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Development Of Enriched And Sustainable Ready-To -Eat Product Of Banana Blossom

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Abstract

The growing interest in sustainable and nutrient-dense food options has led to the exploration of underutilized plant materials, such as banana blossoms. The main aim is to utilize by-product of banana (banana blossoms) by developing a ready-to-eat product with improved nutritional value. In this study, banana blossoms were processed into powder form and integrated into formulations for hummus and bread. The nutritional profile, encompassing protein, carbohydrates, dietary fiber, vitamin C, and antioxidant properties, were thoroughly analyzed. Furthermore, assessments of microbial safety and sensory characteristics were also performed to evaluate the quality and consumer acceptability of the products. The findings demonstrated a notable enhancement in protein, dietary fiber, and vitamin C levels in the fortified products (with banana blossoms) when compared to the control samples (without banana blossoms). Sensory assessments indicated a high level of consumer approval, particularly regarding texture and flavour improvements. Microbial safety tests confirmed that the developed products were safe for consumption. These findings underscores the potential of banana blossoms as a nutrient-rich ingredient in value added food development.

Keywords: Banana Blossom, Hummus, Bread, Nutritional enrichment, Sustainable food, Ready to eat, Antioxidants, Vitamin C

I. INTRODUCTION

Adolescent girls have specific nutritional needs due to their rapid growth and development. A balanced diet incorporating protein, dietary fiber, vitamin C, antioxidants, and iron is crucial for their health (Abd Elmoneim et al., 2014). These nutrients address key concerns such as anemia (iron), digestive health (dietary fiber), nutrient absorption (vitamin C), general well-being (antioxidants), and tissue growth/repair (protein) (Abbas & Easa, 2011). Bananas, botanically classified as berries from the *Musa* genus, are a globally cultivated and consumed fruit, thriving in tropical and subtropical regions (Anand & Sharma, 2019). India is a significant producer, with output consistently rising from 20 million metric tons in 2006 to over 30 million metric tons by 2017. Major banana-producing countries include the Philippines, China, Ecuador, Brazil, and Indonesia. India experienced a remarkable 77% increase in banana production from 2005-2006 to 2010-2011. Optimal banana growth (*Musa paradisiaca*) occurs in humid tropical environments with a daytime temperature of 27°C and a minimum of 13°C. India leads global banana production with 13.90 million tons, followed by Uganda (10.14 million tons). Banana blossom, the edible flower found at the tip of the banana plant, is a rich source of nutrients and antioxidants, offering various health benefits. Scientifically known as *Musa acuminata*, it's recognized for its nutritional value, including dietary fiber and biologically active compounds like vitamin C and tannin (Anand & Sharma, 2019). The blossom is part of the banana plant's inflorescence, containing both male and female flowers (Aurore et al., 2009). The female flowers develop into fruits from the basal nodes, while male flowers emerge from the upper digital nodes. These finger-shaped blossoms are covered by reddish- or purple-colored scales that fall off as the fruit matures (Castelo-Branco, 2017). The tough maroon bracts surrounding the drop-shaped purple flower are inedible and must be removed. Being a byproduct, banana blossom is considered a beneficial functional food (Mohapatra, et al, 2010) particularly due to its iron content, which can help combat anemia (Debabandya et al., 2010). Despite its significant nutritional value, banana blossom is highly perishable. Dehydration is an effective preservation method to extend its shelf life and retain nutrients. Previous studies indicate banana flowers are a good source of antioxidants like phenolics and flavonoids (Castelo-Branco, 2017) crucial for enhancing human resistance to diseases. Extracts from *Musa sapientum* flowers (chloroform, water, ethanol) have shown hypoglycemic activity in alloxan-diabetic rats (Chen et al., 2020; Debabandya et al., 2010) Currently, banana blossom consumption is low in metropolitan areas due to the perceived complexity of preparing it. To make it more accessible, researchers aimed to develop ready-to-eat products. Our study aimed to prepare banana blossom powder and banana pulp powder and incorporate it into Hummus and bread respectively, to enhance the nutritional value of a ready-to-eat product.

II. MATERIAL AND METHOD

Raw materials and Reagents
Fresh banana blossoms and unripe bananas were collected from a banana farm in Lucknow. The materials used included DPPH (2,2-Diphenyl-1-picryl-hydrazyl-hydrate), potassium sodium tartrate, copper sulfate, a Stomacher blender, glucose, chloramphenicol agar medium, citric acid, FCR reagent, phenol chloroform and a spectrophotometer,
Raw Material Preparation
To fortify bread and hummus, firstly, banana blossom powder and banana flour was prepared were prepared as per standard protocol as follows:
Preparation of Banana blossom powder
Banana blossom powder was prepared by the protocol previously mentioned. (Aurore et al., 2009). Briefly, whole banana flowers were collected and dipped in 0.5% of citric acid solution, which reduces the enzymatic browning and followed by drying in hot air oven at 50°C–60°C, for 2 hours. The dried banana blossoms were grounded into fine powder using mixer. The prepared powder was stored in an airtight container and placed at room temperature until use

Figure 1. Banana blossom dipped in citric acid solution

Preparation of raw banana pulp and peel powder

Raw banana pulp and peel powder were prepared to minimize darkening due to enzymatic browning, Briefly, the uniformly sliced raw banana pieces were immersed in 0.5% of citric acid solution for 2-3 minutes. The pre-treated raw banana sample was dried for 4 hours at 60°C-70˚C. Dried raw banana slices were then grounded into fine powder and stored in an airtight container at room temperature until use. (Rahman et al., 2021)

Figure 2. Raw banana slices (a) before and (b) after drying

Figure 3. Prepared raw materials (a) banana blossom powder (b) banana pulp and peel powder

Preparation of banana blossoms fortified hummus

To prepare fortified hummus, following ingredients were taken namely Bengal gram, tahini, lemon juice, butter, garlic, and salt. The fortified hummus included the same ingredients, with the addition of banana blossom powder prepared previously. Both plain and fortified hummus was prepared according to standard hummus-making procedures described previously (Lowry et al., 1951). Banana flower powder was integrated into the hummus blend at predetermined proportions. Briefly, the Bengal gram was soaked in water overnight to soften followed by draining and rinsing them with cold water. Further, the soaked and rinsed Bengal gram was added along with tahini, butter, garlic, cumin powder, lemon juice, and a pinch of salt. This mixture was then blended until a coarse paste formed. The blending process creates an emulsion mixture of butter and water-based ingredients which is stable. To achieve the desired consistency water was gradually added while blending until a smooth and creamy texture is achieved. The prepared hummus was transferred to a serving bowl. A drizzle of butter and a sprinkle of coriander were added on top for garnish. The hummus can be served with bread, fresh vegetables, or as a dip.

Preparation of fortified bread

The bread was made according to the method described by Kent (1994) (Anhwange, 2008). The yeast was initially rehydrated (8 ml of water/g of yeast) in warm water (40°C) for 10 minutes to start fermentation. Sugar and salt were dissolved in a measured amount of water. All the ingredients were mixed for about 10 minutes to prepare control and fortified bread. The prepared dough was left 2 hours away to allow the fermentation process. To avoid dehydration, the dough was coated with moistened fabric. Upon two hours of fermentation, the gas involved was "knocked out" so that the temperature could stand, and the thorough mixing could be carried out. After 1 hour of resting, the dough is divided into roughly shaped loaf size (i.e., 200 gm). The dough pieces were rested at around 27°C for 10-15 minutes (1st proof) and shaped into final form to tighten the dough mechanically so that the gas and water could better spread, be stored, and placed in pre-greased baking cups. The dough was again rested in the baking pan for the final tests at 37°C for 60 minutes and then baked for 40 minutes at temperature 230°C in the oven. The loaves were allowed to cool for a minimum of 2 hr. at 24°C before evaluation.

Estimation of nutritional profile

Protein Estimation by Lowry method

The amount of protein in all prepared products was determined using the Lowry method which is based on the reaction between proteins and a mixture of copper ions (Cu^{2+}) and Folin-Ciocalteu phenol reagent. The OD was taken using a spectrophotometer at 750 nm.

Carbohydrate Estimation

Carbohydrate content in all prepared products was determined using the phenol-sulfuric acid method (Masuko et al., 2005)

Total Dietary Fiber

Total dietary fiber (TDF) was determined by homogenizing and drying food samples. After enzymatic digestion, the insoluble residue was filtered, washed, and dried. This residue was then weighed for insoluble dietary fiber. Finally, ash content was determined by incineration, and combined with the insoluble fiber weight to calculate the total dietary fiber. TDF was calculated using following formula

$$\text{Total dietary fiber} = \text{Weight of insoluble dietary fiber} + \text{Weight of ash}$$

Vitamin C Concentration

Vitamin C in hummus samples was determined using the iodine-starch titration method. Standardized iodine solution was prepared and its concentration verified with ascorbic acid. Both control and banana blossom fortified hummus samples were then titrated with the iodine solution until the blue starch-iodine complex disappeared, indicating the endpoint. The amount of Vitamin C in the sample was calculated using the formula:

$$\text{Amount of Vitamin C (mg)} =$$

$$\frac{(\text{Volume of iodine solution used for unknown} \times \text{Normality of iodine solution} \times \text{Molecular weight of Vitami}}{\text{Volume of sample taken}}$$

Antioxidant Activity

Antioxidant activity in all prepared products was measured using the DPPH radical inhibition assay with a biospectrophotometer, performed in triplicates. Absorbance was then monitored at 517 nm until constant readings were obtained. The anti-oxidant activity was expressed as % inhibition of the DPPH radical and is determined using the following equation

$$\% \text{ Inhibition or } \% \text{ RSA } \frac{\text{Control absorbance} - \text{ Sample absorbance}}{\text{Control absorbance}} \text{X } 100$$

Estimation of Microbiological profile

Colony Forming Units (CFU)

To prepare for yeast and mold counts in yogurt, Potato Dextrose Agar (PDA) and peptone water were prepared and sterilized by autoclaving. The sterilized PDA was poured into plates and dried overnight. All samples (1 gram) were diluted with 9 mL of sterile 0.1% peptone water, followed by a ten-fold serial dilution (10^-2). For enumeration, 0.1 mL of each dilution was spread onto solidified PDA plates using a sterile spreader. Plates were dried, then incubated upright anaerobically at 35°C for 48 hours and 5 days. Counts were performed on days 1 and 7, calculating Colony Forming Units (CFU) per gram from plates with 15-300 colonies (Tasnim et al., 2020). The number of Colony Forming Units (CFU) on plates containing 15 to 300 colonies [Tasnim et al., 2020] was calculated per gram of samples as shown below.

$$\text{Number of CFUs per ml sample} = \frac{\text{Number of colonies per plate x Dilution factor of the counted plate}}{\text{Volume of innoculant plate}}$$

Total Plate Count (TPC)

Microbial analysis, specifically yeast and mold detection, was performed on banana bread, control bread, banana hummus, and control hummus. Samples were meticulously prepared, diluted, and plated on PCA media in triplicates under sterile conditions. Plates were then incubated at 37°C for 24-48 hours, after which all colonies were counted to assess microbiological quality. For numerical estimation, colonies per plate were multiplied by proper dilution factor and the results recorded as plate count per milliliter or plate count per gram (pc/ml or pc/g).

$$N = \frac{C}{(N1 + 0.1N2)D}$$

C is the sum of colonies counted on all the dishes retained
N1 is the number of dishes retained in the first dilution
N2 is the number of dishes retained in the second dilution
D is the dilution factor corresponding to first dilution

Yeast and Mold Count

Microbial analysis of banana bread, control bread, banana hummus, and control hummus assessed their microbiological quality by detecting yeast and mold. Samples were serially diluted and inoculated onto YGCA media. Plates were incubated at 24-27°C for 5 days, then colonies were counted and differentiated by their distinct appearances (fuzzy for mold, smooth for yeast).

$$\text{Yeast and mould count} = \text{CFU/g or ml.}$$

Colony counts helped calculate yeast and mold concentration per gram or milliliter.
The number of yeasts and molds per gram or per milliliter is equal to:

$$N = \frac{C}{(N1 + 0.1N2)D}$$

C is the sum of colonies counted on all the dishes retained
N1 is the number of dishes retained in the first dilution
N2 is the number of dishes retained in the second dilution
D is the dilution factor corresponding to first dilution

Evaluation of Sensory properties

All types of samples were subjected to sensory evaluation using semi-skilled panelists (students and staff of Institute of Food processing and technology, University of Lucknow). Panelists evaluated all samples for sensory attributes (color, texture, flavor, taste, appearance, acceptability) using a 9-point hedonic scale in a controlled environment.

III. RESULTS

Preparation of a ready to eat product (banana blossom enriched hummus and bread)

The incorporation of banana blossom not only enhances the nutritional profile of bread but also introduces unique flavors and textures that appeal to health-conscious consumers. The humus can be consumed with bread as a ready to eat product. The fortified hummus (fig. 4) and bread (fig 5) was successfully prepared for consumption. All products were stored at room temperature until further analysis.

(a) (b)

Figure 4. Prepared hummus (a) hummus prepared with same ingredients but Enriched with banana blossom powder (b) control hummus with normal ingredients

(a) (b)

Figure 5. Preparation of bread (a) Raw banana bread fortified with banana blossom powder and (b) Raw banana bread

Protein Concentration

Quantitative assessment of protein content across the sample set, comprising fortified products and their respective control samples, was conducted and enhanced protein content was observed in the enriched products (table 1 and fig 6).

Table.1 Protein concentration of 4 different samples, B.B, C.B, B.H, C.H. B.B (Banana flour fortified bread), C.B (Bread prepared using standard ingredients), B.H (Banana blossom powder fortified hummus), C.H (Hummus prepared using standard ingredients)

Samples	O.D Value	Protein Concentration
B.B	0.698	184 × 10 $^{-1}$ µg/mL
C.B	0.435	105 × 10 $^{-1}$ µg/mL
B.H	0.956	245 × 10 $^{-1}$ µg/mL
C.H	0.842	204 × 10 $^{-1}$ µg/mL

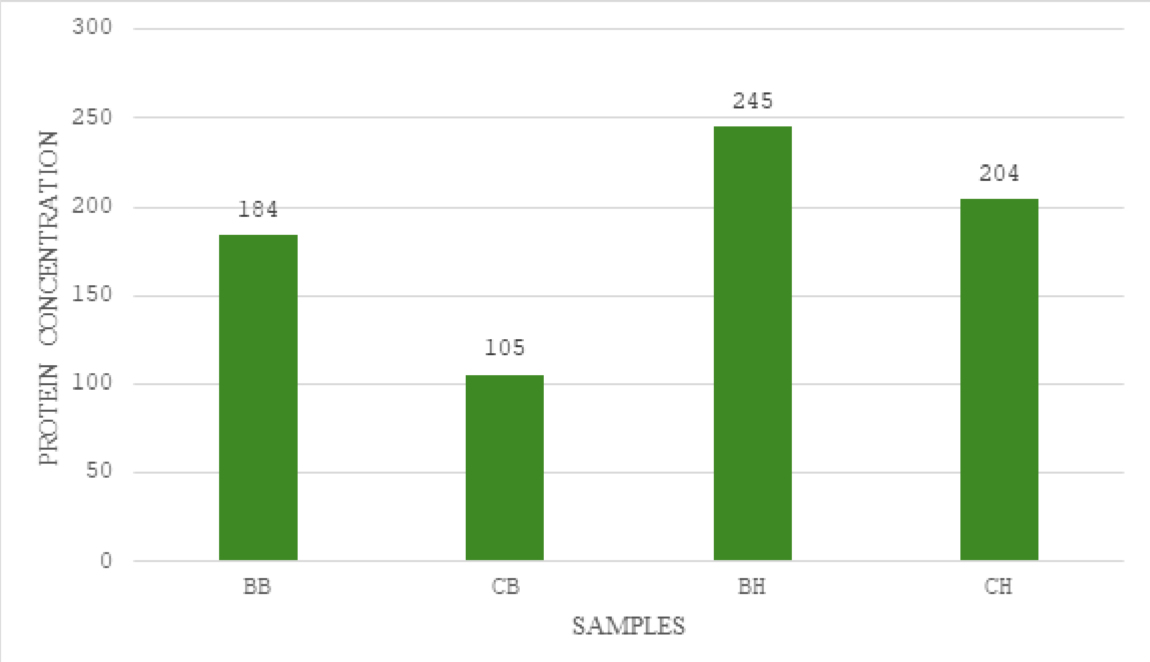

Figure 6 Represent the Protein concentration of 4 different samples i.e. B.B(Banana flour Enriched bread),C.B(Control bread), B.H(Banana flower Enriched hummus), C.H(Control hummus).

Carbohydrate Concentration

Upon analysis, a consistent trend emerged, wherein the fortified products exhibited substantially elevated carbohydrate content when compared to their corresponding control samples. The fortified products included bread fortified with raw banana flour and hummus fortified with banana blossom powder, while the control samples comprised regular bread and normal hummus (table 2 and fig 7).

Table.2 The O.D values and the carbohydrate concentration of all samples. B.B (Banana flour fortified bread), C.B(Bread prepared using standard ingredients), B.H(Banana blossom powder fortified hummus), C.H(Hummus prepared using standard ingredients)

Samples	O.D Value	Carbohydrate Concentration
B.B	0.94	240 µg × 10 $^{-1}$ µg/mL
C.B	0.73	211µg × 10 $^{-1}$ µg/mL
B.H	0.50	164µg × 10 $^{-1}$ µg/mL
C.H	0.30	100µg ×10 $^{-1}$ µg/mL

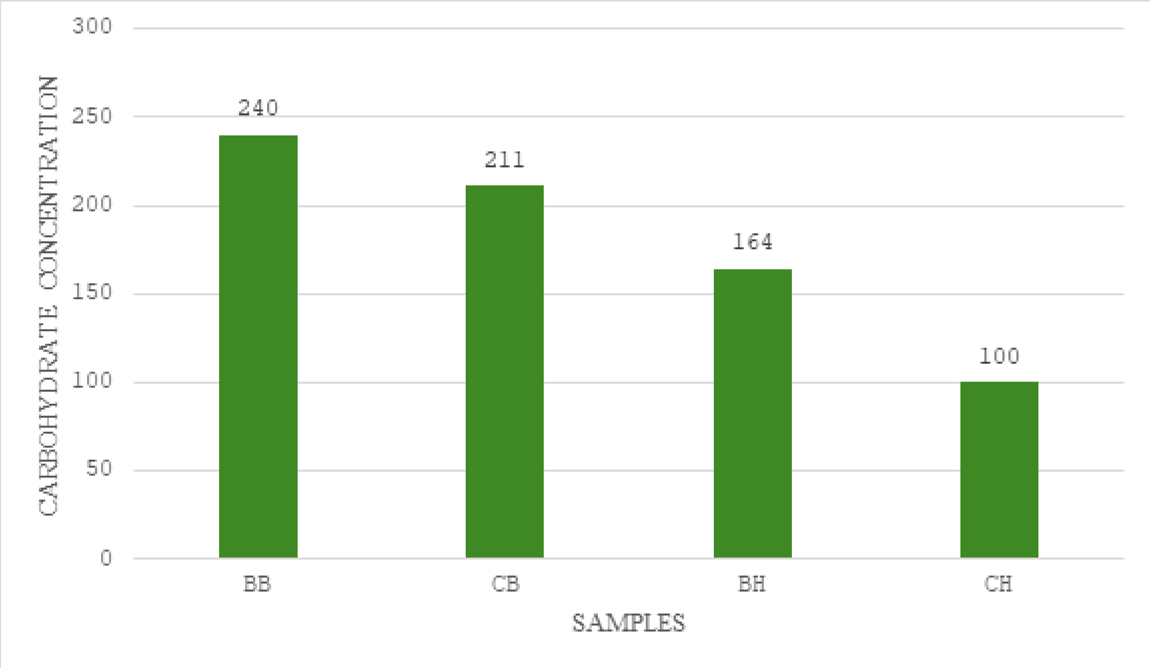

Figure 7. Represent a bar graph showing the carbohydrate concentration of all samples. B.B (Banana flour fortified bread), C.B(Bread prepared using standard ingredients), B.H(Banana blossom powder fortified hummus), C.H(Hummus prepared using standard ingredients)

Total Dietary Fiber

The results revealed a difference between the two bread samples. The bread fortified with raw banana flour exhibited a significantly higher total dietary fiber content in comparison to the standard control bread (table 3 and fig 8).

Table.3 Chemical Parameter results for Banana bread and Control bread

S. No.	Product	Dietary Fiber (%)
1.	Control Bread	14.16%
2.	Banana Bread	16.35%

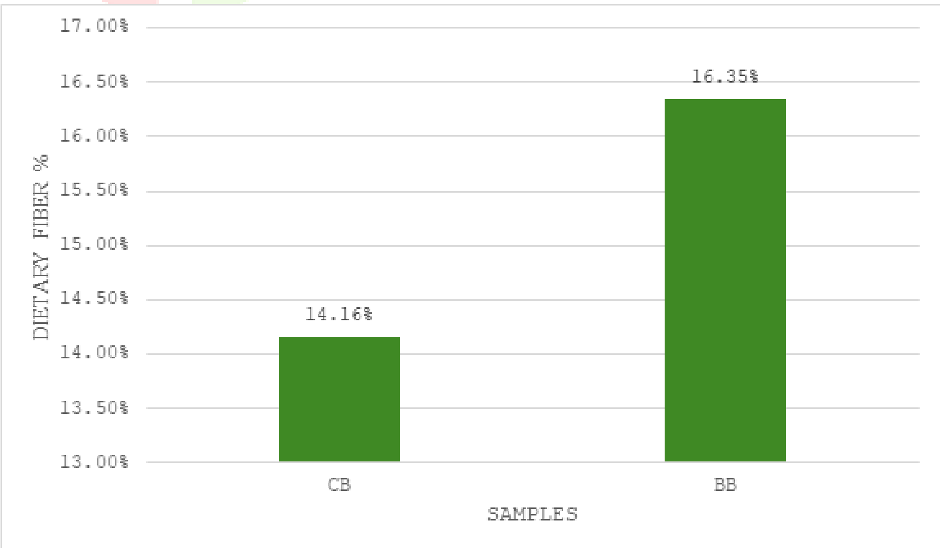

Figure 8 Total dietary fiber content in all samples. B.B (Banana flour fortified bread), C.B(Bread prepared using standard ingredients)

Vitamin C Concentration in hummus

The observed result indicated that the Vitamin C content in hummus fortified with banana blossom powder was higher compared to the control hummus (Table 4 and fig 9).

Table.4 Represent the strength of Vitamin C Concentration in hummus sample.

Sample	Strength
Control Hummus	2.80×10^{-1} µg/mL
Banana Hummus	3.69×10^{-1} µg/mL

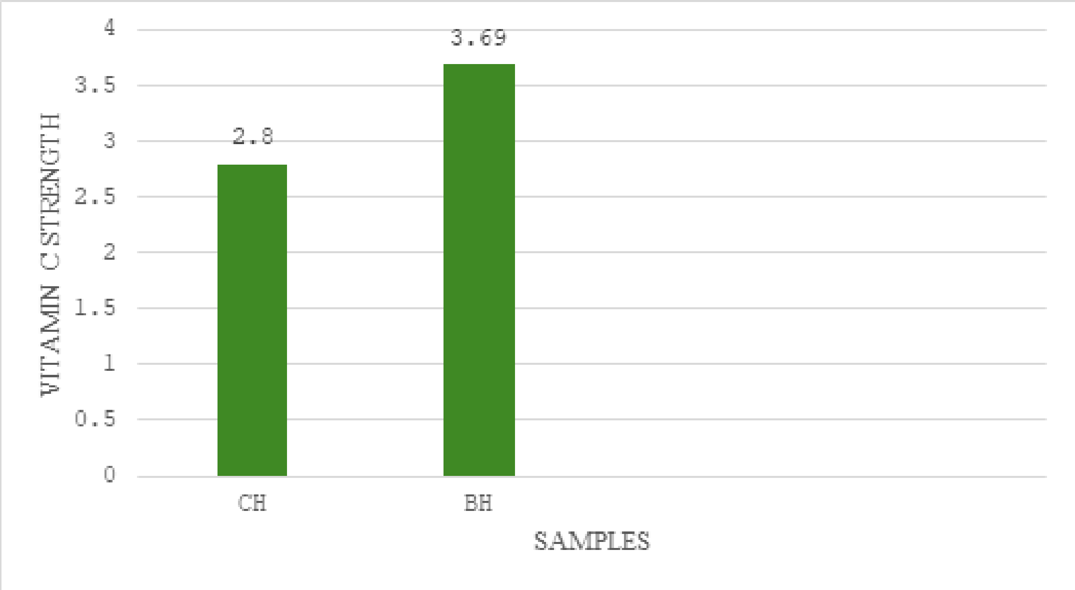

Figure.9 Represent the strength of Vitamin C Concentration in each sample in the form of bar graph. B.H (Banana blossom powder fortified hummus), C.H (Hummus prepared using standard ingredients)

Antioxidant Activity

The results demonstrated that the banana blossom Enriched hummus exhibited a significantly higher capacity to scavenge DPPH radicals compared to the control hummus. This observed enhancement in antioxidant activity can be attributed to the presence of banana blossom powder in the enriched hummus formulation.

Table.5 Represent the antioxidants activity in all hummus samples. Values are represented in % inhibition value.

SAMPLE	% INHIBITION
Control hummus	22.66%
Banana hummus	45.01%

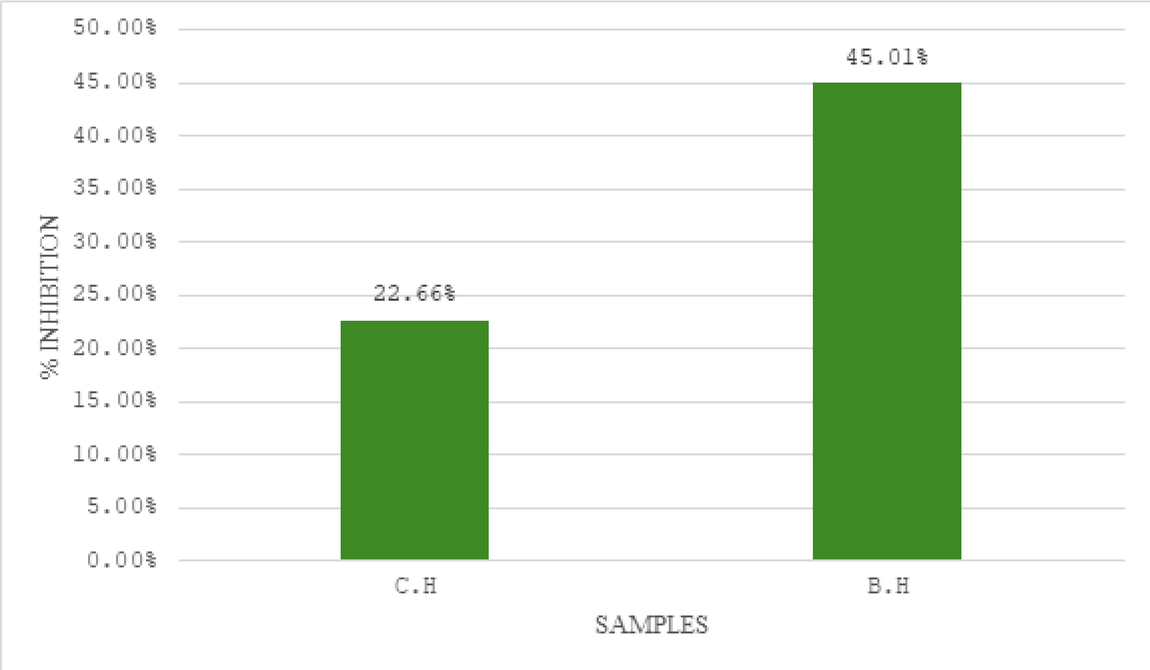

Figure 10. Represent the antioxidant activity in prepared hummus samples i.e. control and banana flower Enriched respectively and their corresponding % inhibition value

Microbial Analysis
TPC in all samples shows that fortified products are enriched in nutrients (table 6, fig 12). In all samples yeast and mold count also shows the safety of all prepared ready to eat products.(fig 12, table 6)

Table.6 Represents the yeast and mold count and TPC in CFU/g in each product

S.No.	**Product Name**	**Yeast and Mold Count**	**TPC**
1.	Control bread	$2.3x10^3$ CFU/g	$2.1x10^4$ CFU/g
2.	Banana Bread	$4.4x10^3$ CFU/g	$2.1x10^4$ CFU/g
3.	Control hummus	$4.9x10^2$ CFU/g	$8.9x10^3$ CFU/g
4.	Banana hummus	$7.2x10^3$ CFU/g	$8.4x10^3$ CFU/g

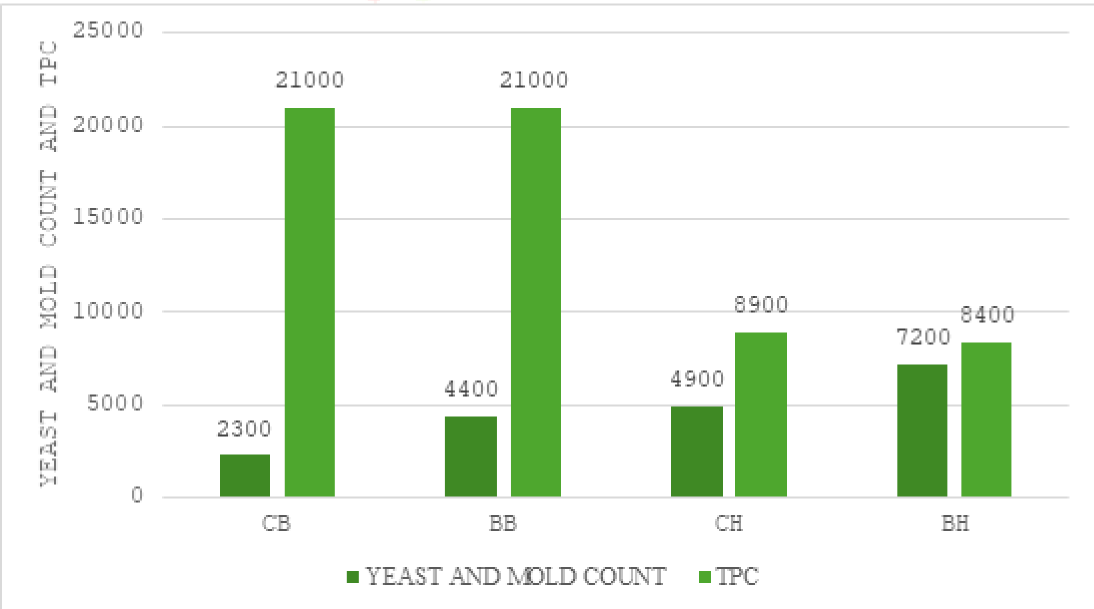

Figure.11. Represent yeast/mold count and TPC in each sample in the form of bar graph

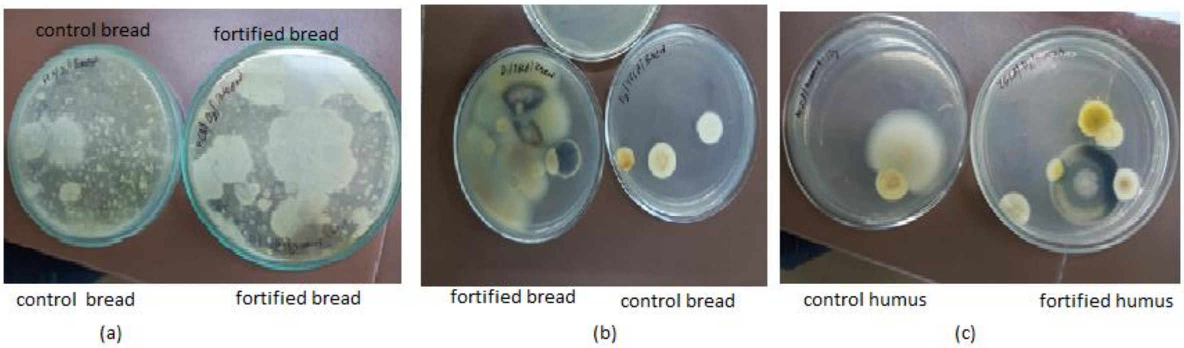

Figure.12. Microbiological analysis of all prepared products. (a) Total Plate count (b) Yeast and mold growth in bread (c) Yeast and mold growth in Hummus

Sensory Evaluation

The results of the sensory evaluation indicated that there was minimal difference in the overall acceptance of both the fortified banana bread and the control bread. However, when the panelists assessed specific attributes, they found that the texture, mouthfeel, and flavor of the fortified banana bread were notably more appealing. This enhancement in sensory experience could be attributed to the incorporation of banana flour, which appeared to positively influence the bread's texture, resulting in a more enjoyable eating experience. Likewise, in the case of the fortified hummus and the control hummus, the overall acceptance scores were similar, with slight differences. However, certain attributes were more prominent in the fortified hummus. The aroma, flavor, texture, and mouthfeel of the fortified hummus received higher appreciation from the panelists when compared to the control hummus. The addition of banana blossom powder appeared to introduce distinctive and appealing sensory qualities to the hummus, which contributed to its elevated sensory appeal. The observed differences in sensory perception can be attributed to the unique properties and flavors introduced by the added ingredients. In the fortified banana bread, the banana flour likely contributed to a smoother and more pleasurable texture, enhancing the overall eating experience. Similarly, the incorporation of banana blossom powder in the hummus led to a heightened aroma and flavor profile, along with improved texture and mouthfeel, resulting in a more flavorful and satisfying consumption experience.

Table.7 . Represents the mean, median and mode values of how much individual liked the various samples: - BB (Banana flour fortified bread), C.B(Bread prepared using standard ingredients), B.H(Banana blossom powder fortified hummus), C.H(Hummus prepared using standard ingredients)

Sample	Flavour			Aroma			Colour			Appearance			Texture			Acceptance		
	Mean	Mode	Median	Mean	Mode	Median	Mean	Mode	Median	Mean	Mode	Median	Mean	Mode	Median	Mean	Mode	Median
B B	9	9	9	8	8	8	8	8	8	8	8	8	9	9	9	9	9	8
C B	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
B H	9	8	9	8	8	8	9	8	9	8	8	8	9	9	9	9	9	8
C H	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

IV. DISCUSSION

This study explored the potential of raw banana flour and banana blossom powder as functional food ingredients in bread and hummus, respectively, highlighting their significant nutritional contributions and positive consumer acceptance. Both raw banana flour and banana blossom powder proved to be an excellent sources to enhance the essential nutrients. A significant increase in protein content in fortified bread and hummus, addressing potential protein deficiencies, especially in vegetarian diets. These ingredients contribute diverse proteins, including enzymes and lectins, offering potential health benefits like digestive aid and immunomodulation. The carbohydrate content remained stable in bread and hummus ensuring the energy value of the fortified products was maintained. Importantly, the total dietary fiber content was significantly higher in both fortified bread and hummus due to the inherent fiber in banana blossoms. This increase in fiber, including soluble and insoluble types like pectin and resistant starch, is crucial for gut health, blood sugar management, and digestive regularity. Furthermore, banana blossom-fortified hummus showed a notable increase in vitamin C levels and thus attributed to the blossom's natural richness in vitamin C and other antioxidants like flavonoids, phenolic acids, and carotenoids, which protect Vitamin C from oxidation (Castelo-Branco, 2017). The minimal heat exposure during hummus preparation and the synergistic interaction of ingredients (Bengal gram, tahini, lemon juice) further contribute to Vitamin C retention and stability (Chen et al., 2020; Debabandya et al., 2010). The study on antioxidant properties also confirmed that banana blossom powder significantly boosted the antioxidant levels in both products vital for combating oxidative stress and reducing chronic disease risk. Microbiological analysis revealed that prepared product is safe to consume. A 9-point hedonic scale sensory evaluation revealed strong consumer acceptance for the banana blossom-fortified products. Panelists highly rated the appearance, texture, and flavor of both the hummus and bread. The slightly darker hue from the banana blossom powder was found attractive, and the texture was improved, with hummus becoming smoother and bread heartier. These findings highlight the impact of natural additives such as banana flour and banana blossom powder on the sensory characteristics of food products. The subtle variations in attributes such as texture, aroma, flavor, and mouthfeel can greatly influence the overall perception and enjoyment of the products. The sensory evaluation results support the notion that these additives can enhance the sensory appeal of the final products, making them more appealing to consumers. A subtle nutty flavor from the banana blossom was also noted and generally favored. This positive feedback suggests high marketability and consumer appeal for these novel products. Our study supports the movement towards a more sustainable and nutritious food system. In summary, using banana by-products, especially the blossoms, presents a promising opportunity for boosting nutrition and minimizing food waste.

V. CONCLUSION

This research underscores the promise of banana blossoms as a valuable and sustainable food ingredient. By utilizing this often-discarded by-product of banana farming, the study contributes to reducing food waste and creating value-added products. While the findings are encouraging, the study acknowledges limitations, including a relatively small sensory evaluation sample size and a lack of long-term stability or shelf-life data. In summary, this study points out that banana blossom powder is a valuable ingredient for creating enhanced food products, supporting sustainable food practices and better nutrition for the public. In future developing strategies to enhance consumer awareness and acceptance will be crucial for the widespread success of banana blossom-enhanced foods, paving the way for a more sustainable and nutritious food system.

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CONFLICTS OF INTEREST
There is no conflicts of interest among the authors.

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