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Production of nutri bar with fruit peels and seeds by incorporating spirulina as a microalgae for formulation and standardization

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Abstract
This paper tackles the pressing issue of waste in the global agro-food and fruit industry, where approximately half of all fruits and vegetables produced are discarded, amounting to a staggering 1.6 billion tons of "primary product equivalent," as reported by the United Nations. However, the paper shifts the focus to the hidden potential within fruit waste, such as peels and seeds, which harbour a wealth of bioactive compounds. By harnessing these valuable resources, the paper proposes the development of an innovative food product aimed at fortifying the human immune system, achieved through their incorporation alongside microalgae Spirulina. The paper comprises three critical sections: a comprehensive literature review and quantitative analysis establishing the link between fruit waste and human health, the extraction of high-value bioactive compounds from fruit waste, and the practical integration of these compounds into new, health enhancing food products. The paper also evaluates the shelf-life of these products, a pivotal aspect in their ability to contribute to the global "zero waste" initiative. This multifaceted approach merges scientific evidence, innovation, and practicality, offering a promising solution that addresses environmental concerns while promoting human well-being.

Keywords: Spirulina, fruit waste, banana peel, micro-algae, watermelon seeds

Introduction
Waste generated from the agro-food industry, with a particular focus on the fruit sector, has emerged as a critical disposal issue with far-reaching environmental implications [1]. In the context of India, fruit processing yields substantial quantities of waste materials. These waste by-products, often overlooked, harbour a hidden treasure trove of antioxidant polyphenols. Recognizing the untapped potential of fruit waste, there has been a growing interest in research and development within the food industry [2]. This involves the transformation of fruit waste into value-added food products, thereby addressing not only the pressing concern of food waste but also advancing environmental sustainability [3]. Fruit waste is far from mere detritus, it contains a wealth of essential nutrients, dietary fibre, and bioactive compounds [4]. These compounds are known to confer various health benefits, and their extraction and incorporation into different food products offer an innovative approach to both waste reduction and the creation of healthier and more sustainable food options for consumers. These fruit by-products are rich in nutrients, including vitamins, organic acids, dietary fibres, and phenolic compounds, with a versatile range of actions. These actions encompass antioxidant properties, cardiovascular protection, anti-cancer effects, and even antibacterial and antiviral activities, among others [5].

Materials and Methodology
Materials
The selection of ingredients for this study adhered to strict quality standards. Unripe banana peels and orange peels, procured from a local fruit market, were chosen for their inherent characteristics. Supplementary ingredients, comprising watermelon, muskmelon, peanuts, Spirulina, date syrup, vanilla essence, and compound chocolate, were carefully sourced from reliable local suppliers to meet our project's specifications.

Methodology: Processing of nutri bar

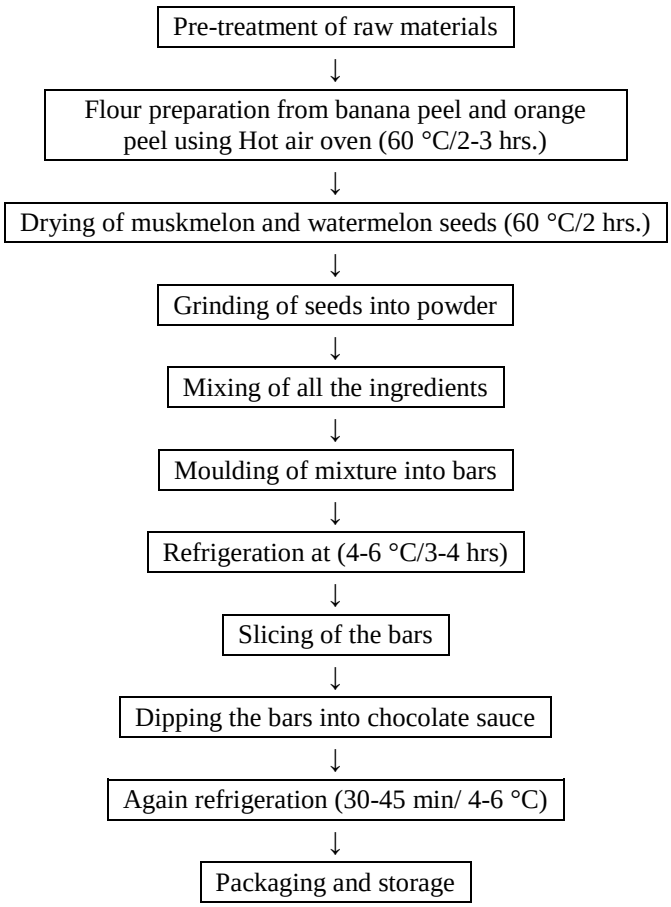

Fig 1: Flow chart for the preparation of nutri bar

Preparation of unripe banana peel flour

Fig 2: Banana peel powder

Unripe banana peel flour preparation commenced with a systematic cleaning process involving water immersion to eliminate latex and contaminants. Subsequently, the peeling of bananas transpired. Blanched peel sections underwent controlled drying using hot air oven at 60 ℃ for 4 hrs. (Fig 2) The dried peels were then finely ground into a flour form, optimally preserved in an airtight container [6].

Preparation of orange peel powder

The process to produce orange peel powder initiated with the detailed cleaning and peeling of fresh oranges. The peeled orange rinds underwent a uniform drying procedure in a hot air oven at 60 ℃ for an exact 4 hrs period. (Fig 3) Post-drying, the orange peels were methodically processed into a fine powder, suitable for storage in hermetically sealed containers.

Fig 3: Orange peel powder

Seeds preparation

Seeds obtained from watermelon and muskmelon fruits were meticulously separated. Subsequently, the seeds were subject to precise drying under controlled conditions at 30 ℃ for a precisely timed interval of 2 hrs. (Fig 4) This approach guaranteed the preservation of seed integrity and quality while rendering them suitable for integration into our product.

Fig 4: Watermelon seeds and muskmelon seeds

Product preparation

The final product formulation is the culmination of a stringent ingredient selection and preparation process. This includes the finely tuned banana peel flour, expertly processed orange peel powder, meticulously dried watermelon and muskmelon seeds, nutrient-rich spirulina, date syrup for sweetness, groundnut powder for depth of flavour, and the delightful essence of vanilla. (Fig 5)

Fig 5: Spirulina Powder

These ingredients, meticulously measured and blended, undergo a careful mixing process. The resultant mixture is subjected to two consecutive refrigeration phases, both prior to and after a brief immersion in compound chocolate. Trials were carried out with unknown quantity of ingredients selected for first two trials and final trial the amount of ingredients finalized in order to each good consistency. (Fig 6) This ensures the product achieves and maintains optimal quality, delivering a delectable and nutritionally enriched culinary experience.

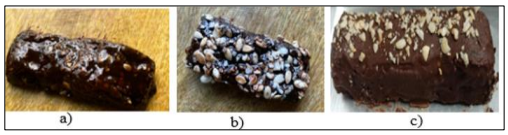

Fig 6: a) Trial 1 b) Trial 2 and c) Final trial Nutri bar enriched with fruit waste and spirulina

Results and Discussion

Analysis of nutritional content of fruit peels

The analysis of moisture content in both the raw materials (Peels and seeds) and the final product was conducted using a hot air oven, maintaining a constant temperature of 60 °C for duration of 4 hrs. To determine the ash content, both the raw materials and final product were subjected to a muffle furnace, with the temperature held at 550 °C for 6 hrs. Furthermore, we assessed the moisture, ash, phenolic content, and Vitamin C levels in the peel and seeds flours. (Table 1.1)

Table 1.1: Analysis of nutritional content of fruit peels

Sample	Moisture (%)	Ash (%)	Vitamin C (mg/ml)
Banana peel flour	5	11	2.8
Orange peel flour	7.8	4	1.8

Weight of the nutri bar product

The product underwent a rigorous standardization process, refined through a systematic trial-and-error approach. The resulting final product weighed approximately banana peel flour (10 gms), orange peel flour (4 gms), musk melon seed powder (7.5 gms), watermelon seed powder (7.5 gms), dates syrup (21 gms), groundnut (10 gms), vanilla essence (1 gm), spirulina powder (1 gm), and coated compound chocolate (18 gms) total weight of the end product 80.0gms

Analysis of nutritional content of final product

The estimation of crude protein in the final product followed the IS: 8184-1976 method, and for the determination of crude fibre in the final product, the same standard method was employed. To ascertain the fat content in the finished product, the Soxhlet method was utilized. This rigorous approach ensured the comprehensive characterization of the product's nutritional composition and quality. (Table 1.2)

Table 1.2: Assessment of nutritional content in final product

Sample	Moisture %	Ash %	Vitamin C mg/ml	Phenolic content (mg/GAE/g)	Crude Fat %	Crude fibre (g)	Crude Protein (g)	Carbohydrate (g)
Finished Product	13	6	4.6	19	20	4	12	62.68

Analysis of total plate count

The analysis of the total plate count for yeast and mould in nutri bar is represented as below (Table 1.3). The results clearly indicate that the nutri bar sample exhibits a significantly lower total plate count. this reduction can be attributed to the presence of banana peel powder within the formulation. additionally, it's noteworthy that the yeast and mould count for both samples were found to be negligible.

this outcome aligns with previous research, which underscores the antimicrobial properties of banana peel powder and spirulina. these natural components effectively inhibit microbial growth, contributing to the enhanced shelf-stability of the nutri bar. the microbial analysis data supports the assertion that the nutri bar remains shelf-stable for up to 15 days at room temperature and extends to an impressive 30 days when stored under refrigeration. This resilience against spoilage underscores the product's suitability for prolonged storage while maintaining its quality.

Table 1.3: Analysis of the total plate count: yeast and mould count

Dilutions	TPC (CFU)	Fungal count (CFU/g)
10^-3	150	Nil
10^-4	90	Nil
10^-5	70	Nil

Sensory evaluation

The evaluation of the finished product's acceptability was conducted with meticulous attention to detail, employing a hedonic rating scale to gather insights from a diverse panel of 20 semi trained individuals. This approach was chosen to ensure a fair and unbiased assessment of the product's sensory attributes. The attributes considered for scoring, such as appearance, colour, taste, texture, aroma, and overall acceptability, represent crucial factors in determining a product's success in the market. Consumers often make their purchasing decisions based on these attributes, which underscores the importance of this comprehensive evaluation.

To achieve a standardized and high-quality product, a rigorous process was undertaken. Five trials were meticulously conducted, with three of them subjected to sensory evaluation tests. The invaluable feedback received from these evaluations guided the optimization of the product's composition, with a specific emphasis on enhancing taste and aroma. This iterative approach aimed to fine-tune the sensory experience of the nutri bar to align it with consumer preferences. The results of this thorough evaluation yielded a clear and compelling conclusion: Sample 3 surpassed Samples 1 and 2 in terms of overall acceptability, as illustrated in Fig 2. This observation reinforces the effectiveness of the iterative refinement process in creating a product that meets or exceeds consumer expectations.

The remarkable overall acceptability of the nutri bar, as demonstrated in this study, is a testament to its potential for success in the market. It reflects the product's readiness for commercialization and suggests that it is poised to provide consumers with a sensory experience that is both satisfying and enjoyable. The product is positioned favourably in the competitive landscape due to its ability to align with customer preferences for flavour and taste. This not only ensures consumer satisfaction but also bodes well for its commercial viability and market acceptance.

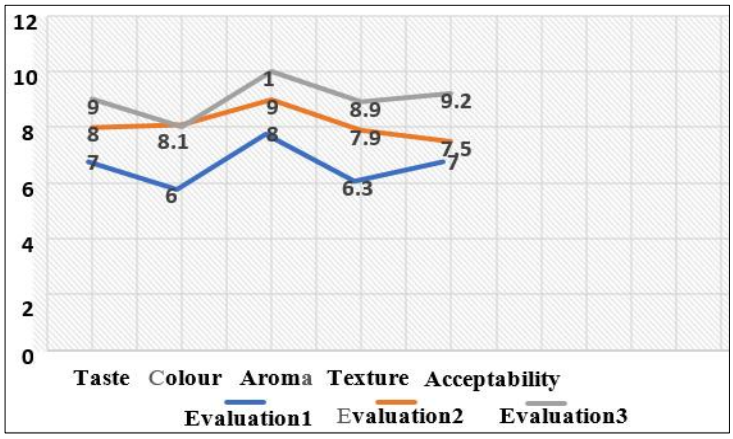

Fig 7: Sensory evaluation graph of Nutri bar

Shelf-life study

The assessment of the product's shelf-life was undertaken over one-month duration, with samples placed under two distinct storage conditions. Sample 1 was stored at room temperature for 15 days, utilizing proper packaging in zip lock pouch bags, while Sample 2 was maintained under refrigeration for the full 30-day period. This method allowed for a comparative study to analyse the product's stability and quality under different temperature conditions over the designated time frame.

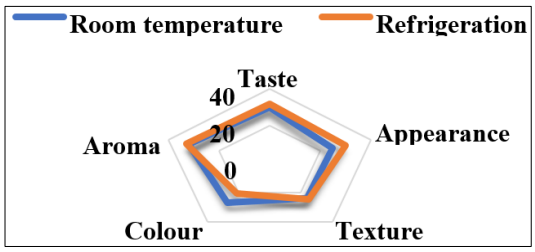

Fig 8: Shelf life study of nutri bar

While the vast majority of product characteristics remained consistent and unchanged throughout the evaluation, there were some minor textural differences observed in the product after the 30-day period. These discrepancies, although subtle, indicate that some minor alterations in the product's texture might occur over an extended period. Based on these findings, it is reasonable to conclude that the product exhibited remarkable stability for a one-month duration under the specified storage conditions. This suggests that the packaging and formulation were effective in preserving the product's quality within this timeframe. To extend our understanding of the product's shelf-life further, future studies can be designed to explore its stability over longer periods. This would provide valuable insights for product developers and manufacturers, enabling them to determine the product's suitability for extended storage and distribution, and thus enhance its market competitiveness. The study's ability to demonstrate a one-month shelf-life provides a promising starting point, instilling confidence in the product's ability to maintain its quality and integrity within a reasonable timeframe. These results serve as a foundation for future research efforts aimed at uncovering the product's longevity under varied storage conditions.

Biological activities and health benefits

Banana peels

Banana peels often overlooked, represent a promising source of phytochemical compounds with significant applications in food science. They are particularly rich in antioxidants, including phenolic compounds, flavonoids, gallocatechin, delphinine, cyaniding, anthocyanins, and catecholamine's [7]. These antioxidants play a crucial role in preventing oxidative reactions and enhancing the shelf life of food products [8]. Moreover, the presence of 3-carotenoids and various vitamins in banana peels provides opportunities for fortification of food items, contributing to their nutritive value [9]. The phenolic compounds in banana peels also exhibit antimicrobial properties, which can be harnessed to extend the microbiological stability of food products [10].

Orange peel

Orange peel is a valuable resource for food scientists due to its high content of dietary fibres and phenolic compounds. These dietary fibres can be utilized to enhance the textural properties of food products, providing improved mouth feel and structure.

Additionally, the phenolic compounds in orange peel offer excellent antioxidant properties, which are vital for preventing lipid oxidation and extending the oxidative stability of fats and oils in food formulations [11]. The presence of phytochemical agents in orange peel not only contributes to the organoleptic properties of food but also imparts health benefits without the side effects often associated with pharmaceuticals [12].

Watermelon seeds

Water melon seeds have gained recognition in food science for their remarkable composition. They are an excellent source of proteins, vitamin B complex, polyunsaturated fatty acids, essential and non-essential amino acids, and phenolic compounds [13]. The protein content in watermelon seeds can be utilized for protein enrichment in various food products, catering to the growing demand for plant-based protein sources. Furthermore, the phenolic compounds offer antioxidant potential, which is pivotal in preventing oxidative deterioration of fats and oils, making watermelon seed extracts valuable as natural antioxidants in food preservation [14].

Muskmelon seeds

Musk melon seeds are valued for their nutritional composition. They contain a diverse array of bioactive compounds, including tocopherols, phospholipids, and sterols. These components have multifaceted applications, with tocopherols acting as natural antioxidants and vitamins essential for food fortification [15], the presence of phospholipids and sterols contributes to the health-enhancing attributes of muskmelon seeds, offering potential applications in functional foods designed to promote cardiovascular health and overall well-being.

Spirulina

Spirulina while not a fruit waste product is an essential component in the food science realm. It is a microalgae celebrated for its high concentration of nutrients, including proteins, vitamins, minerals, and omega-3 and omega-6 fatty acids [16]. The bioactive compounds found in Spirulina, such as phenols, phycocyanin pigments, and polysaccharides, offer opportunities for developing functional and health-promoting foods [17]. These compounds have antioxidant, anti-inflammatory, and immune-enhancing properties, making them ideal candidates for the development of functional and Nutraceuticals food products [18]. In essence, each of these fruit waste sources provides food scientists with a plethora of valuable components, ranging from antioxidants and dietary fibres to essential nutrients and bioactive compounds. Leveraging these resources is integral to enhancing the nutritional quality, safety, and sensory attributes of food products while simultaneously addressing the issue of waste reduction and sustainability in the food industry. The comprehensive biological activities of these fruit waste components are awe-inspiring. They encompass anti-inflammatory, antioxidant, anti-obesity, anti-cancer, anti-diabetic, antihypercholesterolemic, anti-hypertensive, anti-ulcer, anti-tumour, hepatoma and neuro protective effects [19]. Additionally, these compounds exhibit antibacterial, anti-Alzheimer, and diuretic properties. Their application to design and develop innovative functional food products with added value is paramount for ensuring sustainability throughout the food supply chain.

Conclusion

In conclusion, the concept of this Nutri bar presents a promising and transformative innovation within the snack industry. These bars offer a unique blend of nutritional richness, sustainability, appealing flavours, functional benefits, and branding opportunities that align with the evolving preferences of health-conscious consumers. The nutritional profile, enriched by the synergy of fruit waste and spirulina, addresses both dietary and environmental concerns, providing a holistic solution that leverages the nutritional potential of otherwise discarded ingredients. This approach not only contributes to reducing food waste but also supports sustainability goals by embracing environmentally responsible practices. As this innovative snack continues to evolve, it has the potential to become a staple in the diet of health-conscious individuals and a symbol of sustainable, forward-thinking nutrition.

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