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Investigation of Consumer Insights and Development of Alternative Protein-Rich Products from Alcoholic Beverage Byproducts

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Abstract

The research aims to promote the transformation of the food system in Vietnam toward sustainable, healthy diets by investigating consumer choices and perceptions regarding alternative protein products and developing a product utilizing alcoholic beverage byproducts. This study consisted of (i) the investigation of consumer knowledge of alternative protein and their attitude about alternative protein products, (ii) the proposition of a production process for protein powder derived from spent yeast, and (iii) the formulation of energy bars using alternative protein. A survey of 260 young people was conducted to gather information on their knowledge of alternative proteins and their desires for a novel energy bar. The spent yeast was hydrolyzed with 1% ethanol (v/w) and the enzyme Alcalase (1% w/w) for 24 hours to achieve a high level of efficiency in protein recovery (84.9%). A novel energy bar was created with alternative protein sources derived from 13.57 g Brewer's Spent Yeast (BSY) protein and 10.9 g Distiller's Dried Grains with Soluble (DDGS) protein, resulting in a product with substantial energy (252.85 kcal/serving) and a significant protein content (14.9 g/serving). The product exhibits a notable energy density of 3.89 Kcal per gram, low Glycemic Index (GI) carbohydrate from oats, unsaturated fat from peanut butter, healthy sweeteners from malt syrup, and a high protein content.

Keywords: Alternative protein, consumer insight, energy bar, brewer's spent yeast.

1. Introduction

The global food industry is undergoing a significant transformation driven by the urgent need to address sustainability and health concerns. With the growing awareness of the environmental impacts associated with traditional animal-based protein sources, alternative proteins have emerged as a viable solution to meet the nutritional demands of an increasing population. These proteins, derived from plants, insects, and microorganisms, offer a promising pathway to a more sustainable and healthy food system. The development of this field is expected to impact the Sustainable Development Goals (SDG) directly as SDG 13: Climate Action, SDG 2: Zero Hunger, and indirectly impact as SDG 1: No Poverty, SDG 3: Good Health and Well-being, and SDG 12: Responsible Consumption and Production [1].

Depending on the raw material and product types, different processes are applied to extract protein from alternative sources. The general process can be described in a five-step procedure: (i) Pre-treatment, (ii) Defatting, (iii) Protein solubilization and recovery, (iv) Protein purification, and (v) Drying [2]. Popular protein extraction techniques currently include chemical extraction, enzyme-assisted extraction, and new methods such as microwave-assisted, ultrasound-assisted, and high hydrostatic pressure-assisted techniques. These novel techniques are being researched for their potential to extract high-quality proteins at high yields [3].

Among novel protein sources, the utilization of byproducts from the alcohol beverage industry represents an innovative approach to producing high-protein food products while reducing waste. Distiller's Dried Grains with Soluble (DDGS), a byproduct of ethanol production, contains high levels of protein and fiber, making it a valuable ingredient for food fortification. Although DDGS is not yet commercially available, research studies have demonstrated that enriching various food products with DDGS can significantly enhance their nutritional value. The high protein and fiber content in DDGS-fortified food products could help prevent the onset of coronary heart disease, obesity, diabetes, and colon cancer. Research has investigated the use of DDGS in various human food applications, including bread, pasta, cookies, and extruded food products [4].

Additionally, Brewer's Spent Yeast (BSY), a byproduct of beer production, is rich in protein and can be processed to enhance its nutritional value. It can be used to formulate new food products and supplements rich in B-complex vitamins, minerals (such as

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selenium and chromium), and polyphenolic compounds with antioxidant activity. Several applications of BSY protein include replacing soy proteins as a snack food ingredient, benefiting from higher digestibility, and being used for the fortification of vegan cakes, increasing their protein, lipid, and carbohydrate content [5].

Autolysis is a degradation process that utilizes the yeast's own degradative enzymes to solubilize cell components. Hydrolytic enzymes, particularly proteases and nucleases, break down insoluble macromolecules such as proteins and nucleic acids into soluble products like peptides, amino acids (mainly glutamate), nucleotides, and amino acid derivatives [6]. Despite its utility, autolysis has notable disadvantages, including high time requirement, low yield, and the poor taste characteristics of the final product. To address these drawbacks, various techniques have been developed, such as mechanical methods, cavitation methods, chemical hydrolysis, and enzymatic hydrolysis [7]. However, research on combining different techniques to enhance protein recovery and increase the purity of yeast protein powder remains limited. Exploring such combinations could potentially yield more efficient and palatable protein extraction methods.

Despite the benefits of alternative proteins, the consumption of these products in Vietnam is still in its nascent stage. However, there is growing interest among young consumers, particularly in urban areas, in sustainable and nutritious food options. Energy bars or cereal bars, primarily manufactured to provide substantial nutrients and serve as energy boosters, are suitable and nutritious for all age groups but are mostly consumed by highly active individuals such as athletes [8, 9]. Therefore, energy bars have the potential to promote new types of protein to young consumers.

This study aimed to (i) Survey consumer awareness of alternative protein products in Vietnam, (ii) Propose a hydrolysis process combining chemical-assisted and enzymatic-assisted to produce BSY protein powder, and (iii) Formulate an energy bar using alternative protein sources (BSY and DDGS) based on consumer preference.

2. Material and Methods

2.1. Materials

BSY was provided by International Food Industry Co., Ltd, located in Hung Yen province, Vietnam. DDGS protein powder was produced and provided by the Biotechnology Research and Development Center at Hanoi University of Science and Technology (HUST). Other ingredients for the energy bar were provided by the Laboratory of Food Technology at HUST. All samples were packed and stored at freezing temperatures until use.

2.2. Consumer Survey Design

To investigate consumer insights regarding alternative proteins and develop a protein-rich product from alcohol beverage byproducts, a consumer survey was designed. The target demographic included individuals aged 18-25 residing in the two major cities of Hanoi and Ho Chi Minh City. The survey was distributed online via Google Forms. It comprised questions including short answers, multiple choice, checklist, and multiple-choice grid questions. These questions focused on consumer familiarity with alternative protein products, their desired characteristics in energy bars, and their attitudes toward the concept of a novel energy bar.

The survey aimed to understand young consumers' awareness and attitudes towards alternative proteins and to identify their preferred characteristics in energy bars.

2.3. Production of BSY Protein

The yeast hydrolysis process in the conditions with the combination of chemical promoter and hydrolysis enzyme was conducted in Fig. 1.

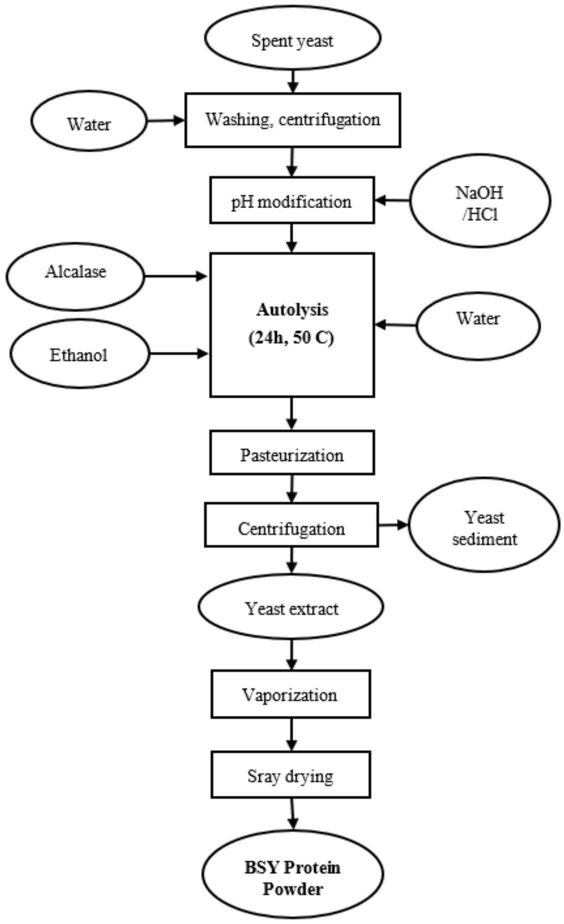

Fig. 1. BSY protein powder procedure

Firstly, BSY was subjected to centrifugation to separate the liquid component, followed by multiple washes and further centrifugation at a speed of 4000 rpm for a duration of 20 minutes, using a distilled water to BSY ratio of 1:5. This process was employed with the objective of reducing the bitterness associated with BSY.

The hydrolysis process was then conducted at an optimum temperature of 50 °C for 24h [6]. Ethanol (1% v/w) was chosen as a lysis promoter to achieve high protein content in yeast extract [10], while Alcalase (1% w/w) was chosen to accelerate the release of intracellular molecules to the extracellular medium [7]. The cleansed biomass was combined with water and a 1% ethanol solution per weight sample, wherein the biomass constitutes 15% of the total weight of the mixture. The mixture is adjusted using NaOH/HCl to reach a pH of 7, which is the optimal pH for Alcalase. The hydrolysis process was conducted within a shaker incubator operating at a speed of 40 rpm. Yeast extract samples were collected at 0 h and 24 h to analyze hydrolysis efficiency.

Following a 24-hour period, the autolysate underwent pasteurization in a water bath maintained at 85 °C for 15 minutes. This procedure stopped the autolysis process, after which the autolysate was cooled to ambient room temperature.

The obtained mixture was subjected to centrifugation to separate the yeast extract from the yeast sediment. The yeast extract was vaporized to increase the Brix to 10 using a rotovapor device, then spray-dried, with an entrance temperature of 110 °C and an output temperature of 70 °C, to produce protein powder. The final yeast protein powder was enclosed within resealable pouches.

2.4. Chemical Analysis

2.4.1. Determination of protein recovery yield (Hr)

The yield of protein recovery *(Hr)* is defined as the content of protein recovered in yeast extract compared to the total protein in yeast autolysate.

$$H_r = \frac{P_{yeast\ extract}}{P_{yeast\ autolysate}} \times 100\ (\%) \quad (1)$$

where H_r is protein recovery yield; $P_{yeast\ extract}$ is crude protein of yeast extract; $P_{yeast\ autolysate}$ is crude protein of yeast autolysate.

2.4.2. Determination of solubility yield (Hs):

$$H_s = \frac{d.m_{yeast\ extract}}{d.m_{yeast\ autolysate}} \times 100\ (\%) \quad (2)$$

where $d.m_{yeast\ extract}$ is dry matter content of yeast extract; $d.m_{yeast\ autolysate}$ is dry matter content of yeast autolysate.

Other chemical analysis methods used in the research include the determination of crude protein content using the Kjeldahl method (TCVN 8125:2015), and protein content was estimated using factor conversion of 6.25 [11] dry matter content (TCVN 8124:2009), total sugar content using the DNS method, and soluble amino acid content (TCVN 8764:2012).

2.5. Formulate the Process of Energy Bar

From the properties obtained through the consumer survey, energy bar formulas would be proposed to meet consumer needs.

2.5.1. Nutritional profile calculation

The calorie and nutrient content of the final samples was calculated based on the Vietnamese Food Composition Table 2007 and information from the manufacturer and literature (the fiber is not included in carbohydrates). Therefore, this information only has theoretical values.

PLC (Protein/Lipid/Carbohydrate) ratio is defined as the calories coming from protein, lipid, and carbohydrate, respectively, compared to total calories.

The Caloric values for each category were calculated as follows:

$$Energy\ value\ (Kcal/100\ g) = (4 \times \%\ protein) + (9 \times \%\ fat) + (4 \times \%\ carbohydrate) \quad (3)$$

The energy density (kcal/g) is calculated by dividing total energy by the serving size of the product.

2.5.2. Sensorial evaluation

The acceptability of energy bars is being assessed using the Hedonic Scale. To evaluate the acceptability of the energy bars, judges used a hedonic scale ranging from 1 to 7 points (7 = Strongly liked, 4 = Neither liked nor disliked, 1 = Strongly disliked).

Feedback is collected via Google Forms and analyzed using Microsoft Excel and SPSS 20 to determine overall acceptability and pinpoint areas for improvement.

The panel consists of participants who are students from Hanoi University of Science and Technology (HUST) of both sexes and familiar with sensory tests. Each participant receives one sample piece from each formulation. Samples are coded with three random digits and served at room temperature alongside water in disposable cups.

3. Result and Discussion

3.1. Findings from the Consumer Survey

The consumer survey targeted young adults aged 18-25 living in Hanoi and Ho Chi Minh City, with 260 respondents participating (57% male and

43% female). Among these, 179 individuals fell within the primary research scope.

3.1.1. Awareness of alternative protein

The survey revealed a high awareness of alternative protein products among the participants, with most participants (84%) being aware of the products but not having used them (Fig. 2). This result is consistent with a previous report by the Good Food Institute (GFI) in APAC, which indicated that a large portion of Vietnamese consumers fall into the 'Curious' category—those who are aware of alternative protein products but have not used them [12]. This group represents a potential customer base for manufacturers of novel foods related to alternative proteins, especially those producing microbial-based protein products. Additionally, social media (54.5%) is the primary communication channel through which consumers access information about alternative protein products.

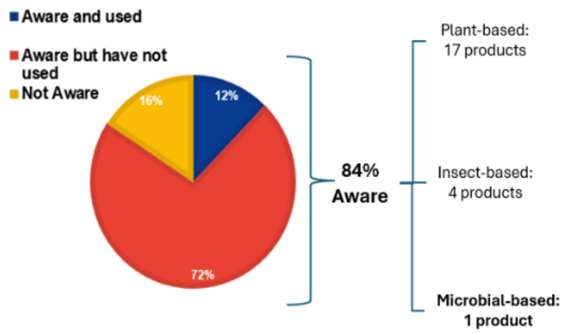

Fig. 2. Consumers awareness of alternative protein products

Additionally, snacks (67.9%) and breakfast (56.1%). are the two meals that participants believe are suitable for novel food products using alternative protein. This result is similar to the choices of consumers in the US, according to McKinsey & Company, with the majority of consumers more interested in trying novel ingredients on the go as a snack, at lunch, or at breakfast than at other meals or times [13].

These findings suggest that the disparity between awareness and usage in Vietnam indicates a significant opportunity for market growth in alternative protein products, particularly those derived from microorganisms. Moreover, convenient, quick-to-prepare, or ready-to-eat products used for snacks or breakfast have the potential to reach the target customers who are aware of alternative protein in Vietnam.

3.1.2. Desired characteristics of energy bars

The most common reason consumers cited for choosing alternative protein products is convenience (67.4%). Additionally, nutritional benefits (49.3%) and use as snacks (24.1%) are also popular reasons.

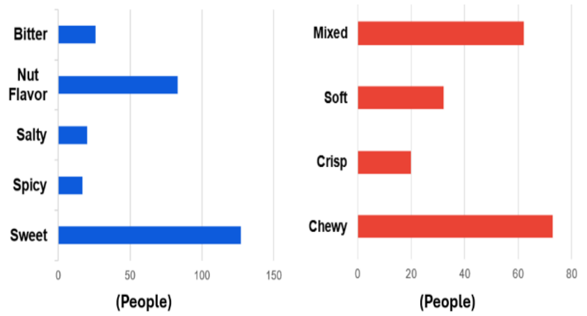

Fig. 3. Desired flavor (left) and texture (right) of energy bars

Regarding product properties, sweet (67.9%) and nut flavors (44.4%) were particularly favored, and consumers preferred energy bars with a mixed texture or chewy consistency (Fig. 3). The importance of desired texture and the impact of ingredients such as roasted nuts and cereal seeds have also been shown to positively affect consumer acceptance of cereal bars [8].

3.1.3. Willingness to try and considerations

Regarding the question on willingness to try a new energy bar product that uses alternative protein sourced from safe by-products of alcoholic beverage production, 46% of participants responded positively (Fig. 4). This result is lower compared to a previous report with US consumers, which indicated an average of 56% willing to try biomass proteins [13].

Among the considerations of consumers for this novel product, issues related to flavor, safety, and price were the most prominent. These issues are major challenges in the application of alternative proteins in the food industry [2].

Understanding consumer behavior is crucial for helping food producers create products that are better suited to the market. Insights into consumer habits, desired product characteristics, and concerns obtained from survey results will enable food producers to design products that align more closely with consumer preferences.

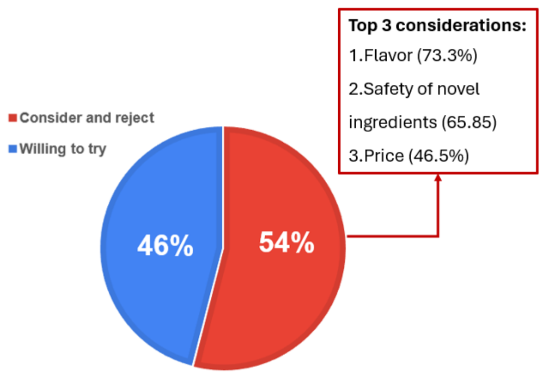

Fig. 4. Consumer willingness to try and main considerations

3.2. Characterization of BSY Protein Powder

The yeast hydrolysis process occurs over a 24-hour period, achieving a solubility yield (H_s) of 64.67% and a protein recovery yield (H_r) of 84.78%. The resulting BSY protein powder is collected after the spray drying process, characterized by its fine texture and pale pink color. It possesses an umami taste accompanied by a bitter aftertaste, primarily due to the high content of free glutamic acid released from proteins during hydrolysis. The chemical properties of the BSY protein powder are detailed in Table 1.

The weight of protein in the powder was assessed using electrophoresis to compare it with the protein content of yeast prior to the hydrolysis process (Fig. 5). The three lines under consideration were the standard line, the yeast protein line, and the autolysis line. Following electrophoresis, two distinct lines became visible: the standard line and the yeast protein line. Additionally, the sample exhibited a substantial concentration of free amino acids, specifically 5.78 g/kg.

Table 1. BSY protein powder characteristics

Criteria	*Value*
Moisture	10.2 %
Solid content	89.8 %
Protein	59.49 %
Carbohydrate	10.68 %
FAN (free amino nitrogen)	5.78 g/kg

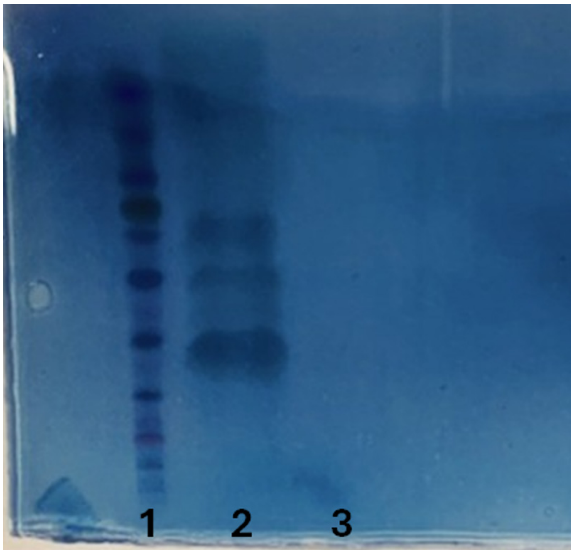

Fig. 5. Electrophoresis result (line 1: standard line, line 2: protein before hydrolysis, line 3 hydrolyzed protein)

This observation suggests that a significant proportion of the protein underwent hydrolysis, resulting in the formation of smaller peptides and amino acids. These hydrolyzed products had a molecular weight of less than 11 kDa, making them undetectable by electrophoresis. This result is consistent with previous reports on the application of Alcalase in yeast hydrolysis, which indicated that enzymatic digestion by Alcalase breaks down proteins into smaller fragments and peptides, significantly increasing the peptide content in the hydrolyzed cells [7].

Tanguler *et al*. reported that the solid and protein contents of spray-dried yeast extract powder produced from the autolysis process are 91.5% and 45.6%, respectively [6]. In the present study, the BSY powder produced from the hydrolysis process had a slightly lower solid content of 89.8% but a higher protein content of 59.49%, indicating a higher protein quantity and purity. This powder may contain a small proportion of nucleotides. Previous studies reported an RNA of 4% (dm) of yeast cells, and this content tended to decrease during cell treatment [11]. Moreover, the interaction of 5′-nucleotides with amino acids (especially glutamic acid) and peptides in yeast extract leads to taste improvement [14].

3.3. Development of Energy Bar Formulations

3.3.1. Formulation of energy bars

Based on the consumer insights obtained from the survey, three formulas for energy bars (Fig. 6) were proposed, as shown in Table 2. The energy bars developed in this study are vegan, deriving their protein primarily from BSY and DDGS.

Fig. 6. Energy bars F1, F2 and F3 (From left to right)

These bars include unsaturated fat sourced from peanut butter, providing a healthy lipid profile. For carbohydrates, oats are used due to their low glycemic index (GI), ensuring a steady release of energy.

Malt syrup is incorporated as a natural sweetener, offering an alternative to refined sugars. Utilizing protein from byproducts of familiar beverages like beer and rice spirit helps reduce the product cost and brings a sense of familiarity to consumers with microbial-based protein. These energy bars are designed to weigh 65 grams each. They have balanced macronutrient contributions, with protein accounting for 23.4% to 23.9% of the total energy, lipids contributing 29.5% to 30.2%, and carbohydrates providing 45.9% to 47.1%. Each bar delivers between 14.56 and 15.17 grams of protein per serving, making them suitable for young and athletic individuals who require high protein intake.

Table 2. Energy bar formulations

		Formula 1 (F1)	Formula 2 (F2)	Formula 3 (F3)
Ingredients	Cashew (g)	13		
	Pumpkin seed (g)	17		
	Oat (g)	25		
	Malt syrup (g)	40		
	Peanut butter (g)	10		
	BSY protein powder (g)	0	27	13.57
	DDGS protein powder (g)	21.75	0	10.9
	Weight (g)	132	126.75	129.47
Nutritional Properties	Energy density (kcal/ g)	3.75	3.99	3.89
	PLC ratio	2.39:3.02:4.59	2.34:2.95:4.71	2.36:2.98:4.65
	Protein (per 65 gr)	14.56	15.17	14.9
	Energy (kcal per 65 gr)	243.89	259.63	252.85

Regarding energy density, the bars exhibited a range of 3.75 to 3.99 kcal/gram. This aligns well with the energy content reported in the literature for the most studied protein bars, which ranges from 3.30 to 4.10 kcal/gram, and is comparable to commercially available options that range from 3.4 to 4.3 kcal/gram [9].

The ingredients were measured according to the prescribed recipe. Pumpkin seeds, cashews, and nuts undergo a process of light frying in order to increase their crispness in the finished product. The sauce was prepared by combining peanut butter with malt syrup. A mixture of protein powder, nuts, seeds, oats, and sauce was mixed together. The mixture was compressed and thereafter put into a mold with a rectangular shape. The mixture is refrigerated for a duration of two hours before being divided into bars of similar size.

3.3.2. Sensorial analysis on energy bars

The participants comprised 51 people (29% female and 71% male), aged between 19 and 24, who are students of HUST. Although F2 with yeast protein received the highest score in color, it scored the lowest in flavor due to its bitterness. F1, using DDGS protein, scored higher in flavor than F2 because it is less bitter.

While F1 exhibited moderate performance in color and appearance, scoring 3.75 ± 1.28 and 3.75 ± 0.94, respectively, it suggested room for visual improvement. Although F2 led in color with a score of 4.78 ± 0.97, it showed mixed results in other categories: its appearance score was 3.98 ± 0.88, texture was 4.18 ± 0.91, and flavor was the lowest at 3.82 ± 1.26, highlighting the need for flavor enhancement.

Table 3. Sensorial analysis

Criteria	F1	F2	F3
Color	3.75±1.28	4.78±0.97	4.41±0.85
Appearance	3.75±0.94	3.98±0.88	4±0.92
Texture	4.47±0.76	4.18±0.91	4.53±0.70
Flavor	4.31±0.93	3.82±1.26	4.47±0.92
Bitterness likeness	4.78±0.86	3.84±1.63	4.82±0.93
Overall acceptability	$4.21±0.53^a$	$4.12±0.65^a$	$\mathbf{4.45±0.45^b}$

Values with a different letter are significantly different ($p < 0.05$) according to Duncan's test

F3 stood out with balanced attributes across all categories. It scored the highest in color at 4.41 ± 0.85 and maintained consistent results in appearance (4.00 ± 0.92), texture (4.53 ± 0.70), and flavor (4.47 ± 0.92). Additionally, F3's bitterness likeness was also favorable at 4.82 ± 0.93, which significantly contributed to its overall acceptability. Consequently, 3 achieved the highest overall acceptability score of 4.45 ± 0.45 among the three formulations. Results from the one-way ANOVA analysis further confirmed that the overall acceptability of F3 was significantly different from F1 and F2. This statistical validation underscores F3's superior balance and appeal, making it the most favored formula in the study.

This indicates that F3 has the most potential for further development and improvement in properties. However, this score still does not reach the level of consumer preference.

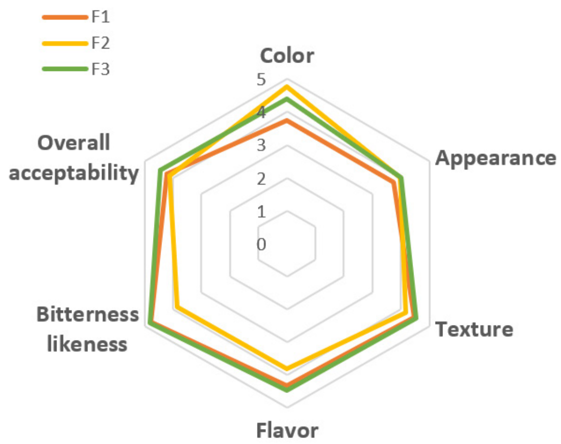

Fig. 7. Radar Chart of Sensorial Characteristics

Regarding the radar chart (Fig. 7), in addition to continuing to improve the general characteristics of the product, improving the appearance and color of F3 will help achieve a balanced sensory profile and higher consumer preference.

4. Conclusion

This study addressed the objectives of investigating consumer awareness of alternative protein products in Vietnam, developing a hydrolysis process for protein powder derived from BSY and formulating an energy bar using alternative protein sources from BSY and DDGS. The survey revealed a consumer base of young Vietnamese individuals, with 84% aware of alternative proteins. The hydrolysis process achieved a high protein recovery yield of 84.78%, producing a BSY protein powder with a crude protein content of 59.49%. The formulated energy bar, incorporating BSY and DDGS proteins, demonstrated substantial energy and protein content, showing promise for further development to meet consumer preferences. These findings underscore the potential of utilizing alcoholic beverage byproducts to create high-protein, sustainable food products. This approach not only addresses environmental concerns by reducing waste but also contributes to a more sustainable food system in Vietnam. By tapping into the growing interest in alternative proteins among young consumers, these products can play a significant role in promoting healthier, more sustainable dietary choices.

Acknowledgments

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