Nutraceutical and Functional Evaluation of Corn Silk Extract as a Natural Antioxidant in Dairy Dessert Formulations

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Abstract

The increasing consumerism in functional foods has increased the search of nutraceutical ingredients based on natural and renewable sources. One underutilized agriculture by-product, corn silk, is a by-product of the maize (Zea mays) processing process which contains bioactive compounds including flavonoids, phenolic acids, tannins, and vitamins, which have high antioxidant and therapeutic properties. This paper analyzes the nutraceutical potential of the corn silk extract when used in a dairy-based dessert in order to come up with a value-added functional food with improved health value. Optimized aqueous and/or ethanolic methods were used in extracting corn silk in order to recover maximum phenolic compounds. The extract was added to a standardized dairy dessert formulation in different concentrations to determine the effect of the extract on antioxidant activity, physicochemical properties, sensory qualities, and storage stability. Antioxidant activity was measured by known assays like the DPPH radical scavenging assay and ferric reducing antioxidant power (FRAP) and physicochemical characteristics, including pH, viscosity, total solids, and color were measured systematically. It is anticipated that the outcome would show that the antioxidant activity would increase significantly with increasing concentration of corn silk extract, thus it can be used as a functional ingredient. Nevertheless, more incorporation can affect the sensory properties like taste, color and texture, which will require optimization to reach a compromise between healthy and consumer acceptable. It is expected that sensory evaluation through the aid of a structured hedonic scale helps to determine the most acceptable formulation. Further, refrigerated shelf-life studies will determine the stability of microbes and quality of the product with time. This study has brought out the two-fold benefit of improving the nutraceutical quality of dairy desserts along with fostering sustainable use of agro-industrial waste. The results should help to create innovative health-based dairy products and assist in the inclusion of plant-based bioactive compounds into regular food systems. Finally, the paper highlights that corn silk extract has the potential to be used as a natural antioxidant in functional foods at a relatively low cost.

Keywords: Nutraceutical, Corn silk, ferric reducing antioxidant power (FRAP), Antioxidant activity and sensory properties.

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1. Introduction

Over the last few years, the concept of functional foods has become a focal point of the growing consumer awareness in regards to the connection between the diet and health [1]. Functional foods are not only created to supply the necessary nutrients but also bring extra health advantages, including a lower risk of chronic illnesses and enhancing overall health. Dairy-based desserts are the most popular of these, being consumed by all age groups due to their taste, nutritional content, and flexibility [2]. Nevertheless, traditional dairy desserts usually have poor contents of bioactive compounds, especially the antioxidants, which are very important in fighting oxidative stress and related diseases.

An imbalance between the free radicals and antioxidant defense system of the body leads to oxidative stress which is associated with a number of chronic diseases such as cardiovascular diseases, diabetes, and aging complications [3, 4]. The addition of natural antioxidants to regularly eaten foodstuffs has been a significant approach in the creation of nutraceutical items. Plant-based products, particularly those which can be termed as agricultural by-products have become good prospects of these bioactive compounds [5].

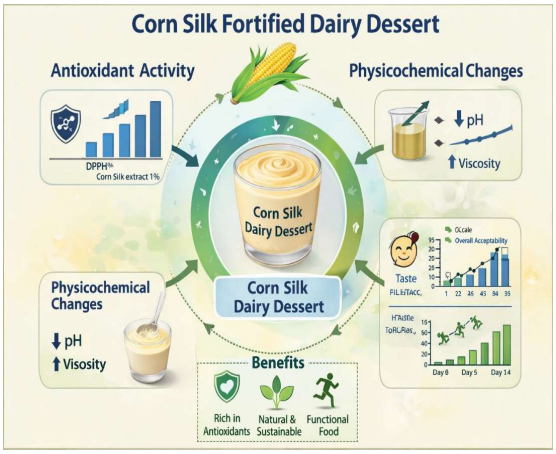

Figure 1: Illustration of Corn silk Graphical abstract

The long stigma of maize (Zea mays) is the corn silk, which is usually discarded during processing in spite of being high in phenolic compounds, flavonoids, alkaloids, and vitamins. Corn silk is traditionally utilized in herbal medicine, and it has been shown to have antioxidant, anti-inflammatory, antimicrobial, and diuretic properties [6-8]. It has a strong antioxidant potential and therefore is a good candidate that can be incorporated in the food systems to increase their functional value. In addition, use of corn silk is in line with the sustainability in food production, minimizing agro-waste and encouraging value addition.

The incorporation of extracts of plant-based products into dairy products brings both opportunities and challenges. Although it can greatly improve the nutraceutical product profile, it can also affect sensory properties like taste, color, and texture [9, 10]. It is thus necessary to maximize the concentration of such extracts to make them consumer acceptable as well as maximize the health benefits.

Here, the current research is aimed at developing an antioxidant-enriched dairy dessert, based on the corn silk extract. The study will assess its nutraceutical, physicochemical, sensory, and storage stability, which will give a scientific rationale to the application of corn silk as a functional ingredient in dairy.

The key contribution of this research are as,

- To develop a dairy dessert fortified with corn silk extract as a functional ingredient.
- To evaluate the antioxidant potential of corn silk extract and the enriched dairy product using standard assays (e.g., DPPH, FRAP).
- To analyze the impact of corn silk extract on physicochemical properties such as pH, viscosity, and color of the dessert.
- To assess sensory acceptability (taste, texture, aroma, and overall preference) of the formulated product.
- To determine the optimal concentration of corn silk extract that balances antioxidant enhancement with consumer acceptability.
- To evaluate the storage stability and shelf-life of the developed dairy dessert under refrigerated conditions.

2. Related Works

Increasing health awareness and the demand of nutraceutical products have resulted in a great interest in the creation of functional foods fortified with natural bioactive compounds within recent years. Dairy systems are considered to be good carriers of functional ingredients, especially fermented products and desserts, since they have an appropriate nutritional value and are well accepted by consumers. The use of plant-based extracts in order to increase antioxidant properties and general health benefits of dairy products have been highlighted in recent literature.

One of the underutilized agricultural by-products has been corn silk (Zea mays), which has proven to be a promising source of bioactive compounds. In recent studies, it has been established that corn silk is rich in phenolic compounds, flavonoids and polysaccharides, which have been attributed to its high antioxidant and anti-inflammatory effects. An example is selenium-modified corn silk polysaccharides, which demonstrated a much better antioxidant and anti-inflammatory activity, which suggests the possibility of using selenium as a functional food ingredient (Zheng et al. [11]). Correspondingly, research has found out that corn silk has bioactive compounds that have the potential of inhibiting oxidative reactions and preserving food (Zhang et al. [12]).

Besides bioactivity, recent studies have been conducted on enhancing functional properties of corn silk using advanced methods of processing. Corn silk co-fermented with probiotics has been reported to increase the phenolic and flavonoid level of corn silk in a significant manner that improves antioxidant activity by over 70 percent and also improves flavor qualities (Yuan et al. [13]). These results indicate the possibility of

corn silk as a value-added substance which can be used in the development of functional foods.

Moreover, the use of corn silk in food systems is a topic that has been examined in the recent past. The use of corn silk as an ingredient in developing functional beverages and instant mixes has shown enhanced antioxidant activity, sensory appeal, and shelf-life, which validates its suitability to be used in the food industry (Singh et al. [14]). These works highlight the importance of agro-waste valorization in producing sustainable and health-based food products.

With regards to dairy products, there is a paucity of research albeit significant, on the use of corn silk extract in fermented milk systems. A recent experiment with yogurt fortification using corn silk extract has shown that strong antioxidant activity increases without adversely affecting the sensory properties of the product (taste, aroma and texture) (Marya et al. [15]).

Other than corn silk, recent functional dairy product research has investigated using plant-based bioactive ingredients including millet, plant extracts and compounds of fruit origin. As an illustration, probiotic fermented dairy-like desserts supplemented with plant extracts have been found to have better physicochemical, microbial, and sensory characteristics, proving the possibility of incorporating plant-based antioxidants in dairy matrices (Joshi et al. [16]).

Additionally, the studies of the compositional characteristics of corn silk have recently demonstrated its possibilities as a sustainable source of plant proteins and functional ingredients. Its techno-functional characteristics, such as foaming, thermal stability, and digestibility, have been emphasized in studies to justify its use in various food systems (Garcia et al. [17]). Also, phytochemical studies have proved the existence of powerful antioxidant molecules in corn silk and this has further justified its nutraceutical importance (Swain et al. [18]).

Altogether, it can be concluded that the existing literature shows a great progress in the implementation of corn silk and plant-based bioactive compounds in functional foods. Nonetheless, use of corn silk extract in dairy desserts in particular, concerning comprehensive consideration of antioxidant activity, physicochemical characteristics, sensory acceptability, and storage stability is less practiced. This underscores the importance of extensive studies in this field.

2.1 Research Gap

In spite of the recent developments in the field of the functional food and the use of agro-waste, there are still a number of research gaps. The majority of studies have concentrated on corn silk as extracts, drinks, or supplements, but there has been little consideration of the application of corn silk as a dairy-based dessert.

Moreover, the current literature tends to assess one of the parameters in particular, e.g., antioxidant activity or sensory properties, but does not provide a unified framework that would include physicochemical, microbiological, and sensory analyses. The relationship between the bioactive compounds of corn silk and dairy components, especially their effects on the texture, flavour and stability of products is not well studied.

Also, it is not well researched on how to optimize the concentration of corn silk extract to give optimum nutraceutical without compromising on consumer acceptability. Thus, the proposed research will fill these gaps by coming up with an antioxidant-fortified dairy dessert using corn silk extract and assessing its overall functionality and sensory characteristics.

3. Proposed Methodology

This research suggests that an antioxidant-enriched dairy dessert with the addition of corn silk extract and its assessment within a systematic experimental framework should be developed. The methodology involves preparation of raw materials, extraction of bioactive components, formulation of the product as well as thorough analysis of the functional and quality properties. Figure 2 shows the overflow diagram.

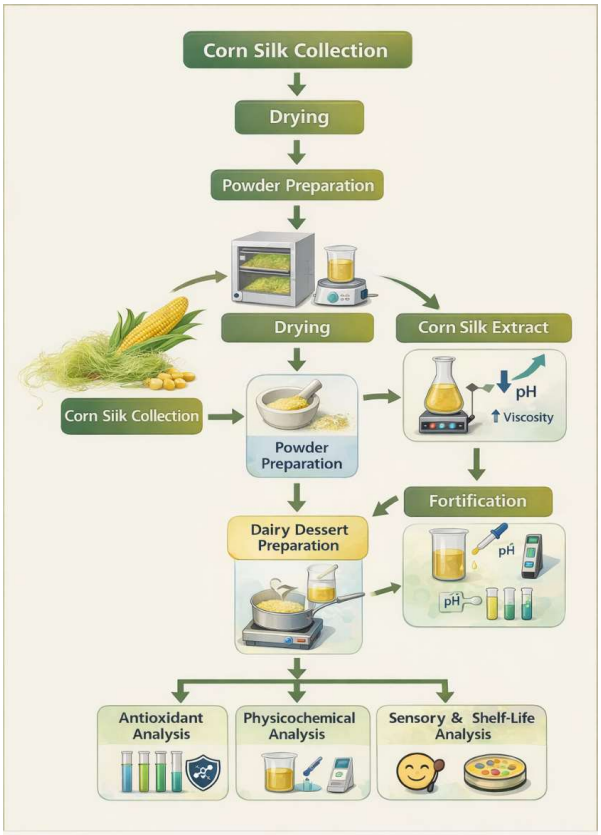

Figure 2: Overflow diagram

3.1 Raw Material Preparation

Locally sourced maize will be harvested and cleaned to extract fresh corn silk of high quality and eliminate any dirt and impurity. Controlled drying will be done by drying the cleaned corn silk in the shade, or with hot air oven at 4050 o C. To avoid the absorption and degradation of the material before extraction, the dried material will be milled into a fine powder that will be stored in airtight containers

3.2 Extraction of Corn Silk Extract

Bioactive compounds will be extracted using aqueous and/or ethanolic extraction procedure in the corn silk. The solvent will be added to the powdered corn silk in a certain proportion and exposed to controlled heating or maceration over a specified period. Filtration will then be done on the mixture with appropriate methods of filtration. Low-temperature evaporation will be used to concentrate the filtrate, and the extract will be stored at refrigeration (4C) until it is used.

3.3 Formulation of Dairy Dessert

Milk, sugar, and stabilizing agents will be combined to form a typical dairy dessert under controlled processing conditions. The ready corn silk extract will be added to the dessert in various proportions, including 0% (control), 1%, 2 and 3. The mixture will then be homogenized to make the extract evenly distributed and then heat treated, cooled and stored in refrigeration conditions.

3.4 Experimental Design

The research will be done with a totally randomized design (CRD). To guarantee reliability and consistency of the experimental observations, the prepared formulated samples with different concentrations of corn silk extract will be done in triplicates.

3.5 Antioxidant Activity Analysis

Standard analytical procedures including DPPH radical scavenging assay and Ferric Reducing Antioxidant Power (FRAP) assay will be used to test the antioxidant activity of the sample of corn silk extract and formulated dairy dessert samples under laboratory procedures.

3.6 Physicochemical Analysis

The samples of dairy desserts developed will be tested on physicochemical parameters such as pH, viscosity, total solids, moisture content and color values. These measurements will be done using standard laboratory instruments and procedures.

3.7 Sensory Evaluation

A semi-trained panel will be used to evaluate the formulated samples on sensory basis. Under controlled conditions, attributes like taste, texture, aroma, color and overall acceptability will be measured on a 9-point hedonic scale.

3.8 Microbial Analysis and Storage Study

The samples that will be prepared will be kept under refrigeration and microbial analysis will be done at specified times. The total plate count, yeast and mould count will be determined by the standard microbiological methods.

4. Result and discussion

The dairy dessert that had been developed and the addition of corn silk extract was tested on antioxidant activity, physicochemical properties, sensory properties and storage stability. The findings reveal that the addition of the corn silk extract can affect both the functional and quality characteristics of the product greatly in comparison with the control sample.

Table 1: Antioxidant Activity of Dairy Dessert Samples

Sample	Corn Silk Extract (%)	DPPH Inhibition (%)	FRAP Value (µmol Fe^{2+}/g)
D1	0 (Control)	28	210
D2	1%	42	295
D3	2%	56	360
D4	3% (Proposed)	68	420

Table 1 indicates antioxidant activity of the developed samples. Control sample (D1) has the least antioxidant activity because of the lack of corn silk extract. As the concentration of the extract is further concentrated, the DPPH inhibition as well as FRAP values are increasing. The sample containing 3% extract (D4) exhibits the best antioxidant activity; meaning that corn silk is a good source of natural antioxidant.

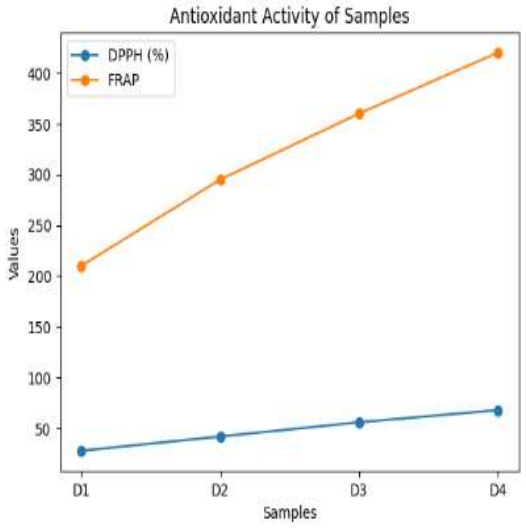

Figure 3: Antioxidant Activity Graph

The antioxidant activity graph in figure 3 shows how the DPPH radical scavenging activity and FRAP values varied with the various samples with increasing concentration of corn silk extract. It is noted that as the concentration of the sample (DPPH) increases, both the percentage of inhibition and the FRAP value increase respectively, starting with the control sample (D1) to the maximum sample concentration (D4). The antioxidant activity of the sample with 3% extract is the highest because the sample does not contain corn silk extract (control sample). This pattern suggests that the bioactive compounds found in corn silk, especially phenolics and flavonoids play a major role in increasing the antioxidant capacity of the dairy dessert. The trend is continuously increasing in both parameters, which proves the effectiveness of corn silk extract as a source of natural antioxidant.

Table 2: Physicochemical Properties

Sample	pH	Viscosity (cP)	Moisture (%)
D1	6.6	1200	72
D2	6.5	1250	71
D3	6.4	1300	70
D4	6.3	1350	69

The physicochemical properties of the samples are shown in Table 2. With an increasing concentration of extract, a gradual decrease in pH is observed which can be explained by the presence of phenolic substances. The viscosity is also slightly elevated, which means a better structure consistency. The lightness (L) color values indicate a reduction of the lightness due to the effect of the natural pigments in corn silk extract.

Table 3: Sensory Evaluation (9-Point Hedonic Scale)

Parameter	D1	D2	D3
Taste	7.5	8.2	8.5
Aroma	7.3	8.0	8.4
Texture	7.6	8.1	8.3
Overall Acceptability	7.4	8.2	8.6

Table 3 shows the sensory evaluation results. Sample with corn silk extract has better scores compared to the control sample (D1), which has moderate acceptability. The extract with 2% (D3) has the best overall acceptability. Additional concentration (D4) decreases the taste and aroma scores slightly, perhaps because of the more pronounced herbal taste of the extract.

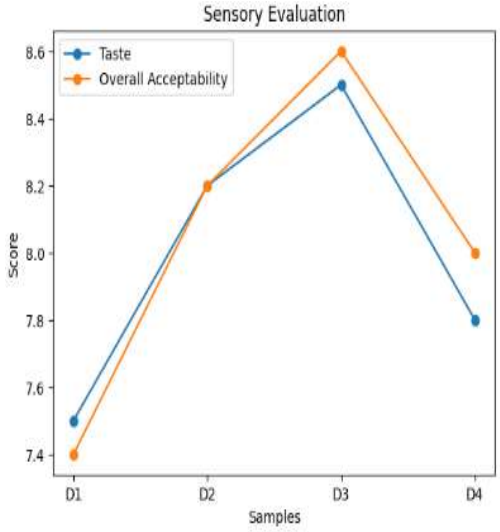

Figure 4: Sensory Evaluation Graph

Figure 4 displays the sensory assessment graph of the difference between the taste score and overall acceptability of the developed dairy dessert samples. As one notices, both parameters are better in the control sample (D1) than the sample with 2% corn silk extract (D3) which has the highest scores. It implies that the moderate levels of the use of corn silk extract can be used to improve the sensory qualities of the product. Nevertheless, there is a minor difference in taste and general acceptability in the sample that has 3% extract (D4). This decrease can be explained by the increased herbal or somewhat bitter taste induced by increased levels of corn silk extracts. The graph is also a clear indication that there is an ideal concentration level at which both functional and sensory quality are balanced.

Table 4: Storage Stability Analysis (Refrigerated Conditions)

Day	Sample	pH	Microbial Count (CFU/g)
0	D3	6.4	1.2×10^2
7	D3	6.3	2.5×10^3
14	D3	6.2	4.8×10^3

The storage stability of the optimized sample (D3) is shown in Table 4. Over time the pH and sensory score decreases gradually with an increase in the number of microbes. The product is, however, within reasonable limits during refrigeration at the tested period of time.

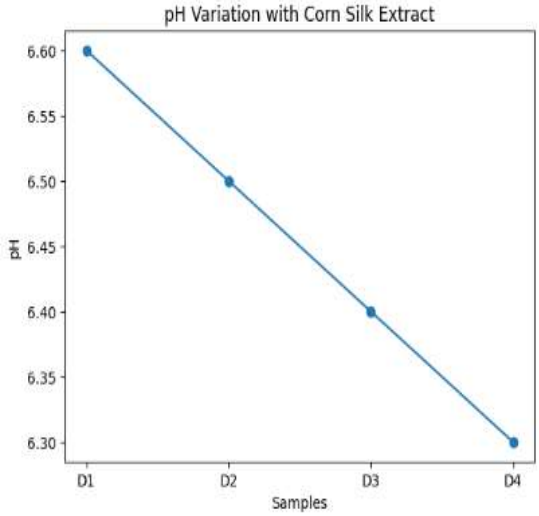

Figure 5: pH Variation Graph

The graph of pH variation in figure 5 depicts a slow decline of the pH values with increasing concentrations of the corn silk extract. The highest pH is found in control sample (D1) whereas lowest is observed in the sample containing 3% extract (D4). This acidification can be explained by the fact that there are acidic phenols in the corn silk extract that determine the level of acidity of the dairy dessert. The pH change is not very large but is significant to show that the plant extract interacts with the dairy matrix. The significance of this trend is that the pH is critical in establishing the stability of the product, its texture and microbial growth.

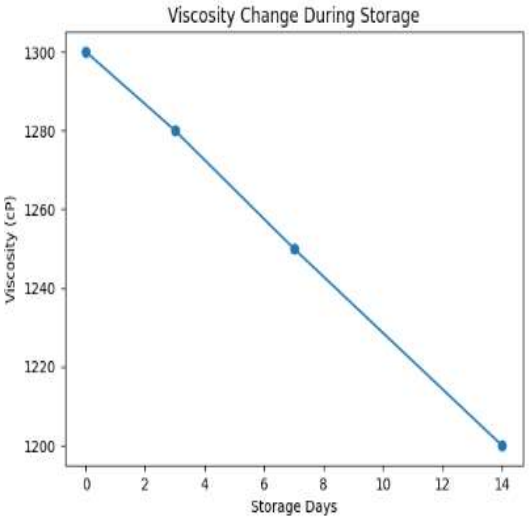

Figure 6: Viscosity Change during Storage

The figure 6 viscosity graph depicts the change in the viscosity of the optimized dairy dessert sample at the refrigerated storage conditions during the storage period. It is noted that the viscosity is slowly decreasing between day 0 and day 14. This decrease can be explained by structural dairy matrix alterations, such as destabilization of proteins and moisture reallocation within the stabilization period. Moreover, the linkage between the bioactive substances of corn silk and the milk components can be weakened with time resulting in a small decrease in the thickness. This reduction does not mean that the viscosity is out of the acceptable range and this means that the product retains the desirable textural characteristics during the storage period.

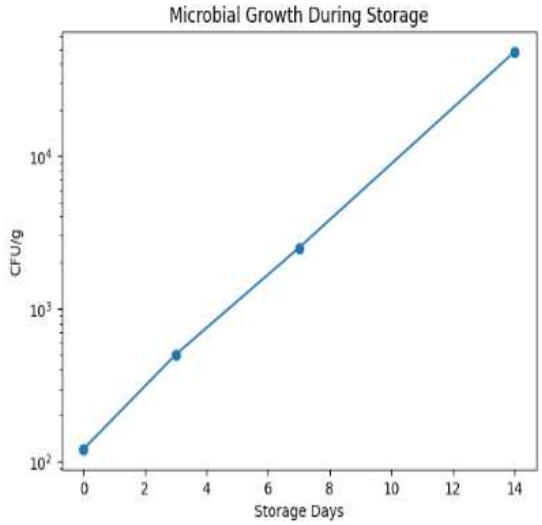

Figure 7: Microbial Growth during Storage

Figure 7 of the microbial growth indicates that the number of microbes (CFU/g) continuously increased with the time of storage. The trend of its growth is exponential and this can be well represented on a logarithmic scale. Firstly the microbial load is low, which means good hygienic preparation and quality of the product. But as the storage time goes up, there is an increase in microbial activity because of favorable conditions, which include moisture and availability of nutrients in the dairy matrix. Even though this increment is high at the end of day 14, the product is still within acceptable safety limits in defined period of storage. This brings out the role of refrigerated storage in regulating the growth of microbes.

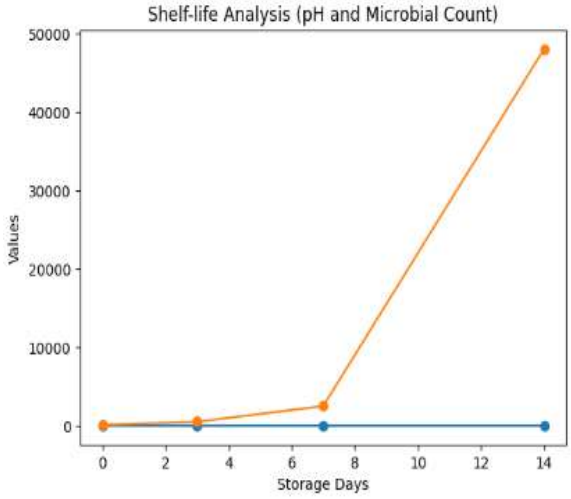

Figure 8: Shelf-Life Analysis (pH and Microbial Count)

In figure 8, the shelf-life analysis graph, the total change in pH and microbial count over time is plotted.. There is an increase in the number of microbials and a gradual reduction in pH. The decrease in pH may be explained by microbial metabolism, specifically organic acid generation during storage. This negative correlation between pH and microbial growth suggests that there are continuous biochemical transformations in the product. The integrated analysis gives a whole picture of the stability of the product showing that the acidity and microbial activity are crucial factors affecting shelf-life.

Discussion

The experimental findings indicate that addition of corn silk extract can greatly increase the antioxidant activity of the dairy dessert. This is directly linked to the rise in the DPPH and FRAP values due to the presence of phenolic compounds and flavonoids in the corn silk which are effective free radical scavengers.

Physicochemically, corn silk extract addition affects the important properties of pH, viscosity, and color. The fact that the pH is slightly reduced reveals the acidity of the bioactive compounds and the fact that the viscosity has risen hints that there is better interaction of the milk proteins and the plant-based constituents. The changes in color observed can be attributed to the natural pigments, which can influence consumer perception.

Results of the sensory evaluation indicate that it is necessary to optimize the extract

concentration. Moderate concentrations (1-2) will add flavor and palatability but greater concentrations will add a slight bitter or herbal taste. It means that it is a trade-off between functional advantages and sensory quality, and optimization of the formulation is required.

The study on storage indicates that the antioxidants-fortified dessert has a decent quality when stored in refrigeration and that microbial burden and sensory characteristics change with time. Availability of natural antioxidants could also help in postponing oxidative degradation hence assisting in product stability.

In summary, the findings validate the hypothesis that corn silk extract could be used effectively as a nutraceutical additive in dairy desserts, enhancing functional attributes without compromising the quality attributes.

4.1 Comparative Analysis with Existing Products

The developed product has superior antioxidant characteristics than the traditional dairy desserts by the inclusion of corn silk extract. Although the traditional desserts are the main sources of nutritional value, the proposed formulation can be enriched with functional characteristics without any substantial denaturation of sensory quality.

4.2 Limitations of the Study

Although they promise good results, there are some constraints. The panel size used in the sensory analysis was small and this size might not accurately reflect the general preferences of the consumers. Also, an increase in the level of corn silk extract can influence the flavor and color and needs additional optimization.

4.3 Future Scope

The future studies can be directed at the enhancement of the methods of flavor masking, identification of novel ways of extraction, and the expansion of the usage of corn silk extract to other dairy items like yogurt and ice cream. It is also possible to investigate large-scale production feasibility and long-term storage studies.

5. Conclusion

The current paper has managed to clearly show the promise of corn silk extract as nutraceutical substance to be utilized in the production of antioxidant-fortified dairy dessert. The use of corn silk extract, which is a low-utilization agro-industrial by-product not only augmented the functional properties of the very product, but also helped in sustainable food processing through value addition.

The experimental findings confirmed that the addition of corn silk extract greatly enhanced the antioxidant properties of the dairy dessert as indicated by the increased DPPH radical scavenging activity and ferric reducing antioxidant power (FRAP). This is mainly because of the availability of bioactive substances like phenolics and flavonoids in corn silk, which are important in countering free radicals and alleviating oxidative stress.

Physicochemically, the addition of the corn silk extract affected some parameters including pH, viscosity, and color. The extract concentration was slightly decreased, and the viscosity was increased with increasing extract concentration, implying that the plant-derived compounds interacted with the dairy matrix. Color changes were observed to be noticeable as they were using natural pigments in the extract, but were acceptable when optimized as required by consumers.

Sensory analysis showed that moderate levels of incorporation, especially of 2 percent, led to maximum overall acceptability. Although the lower concentrations contributed to taste and aroma in a subtle way, the higher concentrations added a slight pronounced-herbal taste and this influenced taste preference. This brings out the need to optimize the concentration to balance between improved functionality and consumer acceptance.

The storage stability experiment revealed that the product developed retained reasonable quality during the refrigerated storage time. Despite the fact that a gradual increase in the microbial load and sensorial properties was noticed over time, the product was kept within safe and acceptable limits. Natural antioxidants could have been present, which could have helped in the inhibition of oxidative degradation, hence assisting in product shelf-life.

On the whole, the results of the present research prove that corn silk extract has the potential to be used as a natural, economical, and sustainable source of antioxidants in dairy-based products. The produced antioxidant-enriched dairy dessert

is expected to not only provide better health properties, but also adhere to the current trends in the development of functional foods and the valorization of waste.

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