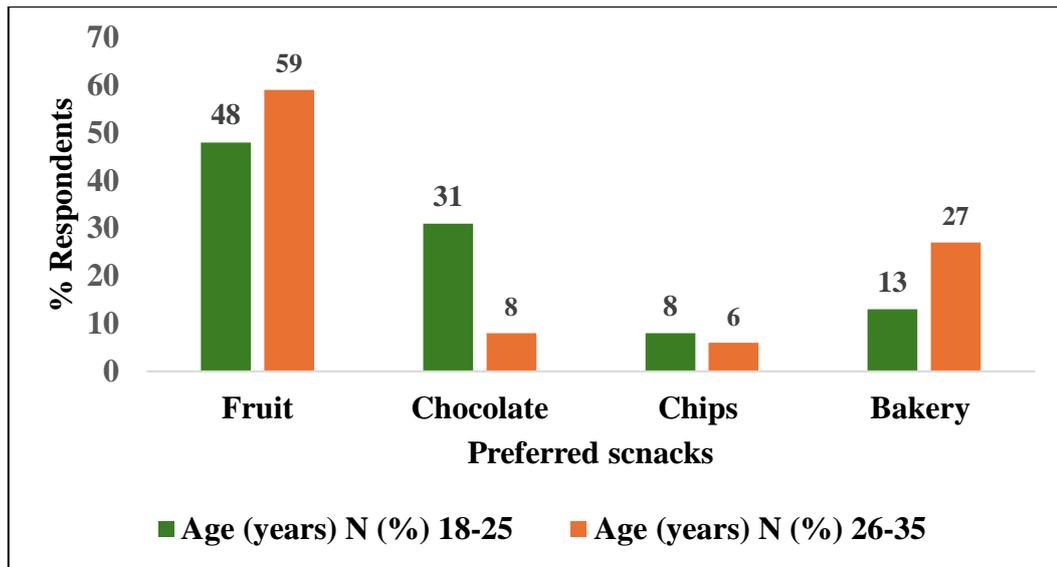
Figure 4.4.1.3 Regularity of Exercise and Physical Activity of the respondents (N=120, %)

All of the research population, comprising athletes and fitness trainers, responded positively when questioned about their frequent exercise or gym attendance, resulting in a 100 per cent affirmative response rate (Figure 4.4.1.3). This suggests a significant degree of physical activity involvement among the participants included in the sample, which is consistent with the study's emphasis on physically active people.

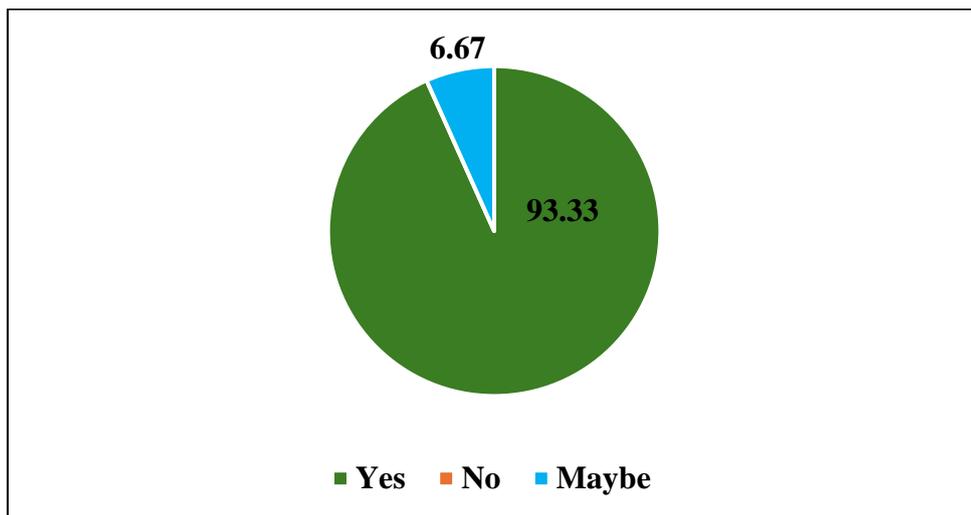
### **4.4.2 The Individuals' Preferences for Snacks and their Previous Experience**

Participants were interviewed on their snack preferences and prior exposure to similar goods. Questions designed to ascertain consumers' inclination towards healthy snack choices and their previous familiarity with such (sports, energy or protein) bars. This section sought to build a baseline understanding of the participants' snack consumption patterns and level of familiarity with sports bars.

The figure 4.4.2.1 presents the preferred snack choices among the study participants categorized by age groups (18-25 years and 26-35 years). Among individuals aged 18-25 years, the most preferred snack choice was fruit, with 48 out of 120 participants (40per cent) selecting it. This was followed by chocolate, chosen by 31 participants (25.83per cent), bakery items by 13 participants (10.83per cent) and chips by 8 participants (6.67per cent). In the 26-35 age group, however, there was a shift in preferences. Fruit remained the most preferred snack, selected by 59 out of 120 participants (49.17per cent). However, the preference for chocolate decreased significantly, with only 8 participants (6.67per cent) choosing it. Chips and bakery items also saw some preference, with 6 participants (5per cent) opting for chips and 27 participants (22.5per cent) preferring bakery items. Overall, fruit remained the top choice for both age groups, but there was a notable difference in preferences for chocolate, chips and bakery items between the two age groups. Younger participants showed a relatively higher preference for chocolate, while older participants leaned more towards bakery items and showed a comparable preference for chips.



**Figure 4.4.2.1 Preferred Snack Choices (N=120, %)**



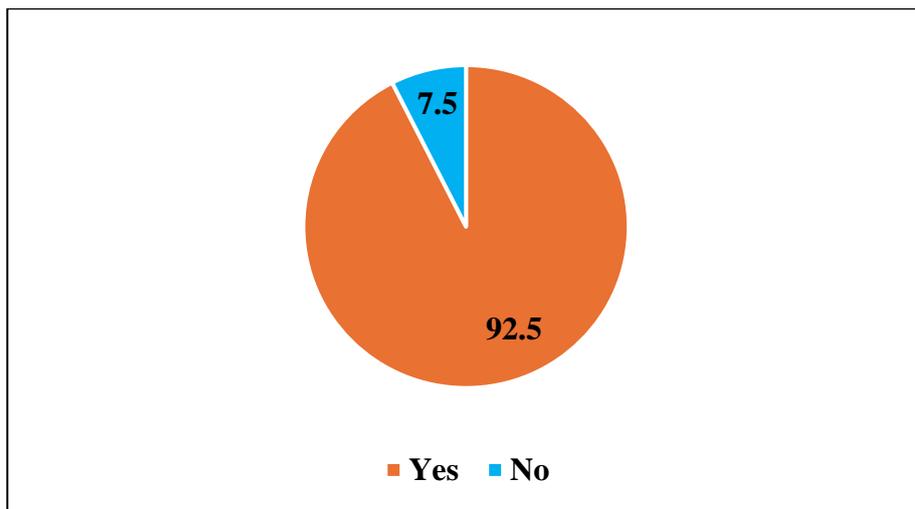
**Figure 4.4.2.2 Preference for Healthy Bars Adjacent to Sweets/Chocolate Section (N=120, %)**

The data in the figure 4.4.2.2 indicates that a majority of respondents, at 93.33per cent, expressed their preference for choosing a healthy bar from the sweets/chocolate department rather than opting for traditional sweets or chocolate. The participants' strong inclination towards healthy snack selections is evident from this high proportion. In addition, all of the respondents replied "Yes," demonstrating a complete lack of outright rejection towards the healthy bar choice. A mere 6.67per cent of respondents expressed uncertainty by selecting "Maybe," indicating some degree of ambiguity or

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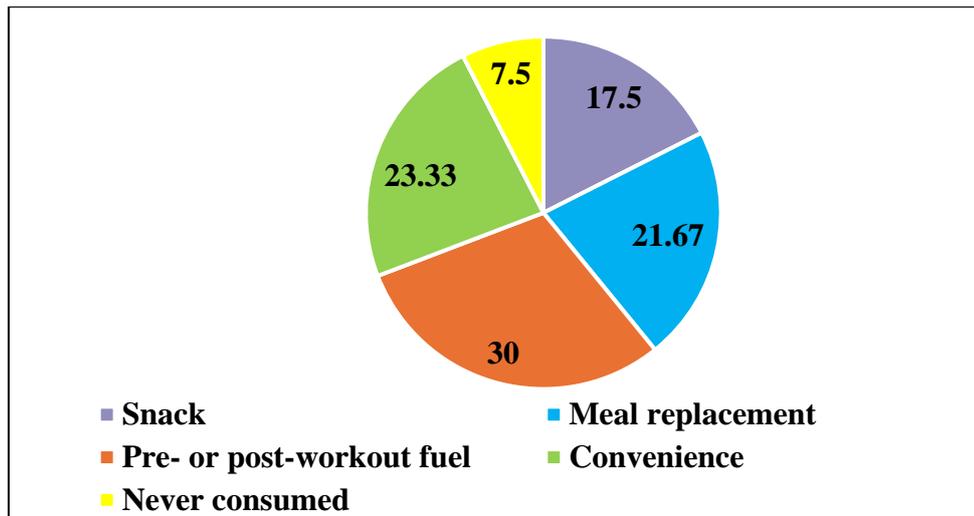
hesitation in favouring the healthy bar over sweets or chocolate. In general, the data indicates that the respondents had a positive view of healthy snack choices.

As shown in figure 4.4.2.3, the data indicates that a significant majority of respondents, approximately 92.5 per cent, reported having eaten a sports bar before, while a smaller proportion, 7.5 per cent, indicated that they had not consumed a sports bar previously. This suggests a high level of familiarity and prior experience with sports bars among the study participants.



**Figure 4.4.2.3 Previous Experience with Sports Bars (N=120, %)**

The responses indicated in figure 4.4.2.4 are various intensions for consuming sports bars among the participants. A significant portion, comprising 30 per cent of respondents, cited using sports bars as pre- or post-workout fuel, highlighting their perceived utility in enhancing exercise performance and aiding in recovery. Another notable reason, reported by 23.33 per cent of participants, was convenience, suggesting that sports bars are valued for their portability and ease of consumption on-the-go. Additionally, meal replacement emerged as a motivating factor for 21.67 per cent of respondents, indicating that some individuals view sports bars as a convenient option for replacing or supplementing meals. A smaller percentage of respondents, 17.5 per cent, identified snacking as their main reason for consuming sports bars. Overall, the data underscores the multifaceted roles of sports bars, serving not only as a source of nutrition but also as a convenient and versatile option for various dietary needs and preferences.



**Figure 4.4.2.4 Primary Reason for Consuming Sports Bar (N=120, %)**

#### **4.4.3 Inquiry on the Satisfaction and Identification of Factors that Influence the Choice**

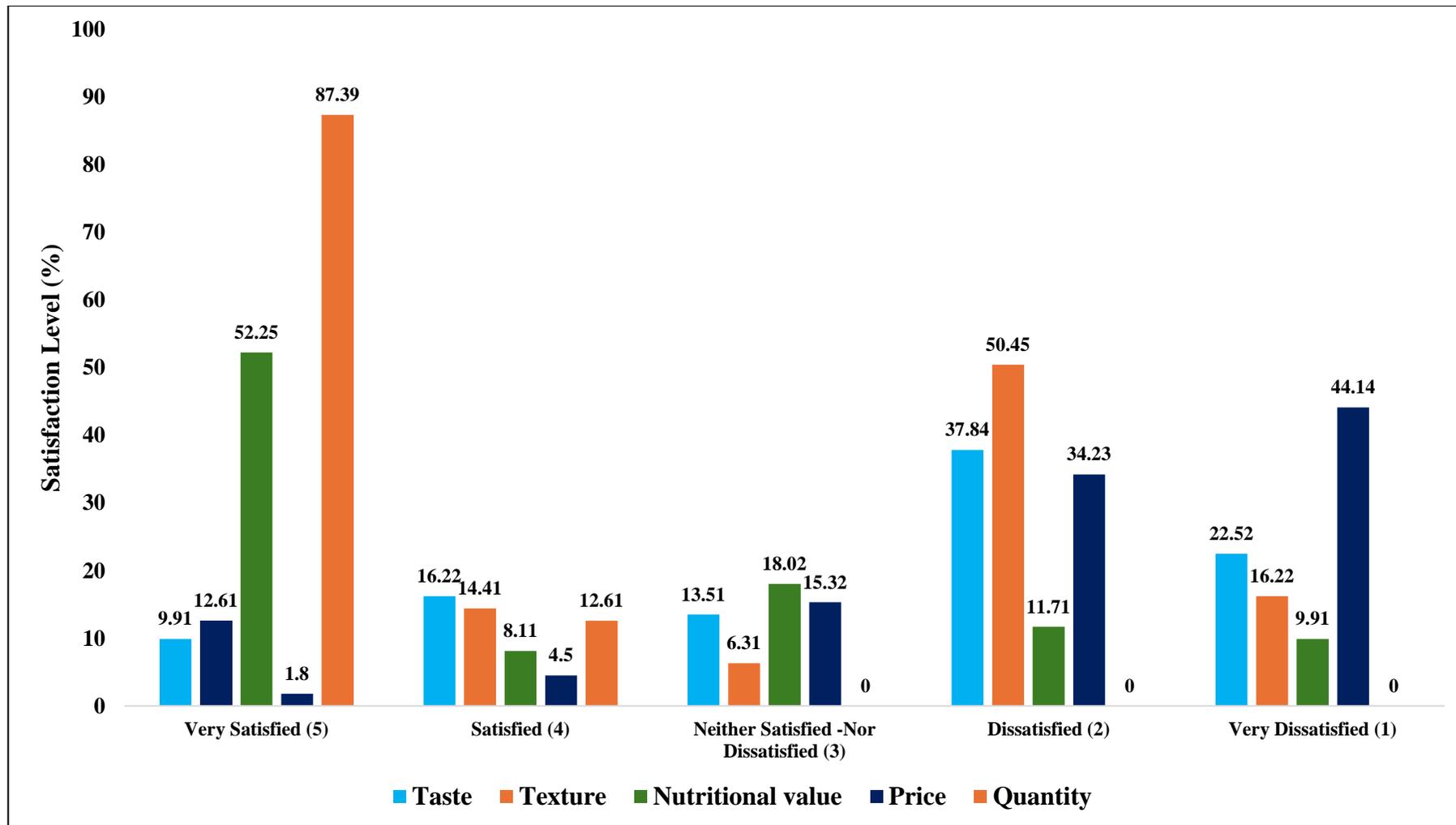
This section focused on evaluating the satisfaction levels of participants with their current snack choices and identifying key factors influencing their selection process. Participants rated their satisfaction with existing options and provided insights into the importance of various factors when choosing a sports bar. This allowed for the identification of critical attributes that drive consumer preferences.

The data in the figure 4.4.3.1 reveals varying levels of satisfaction among respondents with the bars they currently consume or are available in the market, across different attributes. Taste and texture emerged as significant factors influencing satisfaction, with a notable portion expressing dissatisfaction, particularly with taste, where 37.84 per cent rated it as dissatisfactory and 22.52 per cent rated it as very dissatisfactory. However, nutritional value received the highest satisfaction rating, with 52.25 per cent of respondents rating it as very satisfied. Price was a point of contention, with a considerable percentage dissatisfied (44.14 per cent) with the current pricing of bars. Interestingly, a significant portion expressed satisfaction with quantity, as indicated by 87.39 per cent rating it as very satisfied. These findings highlight the importance of taste and price in influencing overall satisfaction with sports bars, while also emphasizing the perceived nutritional value and quantity as positive attributes.

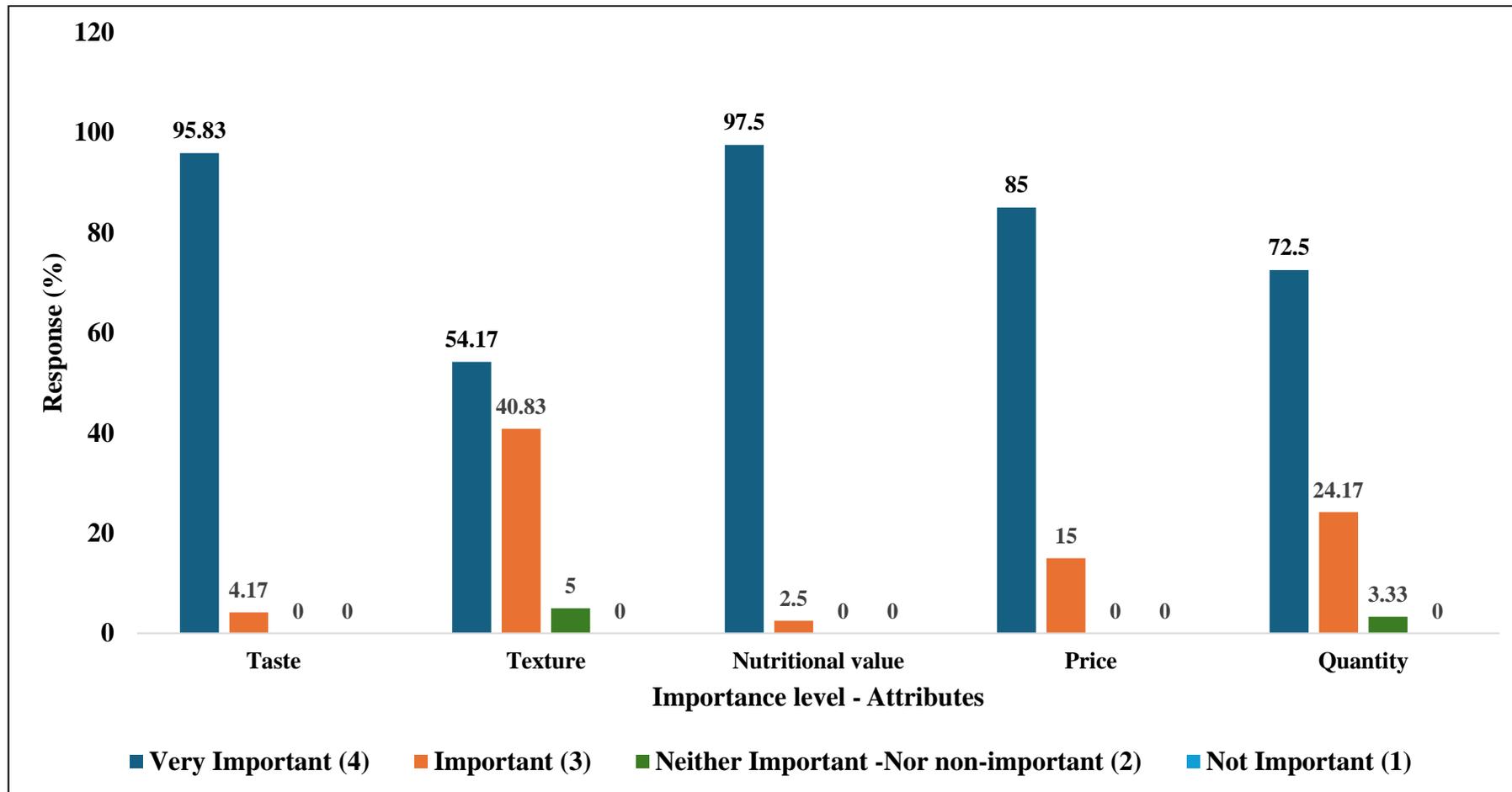
## *Results and Discussion*

The data in figure 4.4.3.2 illustrates the significant importance placed on taste, nutritional value, price and quantity when choosing a sports bar, as indicated by the majority of respondents. Taste emerged as the most crucial factor, with an overwhelming 95.83 per cent rating it as very important, emphasizing the importance of palatability in consumer decision-making. Similarly, nutritional value was highly prioritized, with 97.5 per cent considering it very important, reflecting a strong emphasis on the health benefits offered by sports bars. Price also played a significant role, with 85 per cent of respondents deeming it very important, suggesting a sensitivity to affordability. Quantity was also valued, with 72.5 per cent rating it as very important, indicating a desire for adequate portion sizes. These findings underscore the multifaceted considerations that influence consumers' choices when selecting sports bars, encompassing taste, nutrition, affordability and quantity.

As shown in figure 4.4.3.3 the data presents the budget range preferences of respondents regarding the maximum amount they would be prepared to pay for a sports bar on a regular basis. The majority of respondents indicated a preference for the 80-100 Rupees range, with 42.5 per cent of participants selecting this option. This suggests a common willingness to invest within this price bracket for sports bars. Additionally, 22.5 per cent of respondents favoured the 100-150 Rupees range, indicating a subset willing to allocate a slightly higher budget for these products. A smaller proportion of participants chose the lower budget range: 50-80 Rs., 17.5 per cent or the higher range: >200 Rs., 6.67 per cent, indicating a general preference for moderately priced options among the study population. These findings highlight the importance of price sensitivity in consumer purchasing decisions for sports bars.



**Figure 4.4.3.1 Satisfaction Level with Currently Available Bars in the Market (N=120, %)**



**Figure 4.4.3.2 Importance Ratings of Factors When Choosing a Sports Bar (N=120, %)**

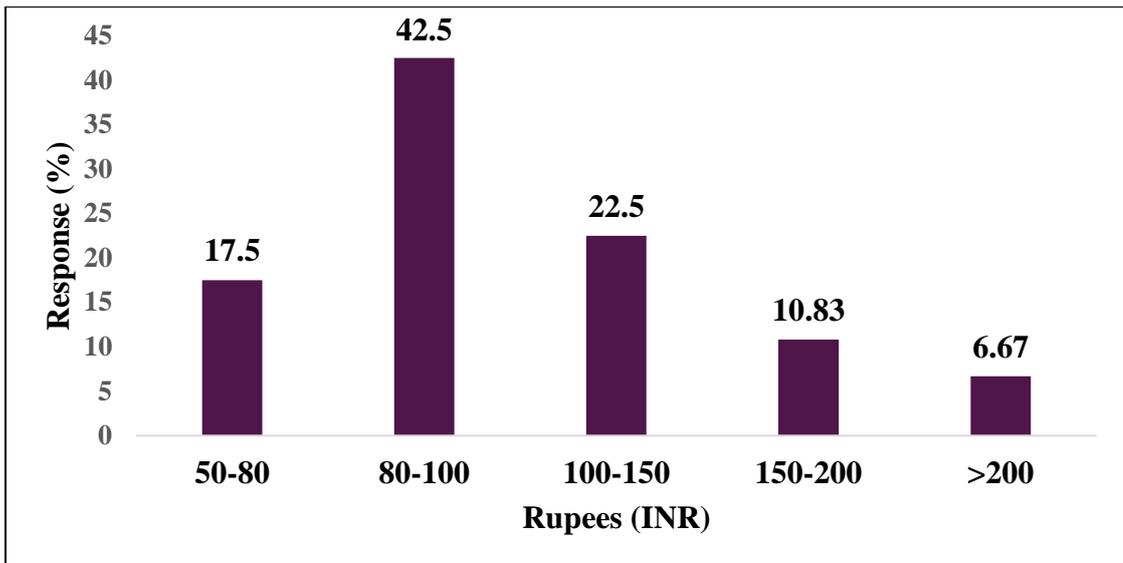


Figure 4.4.3.3 Maximum Price Prepared to Pay for the Bar on a Regular Basis (N=120, %)

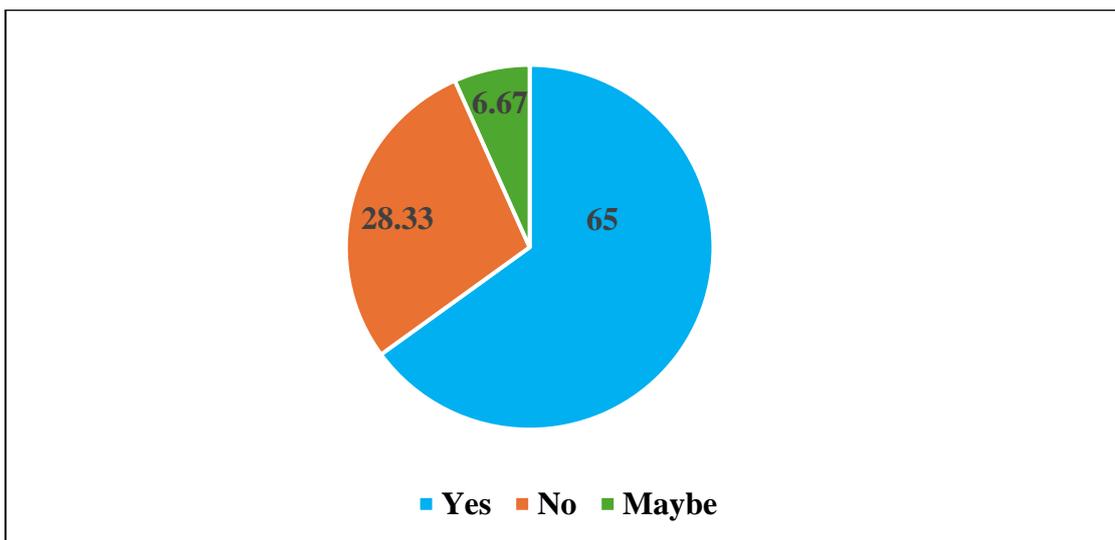


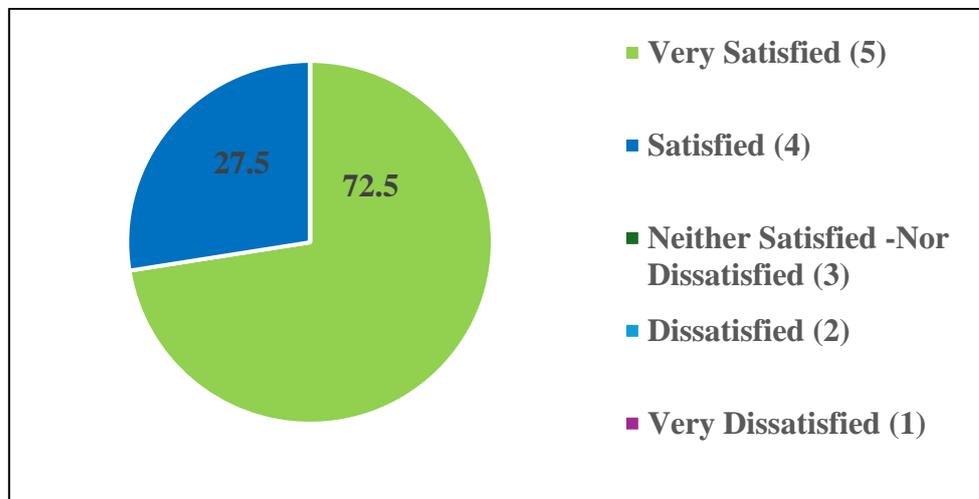
Figure 4.4.3.4 Willingness to Pay Premium for Sports Bars with Additional Nutritional Benefits (N=120, %)

The data shown in figure 4.4.3.4 reveals that over 65% of the participants reported a readiness to pay a higher price for sports bars that provide extra nutritional advantages. This indicates that the participants acknowledge the benefits of improved nutritional content in sports bars, which may include the addition of vitamins, minerals, or protein. In contrast, over 28.33% of participants showed a reluctance to pay a higher amount and a lesser proportion (6.67%) expressed doubt or hesitation about spending more for extra nutritional advantages. These findings emphasise the significance of nutritional factors in shaping customer choices when it comes to purchasing sports bars.

#### 4.4.4 Post-Consumption Assessment and Feedback of the Subjects

Following the consumption of the study bar (P-E bars), participants were asked to provide feedback on their experience. Questions assessed satisfaction levels, willingness to purchase the bar in the future, likelihood of recommending it to others and any additional comments or suggestions for improvement. This phase aimed to capture immediate reactions and perceptions towards the study bar.

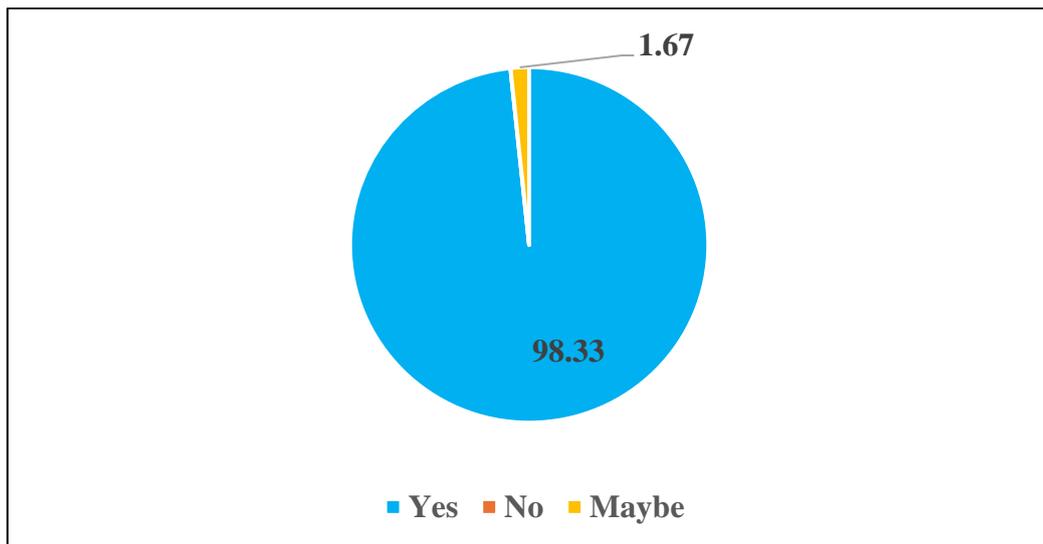
The findings shown in figure 4.4.4.1 reveals a high level of satisfaction among respondents with the sports bar they just consumed, with 72.5 per cent of participants rating their satisfaction as very satisfied. This indicates a positive reception towards the product, reflecting its perceived quality and appeal among consumers. Additionally, 27.5 per cent of respondents reported being satisfied with the sports bar, further underscoring the overall positive sentiment towards the product. Importantly, no participants expressed dissatisfaction with the bar, as evidenced by the absence of responses in the dissatisfied or very dissatisfied categories. These findings suggest that the sports bar was well-received by the study participants, highlighting its potential to meet the preferences and expectations of consumers within the target market.



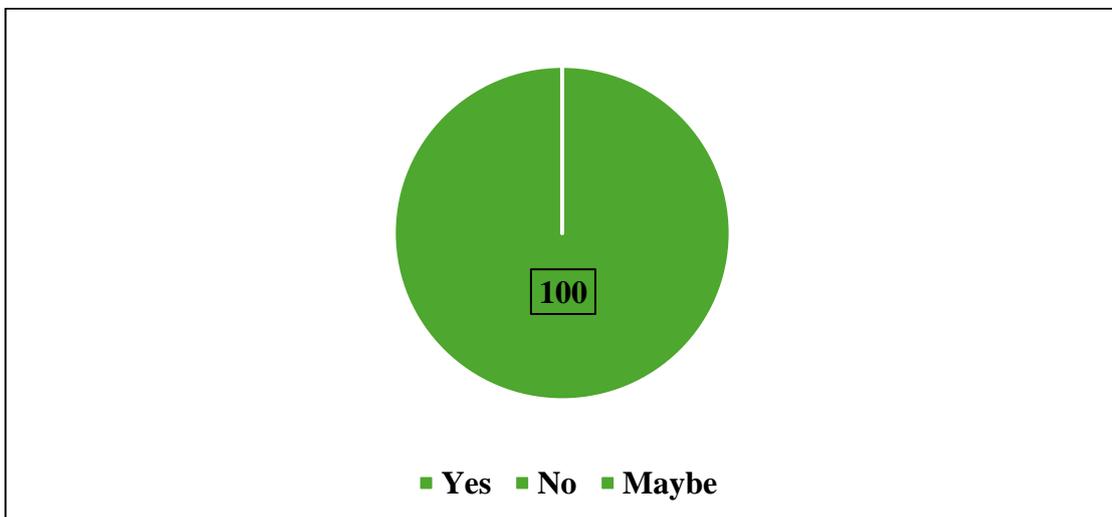
**Figure 4.4.4.1 Satisfaction Rating of P-E Bars Consuming Experience**  
(N=120, %)

The findings in figure 4.4.4.2 indicates an overwhelmingly positive inclination among respondents towards purchasing the sports bar in the future, with 98.33% expressing a desire to do so. This high percentage reflects a strong intent among participants to continue consuming the product, suggesting satisfaction with its taste, nutritional

content and overall appeal. Additionally, no respondents indicated a lack of interest in purchasing the sports bar, as evidenced by the absence of responses in the "No" category. A small percentage (1.67%) responded with "Maybe," indicating some level of reservations or apprehension, regarding future purchases. Overall, these findings underscore the favorable reception of the sports bar among consumers, indicating its potential for continued success in the market.



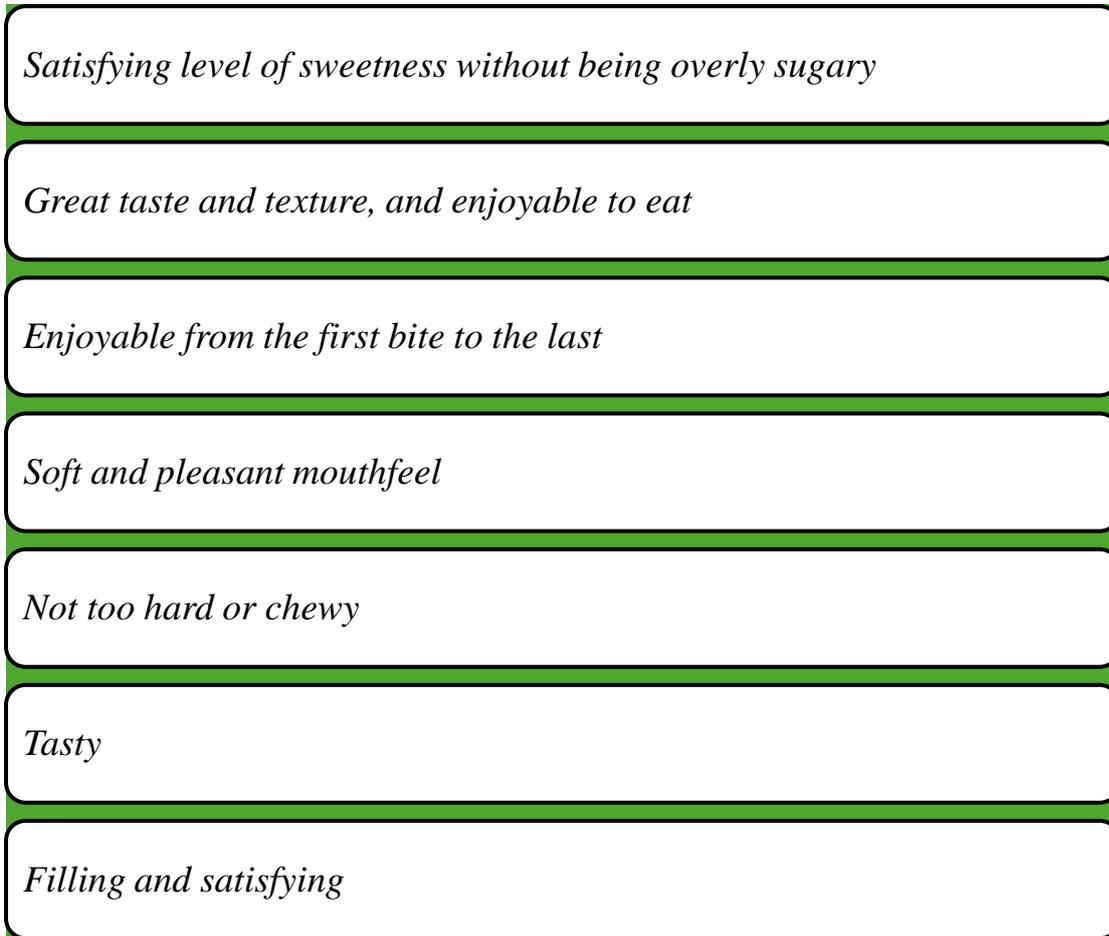
**Figure 4.4.4.2 Future Purchase Intentions for the P-E Bars (N=120, %)**



**Figure 4.4.4.3 Recommendation of P-E Bars to Friends (N=120, %)**

Figure 4.4.4.3 shows data revealing an unequivocal willingness among respondents to recommend the sports bar to a friend, with 100% of participants indicating their intention to do so. This unanimous endorsement underscores the high level of satisfaction and confidence in the product among consumers. These findings highlight

not only the satisfaction of individuals with the product but also their enthusiasm to share their positive experience with others, indicating the potential for positive word-of-mouth promotion and future market growth for the sports bar.



**Figure 4.4.4.4 Respondents' Feedback**

The comments provided (figure 4.4.4.4) offers a valuable insight into the perceived strengths and areas for improvement of the sports bar. Positive comments highlighted the bar's satisfying level of sweetness without being overly sugary, its great taste and texture and its enjoyable eating experience from the first bite to the last. Additionally, participants appreciated the soft and pleasant mouthfeel of the bar, noting that it wasn't too hard or chewy, contributing to its overall tastiness. Moreover, respondents found the bar filling and satisfying, indicating its effectiveness as a snack or meal replacement option. These comments collectively suggest that the study bar was well-received by consumers, with its flavor, texture and mouthfeel meeting or exceeding expectations. However, there is a notable absence of suggestions for improvement, indicating a high level of satisfaction with the product.

**4.4.5 Organoleptic Evaluation using a 9- PHS**

A crucial aspect of the trial involved employing a 9-point hedonic scale to conduct an organoleptic evaluation of the sports bar. Participants rated various sensory attributes such as taste, texture, aroma and overall appeal on a scale ranging from extremely dislike to extremely like. This quantitative assessment provided detailed insights into the Protein-Energy bar's palatability and organoleptic characteristics, facilitating a comprehensive analysis of its acceptability.

**Table 4.4.5.1 Sensory Score of the Acceptability Trial-9 PHS**

<b>(9-Point Hedonic Scale)</b>				
<b>Appearance</b>	<b>Taste</b>	<b>Flavor</b>	<b>Texture</b>	<b>Serving Size</b>
<b>8.02 ± 0.81</b>	<b>8.15 ± 0.74</b>	<b>8.10 ± 0.82</b>	<b>7.90 ± 0.90</b>	<b>8.22 ± 0.63</b>
Each observation is a mean ± SD of 120 subjects (n=120)				

The sensory scores of the acceptability trial, measured on a 9-Point Hedonic Scale (table 4.4.5.1), indicates a positive responses from the 120 subjects who participated. The appearance of the sports bar received a mean score of  $8.02 \pm 0.81$ , suggesting that participants found it visually appealing. Taste, flavor and serving size also received high scores, with means of  $8.15 \pm 0.74$ ,  $8.10 \pm 0.82$  and  $8.22 \pm 0.63$ , respectively, indicating favourable perceptions of these attributes. However, texture received a slightly lower mean score of  $7.90 \pm 0.90$ , suggesting that while generally satisfactory, there may be room for improvement in this aspect. Overall, these scores reflect a positive reception of the sports bar's sensory characteristics among the study participants, with minor considerations for potential refinement in texture.

In Jetavat et al.'s (2019) study, the acceptance scores of milk protein and cereal energy bars were analyzed. Appearance and color were scored at 8.16, flavor received a rating of 7.94, body and texture attained a score of 7.92 and overall acceptability was rated at 7.65 in their survey. These scores indicated that participants liked the milk protein and cereal energy snacks in various sensory characteristics.

**Hypothesis Tested Phase IV**

- Based on the findings of phase IV, the null hypotheses (Ho) proposed at the start of the investigation is rejected.
- The following alternative hypothesis (H1) is acceptable.

*The Protein-Energy Bars will meet acceptability standards among athletes, coaches and fitness trainers regarding sensory attributes and cost-effectiveness.*



**Figure 4.4.5.1 Acceptability Trial**

### **Result Highlights: Phase IV**

- *93 per cent of the panel had prior experience with sports bars, using them as pre-post workout fuel, convenience food, meal replacements, or regular snacks.*
- *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 per cent of the panel would prefer bars regularly if available at a cost between 50-80.*
- *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.*