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Original Research

Evaluation of physico-chemical and sensory properties of tarts by incorporation of broccoli sprouts powder

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Abstract

This study describes the development of tarts by the incorporation of broccoli sprouts powder (BSP). The current study was aimed to assess the quality attributes of tarts prepared with broccoli sprouts (Brassica oleracea L. var. italica) powder. The tarts were formulated using different treatments (labelled as T0, T1, T2, T3 and T4) including Broccoli Sprouts Powder in the ratio of 0, 2, 4, 6, and 8% respectively. The tarts were analyzed for its quality characteristics including physico-chemical, rheological, shelf-life and sensorial properties. The newly formulated tarts showed greater fat, protein, fibre, and ash content with the increasing concentration of broccoli powder. The moisture and carbohydrate content showed a decreasing trend. The incorporation of broccoli sprouts powder significantly ($P<0.05$) increased the phenolic and antioxidant capacity of the tarts. Broccoli-containing tarts also showed a reduction in lightness but a greener hue, providing a darker appearance to the tarts. The textural characteristics such as hardness decreased while, density, weight and spread ratio increased by the incorporation of powder. The incorporation of broccolis sprouts up to 6% showed an optimal balance between enhanced nutritional value and desirable sensory characteristics. The findings present opportunities for growth of food manufacturers as broccoli sprout powder can also be used for preparation of novel baked goods.

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Introduction: Vegetables are grown globally and the ones that belong to Cruciferaceae family are notable not only for their nutritional value but also for their ability to promote good health. They include cabbage, cauliflower, broccoli and spinach that are a great store of phytonutrients [1]. Among these, Broccoli (Brassica oleracea var. italica) has gained significant importance as therapeutic food in recent years. Hence, there have been efforts to understand how the consumption of certain foods such as broccoli can impact the human well-being [2]. Growing public interest and the focus of scientific community have been drawn to plant sprouts, microgreens, and "baby leaf" vegetables in recent years due to their possible health advantages [3]. Sprouts are a great substitute for plant-based meals and are available whole the year round in fresh form. Broccoli sprouts (BS) are one of the best sources of the multifaceted pro-health phytonutrients. Thereby, edible sprouts may be used in functional food items to increase the quality and nutritional worth of foods [4]. Because of their immature physiological state following the germination of seeds, cruciferous sprouts have more than ten times greater glucosinolate contents than the comparable mature inflorescences (broccoli heads) [5]. The sprouted broccoli has originated from the eastern Mediterranean and mostly grown in Italy as well as in most parts of Europe [6]. Though it may be grown throughout Pakistan, broccoli grows best in Balochistan's lower temperatures. In developed nations, the area allocated for broccoli production is growing quickly as a result of increased awareness of the plant's highly valuable health-protecting chemicals. Though it is still limited to Lahore, Islamabad, and the northern regions in Pakistan [7]. Broccoli sprouts have gained popularity recently owing to the facts that their bio-active components are somewhat different from adult broccoli's and are more efficient than the broccoli in preventing illnesses caused due to reactive oxygen species [8]. Broccoli sprouts are 7–9-day-old seeds that are germinating. They are rich in glucoraphanin, indol–glucosinolates (e.g., glucobrassicin), and other important nutrients (vitamins A, C, and E, minerals K, Fe, S, and so on), as well as phenolic compounds (mainly hydroxycinnamic acid glycosylated derivatives and flavonol glycosides) [9]. Due to their immature physiological state following seed germination, cruciferous sprouts displayed more than ten times higher concentrations of glucosinolates than the comparable mature inflorescences (broccoli heads) [10]. Epidemiological studies have demonstrated the use of broccoli sprouts in different food products. The phytoconstituents that are believed to be abundant in edible sprouts prevent numerous chronic and neurodegenerative diseases. In particular, broccoli sprouts' antioxidant and anticancer properties have drawn the most interest and served as the subject of in-depth research in recent years [11-13].

Incorporating BSP into food products can be an effective way to enhance their nutritional value and provide health benefits to consumers. Bakery products have been best suited to produce functional food due to their increased consumption [14-16]. Incorporating functional ingredients derived from plants into baked goods is a new trend in the food industry. Although broccoli sprouts' health advantages have been thoroughly researched, little is known about how they work in baked goods, especially tarts. The market for baking products has been significantly rising in recent years despite the fact that they are not appropriate for major cooking but also are ideal for refreshments [17]. In the current study, with the growth of brunch and dessert industries, tarts have been made by food producers in addition to bakeries [18]. Since the typical diet lacks antioxidants, fortifying grain-based tarts is justified. Somehow, wheat has some antioxidant capability. There have not been several effective studies so far on fortifying the tarts to increase its nutritional potential. Therefore, it is suggested to prepare a brand-new useful item: biscuit tarts that have been enriched with powdered broccoli sprouts (BS) in the ratio of 2, 4, 6 and 8%. The impact of incorporating broccoli sprouts powder (BSP) into tarts will also be analyzed based on their physico-chemical and sensory properties. The primary objective of this study is to determine the optimal level of BSP incorporation that enhances the nutritional profile while maintaining consumer acceptability. Notably, this research work is aimed to include analysis of nutritional composition, texture, color, and consumer acceptance.

2. Materials and Methods

2.1. Procurement of raw material: The study was conducted in the research lab of Department of Food Science and Technology at Jinnah University for Women, Nazimabad Karachi. The ingredients for making tarts such as flour, butter, egg, vanilla essence and sucralose were purchased from local store in Karachi.

2.2. Preparation of broccoli sprouts powder: Broccoli seeds of F1 quality were purchased from an online store in Karachi in September 2022 and were germinated according to the method of Dziki *et al.,* (2014). Dry seeds were soaked in water at 25°C for six hours after being sterilized for five minutes with 1% (v/v) sodium hypochlorite. They were then rinsed with sterilized water. For six days at 25°C and in darkness, seeds were germinated in sterile Petri dishes coated with filter paper (Whatman Grade 2). 6 mL of distilled water were added to the germination seeds each day. On the seventh day, broccoli sprouts (BS) were gathered. Before freeze-drying, they were weighed, and a lab mill was used to grind them into powder form.

2.3. Tarts Preparation: To make dough of the proper consistency, 100 g of various flour ratios were combined with a specified amount of butter, egg yolk, ground sugar and vanilla essence. After that, the dough was refrigerated for 10 mins. Table 1 shows the percentage composition that was used to prepare the tarts.

Tarts were made by kneading the dough and rolling it into little balls. The dough balls were then placed in a tart mold that had already been oiled, and the base was formed by squeezing the dough ball with fingers. Excess dough was removed. The molds were baked at 180°C for 12-15 minutes, until golden brown. The tarts were taken out of the oven and left aside to cool.

2.4. Nutritional Analysis of Tarts: Proximate analysis for the prepared tart samples were carried out. Drying oven was used to determine moisture at 105±5 °C for 24 h until a constant weight was achieved according to method No. 44- 15A. Crude protein was determined using AACC (2000) method No. 46-10 using the Kjeldahl's method. Crude fat was measured using the Soxhlet equipment in accordance with AACC (2000) method No. 30-25. The crude fibre content was determined by using the AACC (2000) method No. 32-10 utilizing defatted sample. The ash content of each tart sample was assessed using the steps described in AACC (2000) technique No. 08-01. The following relation was used to compute the nitrogen-free extract.

NFE=100 – (moisture% + ash% + fiber%+ fat% + protein)

2.5. Viscoelastic properties of composite flour: Using a Rapid Visco-Analyser RVA-4SA (Brabender, Duisburg, Germany) interfaced with a personal computer running thermocline for Windows software, the viscoelastic characteristics of composite flour consisting of wheat and broccoli sprouts powder in the ratio of 2,4,6 and 8% were measured. The AACC method was used to measure the pasting profile (AACC, 2000). The pasting attributes that were assessed included peak viscosity, breakdown viscosity, setback viscosity, final viscosity and pasting temperature.

2.6. Quantitative determination of phytochemicals in extract:

2.6.1. Determination of total phenolic content: The phenolic content was determined following the modified method of Ibrahim *et al.* (2019).100 µL of samples (0.1 g DW/mL) were combined with 1 mL of deionized water and 200 µL of Folin–Ciocalteau reagent (2N). The sodium carbonate solution (1.5 mL, 20%) was added after 3 minutes at 25 ◦C. At the same temperature, the reaction mixture was incubated for ninety minutes. Next, using a UV Spectrophotometer (Jenway 6305), absorbance was measured at 765 nm. Similar procedures were used to prepare gallic acid standards in the 0–100 ppm range in order to produce a calibration curve (r2 = 0.9959) for TPC calculation. The results were represented in milligrams per gram of gallic acid equivalents (mg GAE/g) of dry extract.

2.6.2. Determination of Total flavonoids content: The aluminium chloride colorimetric technique was used to determine the total flavonoid concentration in extracts according to the procedure described by Xuan *et al.*, (2018) with some modification. Samples (0.25 mL) were mixed with aluminium trichloride (0.15 mL, 10%), and sodium nitrite solution (75 µL, 5%). After adding deionized water to bring the mixture's final volume to 2.5 mL, it was incubated for 5 minutes at 30 °C. Then a 2 mL solution of 1M NaOH was added. The obtained concentration was set aside for 15 minutes prior to noting the absorbance at 510 nm using a UV Spectrophotometer (Jenway 6305). A calibration curve was used to quantify the total flavonoids content, which was then translated into mg quercetin equivalent per gram dry weight.

2.6.3. Determination of antioxidant activity by DPPH radical scavenging activity: The radical scavenging activity (RSA) of the crude extracts was adopted to measure antioxidant activity using the DPPH method as reported by Alam and Bristi (2013). A freshly made solution of DPPH (2,2-diphenyl-1-picrylhydrazyl) (1 mL, mM) was combined with samples (5 mL, 0.1 g DW/mL). After vortexing the reaction mixture, it was left to stand at 30 °C for 60 minutes in the dark. At 517 nm, the absorbance of the standard and samples was measured in relation to the blank using a UV visible spectrophotometer (Jenway 6305). The DPPH radical scavenging capacity of the sample was expressed as µM Trolox equivalent (TE) per gram of dry matter. Trolox was used as standard. The following formula was used to determine the percentage of the DPPH scavenging activity.

DPPH free radical scavenging activity (%) = (A0-A)/A0 x100

Where,

A0: absorbance of the control

A: absorbance of the sample

2.7. Colour determination: The color of tarts was measured by a colorimeter (UltraScan and EashMatch VIS, Hunter Lab Inc., Reston, VA, USA). The device was calibrated before to measurements using black, green, and white tiles provided by the manufacturer. Three samples were chosen at random from each formulation. The L*(lightness), a*(redness), and b*(yellowness) values were measured at least thrice and expressed as the average value. For comparison with broccoli extract and powder containing samples, normal tarts containing 0% of broccoli extracts or powder (control) was utilized as the standard. The Hunter L*, a*, and b* colour values were determined from the samples, and the colour differences L*, a*, and b* were calculated. The results were expressed as L* (L*= 0 (darkness) and L*= 100 (lightness)), a* (+a* = redness and −a* = greenness) and b* (+b* = yellowness and −b*=blueness). The total colour difference (ΔE) and chroma value are determined by the equations given below as described by Wibowo *et al.*, (2015).

$$\Delta E=\sqrt{(\Delta L)^2+(\Delta a)^2+(\Delta b)^2}$$

$$C^*=\sqrt{a^2+b^2}$$

2.8. Textural analysis: The textural profile analysis was measured by method of Boki´c *et al.*, (2022). A TA.XT2 Texture Analyzer connected to Exponent software v. 5.0.6.0 fitted with a test compression probe was used for the measurement. The findings reflect the mean of three measurements for each formulation. The readings were taken in replicates post-baking.

2.9. Density, weight and spread ratio: The weight of each sample was taken after baking on the same day and results for three tarts were averaged for every formulation. The volume of each sample was calculated manually using Vernier calipers by measuring length, width and height of the tarts after baking. Using a Vernier caliper, the diameter (D) and height (H) were measured as reported by Mahloko *et al.,* (2019) [19]. The spread ratio was calculated with slight modification. Six biscuits were arranged edge to edge, their total diameter was measured. The tarts were rearranged for six times, and each time the diameter was noted. The height of six biscuits stacked on top of one another was measured with a Vernier caliper. The height of each biscuit was measured after six arrangements. The diameter and height of the biscuits were used to calculate the spread ratio, which was then expressed as a ratio of the biscuits' height to their diameter. Density of each sample was calculated by dividing the weight of each tart into its volume.

2.10. Microbiological Analysis: The tart samples were kept at 25°C for up to 21 days in order to monitor any microbial changes during storage, and the microbial counts were assessed after interval of 7 days according to method described by Lee (2021) with some modification. Total number of bacteria and the existence of molds was identified.

After homogenizing a 10-g sample in 90 mL of peptone water, Stomacher (Seward 3500) was used to homogenize the material for one minute. Saline solution was then used to serially dilute the homogenized samples. 1 mL of the diluted sample was spread out on the nutrient agar and peptone dextrose agar (YPD) media for bacterial and mold count respectively. The media was incubated for 48 hours at 37°C to assess the total aerobic plate count and mold count after storage for 21 days. Colony forming unit per gram (CFU ⁄ g) was used as the unit of measurement for counts. Three duplicates were used for the analysis of each sample.

2.11. Shelf-life study of tarts: The tarts were prepared and packaged in polypropylene pouches. For the duration of the analyses, the tarts were kept at 30 °C for 0, 7, 14 and 21 days. Three replicates were used for the analysis of each sample.

2.11.1. pH: The pH was measured using the pH meter (Mettler Toledo, FP20) according to the procedure described by N'guessan *et al.,* (2017). There were four parts to the tart. The pH meter's probe was inserted into each component of the tart to take the measurement. The average of the four measurements was used to determine the pH of tarts. Prior to each use, the pH meter was calibrated.

2.11.2. Water Activity: The AquaLab (4TE, Rotronic Hygrolab, USA) was used to measure the water activity (aw) at 23±2°C as discussed by N'guessan *et al.*, (2017) [20]. The method of mirror dew point was applied. A cup containing one-third of the tart's volume was introduced into the AquaLab as part of the measurement. This section of the tart was taken from the inside, without the crust. Prior to every measurement, the measuring apparatus was calibrated.

2.12. Sensory analysis: As defined by Millar *et al.* (2017) [21], evaluation for numerous quality factors on the basis of texture, colour, look, and overall acceptability by assigning ratings from 1 to 9 using hedonic scale where (1 = unacceptable, 5 = neither acceptable or unacceptable, 9 = acceptable). In total, 09 attributes were evaluated. The assessments were carried out in a sensory laboratory room under normal lighting conditions at room temperature, fulfilling the requirements of the ISO standards (ISO 8586:2012). The sensory examination was completed by a group of professionals, and data was gathered.

2.13. Statistical Analysis: The data was largely analyzed using simple statistical techniques in Microsoft Excel (2013). Each investigation's results are the average of at least three readings therefore, all chemical and technological analyses were performed in triplicate. Tukey's pairwise comparison at $P< 0.05$ was used to assess the significance of differences between the samples after the results went through one-way analysis of variance (ANOVA). Using Statistic 8.1 software, the mean and standard deviation of the parameters from the proximate analysis, physical properties, and texture analyses were computed, and the variations between the formulations were assessed.

3. Results and Discussion

3.1. Proximate Analysis of tarts: Table 1 exhibits the mean values for proximate composition of the tarts made from broccoli sprouts powder, and the results were found to be statistically significant ($P<0.05$). The tarts showed an increase in the protein, ash and fibre contents while, moisture and carbohydrate content showed a decreasing trend. The fat content did not show significant change. The highest protein content was depicted by T4 (8.86) while, T0(8.02) had the lowest protein content. The findings supported the theory that broccoli has greater protein content than wheat flour. Similar findings were reported by Anwar et al., (2017) [22] while using broccoli powder which shows that the BSP is rich in protein. The moisture content decreased as the concentration of BSP increased due to the lower moisture content in BSP. T0(8.91) showed minimum moisture content and maximum content was observed in T4 (5.92). The sample T0 showed minimum ash content and T4 showed highest ash content. The highest fibre content was shown byT4 (5.33) and lowest was observed in T0 (2.20) which is reportedly consistent to the findings reported by Boki´c *et al.,* (2022) [3]. The carbohydrate content showed a decreasing trend as the concentration of broccoli powder increased with the maximum value being observed in T0 (75.06) and minimum value in T4 (71.47). The carbohydrate content decreased as a result of broccoli sprout powder replacing some of the starchy durum wheat flour.

3.2. Effect on viscoelastic properties of flour: The readings for the viscoelastic properties of tarts are depicted in Table 2. Significant differences were seen in the pasting parameters as the concentration of broccoli sprouts powder increased. A declining trend in peak viscosity was observed with increasing BSP concentration, with values ranging from (1119 BU) in T0 to (935.7 BU) in T4. Likewise, study conducted by Alamri *et al.,* (2013) [23] showed similar rheological characteristics incorporating wheat flour. The pasting temperature decreased from 67.8°C in T0 to 64.2°C in T4. The mean values for breakdown viscosity were reported as maximum in T0 (208.3 BU) to minimum in T4 (131.7 BU). The final viscosity also showed a decrease from 1050 BU in T0 to 938.3 BU in T4. Anwar et al., (2017) observed similar trend in the pasting characteristics of composite flour incorporating broccoli floret powder. The maximum values for setback viscosity were observed in T0 (102.3 BU) and minimum value in T4 (62.0 BU).

3.3. Colour analysis on tarts: Tart colour is one of the most important factors responsible for consumer acceptance because it is related to product freshness and flavour expectations [24]. The table 2 showed significant effect (P<0.05) in the colour of the developed product. It is evident that all the color indices i.e. L, a*, b*, hue angle and chroma were significantly affected by different treatments. The table 2 shows that the lightness (L) value and yellowness (b) value also decreases as the concentration of broccoli sprouts powder increases as shown by Anwar *et al.,* (2017) [22]. This trend is observed due to the addition of broccoli-based ingredients. The (a) value showed a decreasing trend and the enriched tarts were found to be greener as compared to the control tarts as depicted earlier by Kozak *et al.* (2021) [25]. This was expected, since a* parameter is related to the greenness of the analyzed sample and the broccoli extract and powder is characterized by high green intensity. The highest value of L was recorded by the control sample T0i.e. 75.76±0.10 while, the lowest value for L was recorded by T4i.e. 63.0±0.18. The highest a* value was recorded by control sample 4.20±0.02 and the lowest value was shown by T4i.e.-4.08±0.02. The lowest value for b* was recorded by T4i.e. 9.70±0.06 while, T0 showed the highest value i.e. 11.88±0.07. Current findings regarding color indices are in close agreement with the previous outcomes of Boki´c *et al.* (2022) [3]. Since customers associate dark colours with high-fibre items, it can be an advantage [26]. The current trend towards "healthier" foods may present an opportunity to promote this form of baked goods, although this greenish appearance of tarts could cause some concern for consumers not used to purchase this kind of products [27].

3.3. Textural characteristics of tarts: The table 3 shows the values for the textural hardness, density, weight and spread ratio of the tarts produced from the broccoli sprouts powder. The tarts showed a decrease in the hardness as the concentration of broccoli increased. The control sample T0 showed higher hardness i.e.110.19±0.03 and the lowest hardness was depicted by 109.77±0.02. On the contrary, density, weight and spread ratio of the tarts showed an increase as the concentration of the broccoli sprouts powder and extract increased respectively. The lowest values were reported by T0 (0.83±0.01, 7.74±0.05, 10.06±0.02) and T4 (0.95±0.01, 7.98±0.01, 10.25±0.01). From the perspective of the customer, the textural characteristics are crucial to guarantee food products' acceptance. Tart acceptability is mostly determined by its texture, especially its hardness. Gluten production is primarily correlated with firmness [28]. Hardness, which is determined by the maximum force reached during the initial compression, is strongly correlated with the integrity and strength of the protein matrix that is formed during cooking [29]. Consequently, the incorporation of a non-gluten substance (broccoli powder) likely reduced the gluten content and undermined the tart's overall structure [30], resulting in a reduction in its firmness [31].

3.4. Total phenolic and antioxidant capacity of tarts: Tarts prepared from broccoli sprouts extract and powder were subjected to phytochemical screening quantification as well as the assessment of their antioxidant potential. The results were found to be statistically significant (P<0.05) and are shown in Table 4. Among all the treatments, the highest TPC value was shown by T4BP (1.69±0.00 mg GAE/g). The lowest value was recorded for T0 (0.48±0.01 mg GAE/g). The TPC values are similar to those reported by Anwar *et al.*, (2017) [22]. The ABTS assay's scavenging activity is linked to the activity of hydrophilic substances like polyphenols [25]. As a result, the rise in TPC caused by the inclusion of broccoli sprouts powder and extract may be responsible for the increase in free radical scavenging. The results for the TPC of the enriched tarts were found to be greater.

The highest DPPH radical scavenging activity amongst all tarts was depicted by T4BP (1.25±0.03 µmol TE/g). The lowest DPPH value was again shown by the control sample (0.42± 0.05µmol TE/g). Considerably higher value of ABTS free radical scavenging ability was recorded by T4BP (1.37±0.03 µmol TE/g). The lowest value was found against the control sample i.e.0.39±0.05 µmol TE/g. However, the baked tarts had a higher ferric reducing power as determined by FRAP. Moreover, the highest ferric reducing antioxidant power was reported by T4BP (1.71±0.04 µmol TE/g) and lowest free radical scavenging capability was exhibited by T0 i.e.0.21±0.02µmol TE/g. The TPC in tarts increased by 3.5 times in broccoli powder. The antioxidant activity measured by DPPH, ABTS and FRAP showed an overall increase by 2.9, 3.5 and 8.1 times respectively. All the values were found to be statistically significant (P<0.05). It is also important to note that the antioxidant capacity of fortified tarts considerably increased in proportion to the amount of broccoli powder and extract in each formulation, and that this rise was dose-dependent. Amongst all the treatments, the treatment, T4BP showed the highest level of TPC and antioxidant activity through all methods. Due to their numerous health advantages as antioxidants, including the prevention of multiple chronic diseases, phenolic compounds have been widely researched. This observation is further supported by a study conducted by Lafarga *et al.* (2019) [32].

The ABTS assay's scavenging activity is linked to the activity of hydrophilic substances like polyphenols [25]. As a result, the rise in TPC caused by the inclusion of broccoli sprouts powder and extract may be responsible for the increase in free radical scavenging. In most of the studies, the antioxidant potential measured by FRAP increased as the concentration of by-products added increased. This observation is further supported by a study conducted by Lafarga *et al*. (2019) [32].

3.5. Effect on Microbiological analysis of tarts: The tarts were assessed for up to 21 days in order to ascertain whether adding broccoli sprout powder increases the tart's stability during storage. Table 5 and 6 shows the total aerobic plate count (APC) and mold count respectively and the results were found to be statistically significant ($P<0.05$). The aerobic plate count at day 0 storage varied from 0.74 CFU/g in T4 to 1.41 CFU/g in T0. Following the 7 days of storage, the APC was reported to be 4.44 CFU/g in T0. The other treatments were found to have 4.95, 4.87, 4.65 and 3.33 CFU/g in 2, 4, 6 and 8% respectively. After 14 days, the APC values were 6.49 CFU/g in control and 6.12, 5.96, 5.46 and 4.74 CFU/g in T1, T2, T3 and T4 respectively. Further readings were taken after 21 days of storage and the readings were found to be 7.15, 6.42, 6.04, 5.74 and 5.46 for T0, T1, T2, T3 and T4 respectively. The results depicted that there was a progressive increase in bacterial counts across all treatments over the storage period. During storage, we found that the control samples' APC value was noticeably greater than that of the samples supplemented with 2, 4, 6 and 8% broccoli sprout powder. However, the broccoli sprout tarts showed a slower rate of growth than the control. This finding may be explained by the broccoli's antibacterial action in the bread samples, which inhibited the growth of the bacteria that cause spoilage. The consistent reduction in microbial load with increased BSP levels demonstrates a dose-dependent antimicrobial effect. Similar findings were reported by Lee (2021) reported the effect of adding broccoli sprouts powder to the storage stability of bread. Le et al., (2019) [33] also highlighted the potential use of broccoli sprouts antibacterial property. Likewise, Sibi *et al*., (2013) [34] reported use of broccoli sprouts against variety of foodborne bacterial species [35, 36].

On the contrary, the mold growth is associated with food spoilage [37]. The results showed a noticeable increase in the mold count upon 21 days of storage. At the initial stage, T0 showed the highest mold count i.e.6.02 log10 CFU/g and the lowest was shown by T4 i.e.4.03 log10 CFU/g. The other treatment values were reported as 5.21, 4.97 and 4.56 log10 CFU/g for T1, T2 and T3 respectively. After 7 days, the readings showed increase in the mold count. T0, T1, T2, T3 and T4 reported values as 6.73, 6.12, 5.84, 5.05, 5.00 log10 CFU/g respectively. Following the 14days storage, noticeable increase in the mold count was observed and T0 showed 7.15 log10 CFU/g. The values of T1, T2, T3 and T4 were found to be 6.48, 6.34, 5.99 and 5.07 log10 CFU/g respectively. The BSP concentration and mold count were shown to be inversely related. The Broccoli Sprout Powder act as a natural preservative as depicted by its dose-dependent antifungal action.

3.6. Effect on storage stability of tarts: Tables 7,8 and 9 show the water activity, pH and moisture content values over the 21-day storage stability of tarts prepared from broccoli sprouts powder. Water activity is a crucial factor that affects the sensory qualities of food products, chemical reactivity, and microbiological stability while they are being stored. Throughout the storage period, all treatments showed a gradual decrease in water activity. The mean values ranged from 0.96 in T0 to 0.87 in T4. The hygroscopic nature and greater fiber content of BSP, which binds water and decreases its availability, are responsible for the decrease in water activity that occurs with increasing the inclusion of broccoli sprout powder. Furthermore, migration of water in the tart and slow moisture loss during storage could be the cause of the ongoing decrease in water activity over time. Reduced water activity helps to prolong shelf life by preventing enzymatic activity and microbiological development. Interestingly, T4 had the lowest water activity values, suggesting a longer shelf-life and greater potential for microbiological stability.

The pH values ranged from 0.87 (T4) to 0.96 (T0). The pH decreased slightly but steadily over the course of the 21-day storage period for all treatments. The natural acidic components included in broccoli sprouts, such as glucosinolates and the breakdown products they produce (such as isothiocyanates), as well as the dietary fibers and organic acids added by the powder, are responsible for this decrease in pH as the BSP concentration increases. These components assist in the tart matrix's general acidity. Consequently, adding broccoli sprout powder enhances the tarts' nutritional and functional qualities while also improving their physicochemical stability over time [20].

3.7. Sensory evaluation of tarts: Any developed product's sensory qualities should be widely embraced by users. Innovative items that are made with particular health-promoting claims, in particular, need to satisfy consumers' sensory expectations. The sensory characteristics, such as taste, colour, odour, flavour, and aftertaste, were evaluated in this context. The table 5 shows the readings that were found to be statistically significant ($P< 0.05$).

Any developed product's sensory qualities should be widely embraced by users. Innovative items that are made with particular health-promoting claims, in particular, need to satisfy consumers' sensory expectations. The sensory characteristics, such as taste, colour, odour, flavour, and aftertaste, were evaluated in this context. To sum up, the incorporation of broccoli extract and powder affected the overall properties of the tarts but the results were found to be statistically significant ($P< 0.05$) for all the parameters. Nine attributes were selected overall and were thoroughly evaluated for sensory profiling. The tarts produced from both broccoli sprouts powder and extract were evaluated according to Hedonic scale. Each panelist was asked to rate the product on 9-point hedonic scale (0: extremely dislike and 9: extremely like). The tarts produced from broccoli sprouts powder at lower concentrations showed a higher creamy colour, less grassy and broccoli odour, a sweeter flavour and a better aftertaste. From a technological perspective, powdered broccoli sprouts and extract can be utilized in tarts to enhance their flavour. However, as the quantity of broccoli sprouts in the tarts increased, so did the flavour and odour severity. Therefore, it should only be added in moderation. However, as every sample received good sensorial ratings, the findings of the sensory evaluation showed that the addition of broccoli sprouts had no effect on the tart's overall acceptability. This implies that even if there is a perception of broccoli flavour, a significant percentage of the consumer group would still eat the tarts containing broccoli sprouts. Thus, for the concentration of up to 6% the tarts remained acceptable for its texture, flavour, appearance and odour.

Likewise, another study was conducted by Anwar *et al.* (2017) [22] to assess the sensorial properties of the enriched bread produced using 1, 3, 5 and 7% broccoli powder. The findings revealed that upto 3% broccoli powder was acceptable but above this concentration, the textural and sensorial properties of the bread were highly affected. Previous studies conducted by Dziki *et al.* (2014) [38] have suggested that wheat bread produced containing up to 2% broccoli sprouts is generally acceptable by the consumers. These results were found to be in collaboration with the current findings.

4. Conclusion: A great sustainable development strategy to utilize broccoli by-products is to transform them into functional components for food applications. The goal of this research is to establish a suitable food system as a vehicle for delivering enough amounts of bioactive compounds into the human diet. This study was conducted to assess the technological, physicochemical and functional properties of the tarts produced from broccoli sprouts powder. The obtained results indicated that broccoli sprouts can be successfully used as an additive in tarts making. The addition of broccoli sprouts to the tarts greatly improved its several nutritional properties compared to non-supplemented tarts. Thus, adding broccoli sprout extract and powder to tarts could be viewed as a way to boost the consumption of Brassica vegetables without significantly altering the way people eat. In a nutshell the use of broccoli sprouts enhanced the nutraceutical potential without lowering the product's technological or sensory quality. Hence, broccoli sprouts present an intriguing substitute for the food industry to offer consumers new products with increased value. Since there has been increased awareness among people about the nutraceutical and functional food so this product will have a great impact on the baking industry and provide a healthy lifestyle. Additionally, one strategy to reduce the usage of artificial additives in food products is to add natural sources of nutrients, such broccoli sprouts, to the mixture.

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Fig 1. Antioxidant activity of tarts

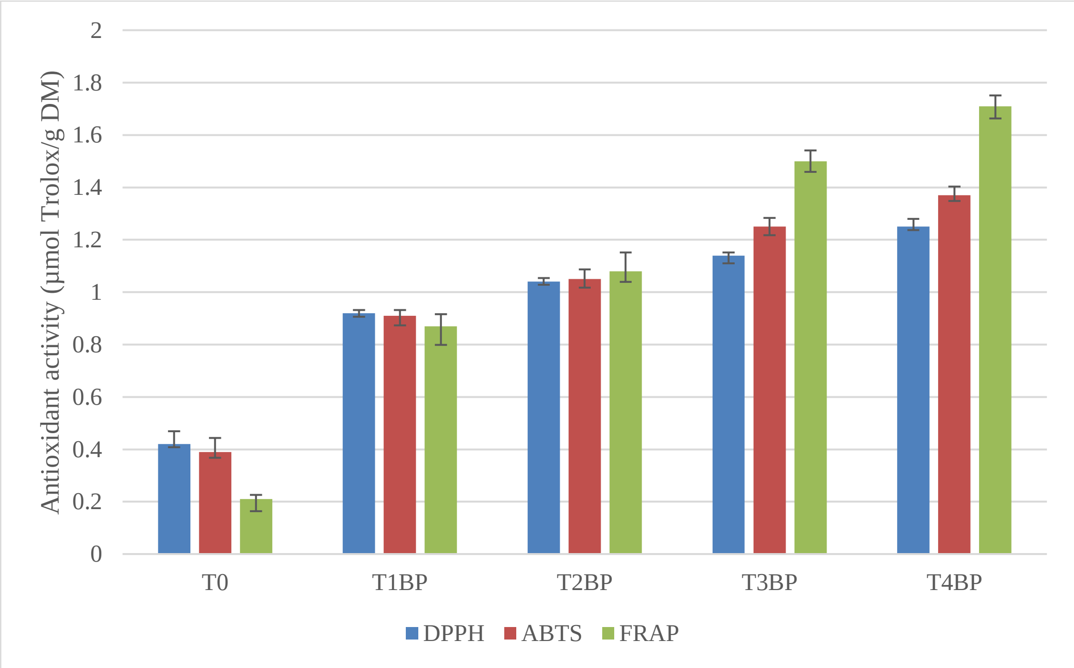

Fig 2. Sensory characteristics of tarts from Broccoli sprouts powder

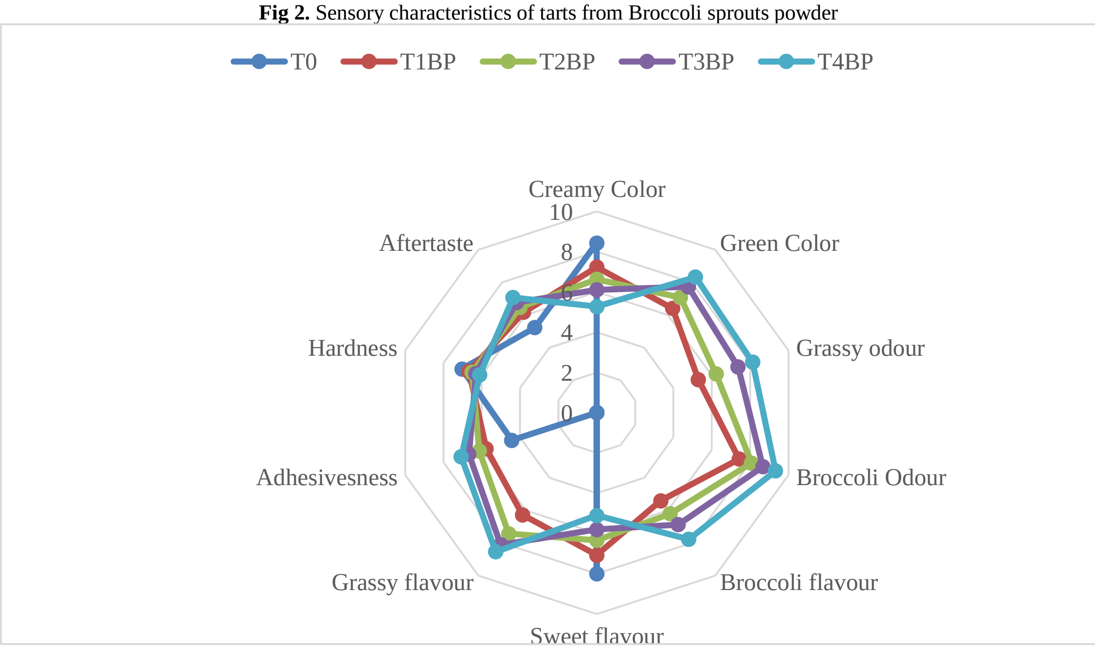

Table 1. Percentage composition of tarts

Ingredients	T_0 (%)	T_1 (%)	T_2 (%)	T_3 (%)	T_4 (%)
Flour	54.5	54.5	54.5	54.5	54.5
Butter	36.4	36.4	36.4	36.4	36.4
Egg yolk	5.5	5.5	5.5	5.5	5.5
Sucralose	2.7	2.7	2.7	2.7	2.7

Vanilla essence	0.9	0.9	0.9	0.9	0.9
BSP*	-	2	4	6	8

*BSP- Broccoli Sprout Powder

Table 1. Proximate analysis of tarts

Treat.	Fat (%)	Protein (%)	Moisture (%)	Ash (%)	Fibre (%)	Carbohydrate (%)
T_0	6.13±0.12^e	8.02±0.03^e	8.91±0.04^a	1.87±0.03^e	2.20±0.24^d	75.06±2.13^a
T_1	6.33±0.17^d	8.33±0.01^d	7.35±0.04^b	1.97±0.02^d	3.37±0.31^c	74.11±1.39^b
T_2	6.50±0.21^c	8.62±0.03^c	6.84±0.02^c	2.06±0.04^c	3.97±0.12^b	73.03±2.05^c
T_3	6.73±0.08^b	8.74±0.02^b	6.17±0.04^d	2.19±0.02^b	4.67±0.12^a	72.41±2.13^d
T_4	6.91±0.12^a	8.86±0.02^a	5.92±0.03^e	2.29±0.02^a	5.33±0.12^a	71.47±2.45^e

Values in the column showing different letters are significantly different at $P< 0.05$.

Table 2. Viscoelastic properties of tarts

Treatment	Pasting temperature (°C)	Peak Viscosity (BU)	Breakdown Viscosity (BU)	Final Viscosity (BU)	Setback Viscosity (BU)
T_0	67.8±0.2^a	1119±5^a	208.3±5^a	1050±6^a	102.3±4^a
T_1	66.4±0.3^b	1094.8±7^b	185.0±4^b	1025±4^b	94.0±3^a
T_2	65.6±0.4^c	1035.7±8^c	172.3±6^{bc}	997.8±5^c	82.7±5^b
T_3	64.9±0.3^d	991.7±4^d	156.7±4^c	968.3±4^d	72.3±6^c
T_4	64.2±0.1^e	935.7±5^e	131.7±8^d	938.3±3^e	62.0±4^d

Values in the column showing different letters are significantly different at $P< 0.05$.

Table 3. Color characteristics of tarts

Treat.	L	a*	b*	ΔE	C
T_0	75.76±0.10^a	4.20± 0.02^a	11.12± 0.08^a	0.00±0.00	11.88±0.07^e
T_1	72.52±0.25^b	-1.58± 0.07^b	10.68±0.04^b	6.15±0.24^a	10.80±0.03^a
T_2	68.78±0.87^c	-1.83± 0.07^c	10.08± 0.03^c	6.83±0.08^b	10.40±0.03^b
T_3	65.49±0.51^d	-2.01± 0.02^d	9.90± 0.05^c	7.13±0.24^c	10.14±0.07^c

T_4	63.00±0.18^e	-2.20± 0.07^e	9.70± 0.06^d	8.76±0.10^d	9.81±0.14^d

Values in the column showing different letters are significantly different at P< *0.05.*

Table 4. Textural characteristics of tarts

Treatment	Hardness (N)	Density (g/cm^3)	Weight (g)	Spread ratio
T_0	110.19±0.03^a	0.83±0.01^d	7.74±0.05^c	10.06±0.02^d
T_1	110.04±0.03^b	0.86±0.01^{cd}	7.85±0.01^b	10.14±0.02c
T_2	109.95±0.03^b	0.89±0.01^{bc}	7.92±0.02^a	10.19±0.01^{bc}
T_3	109.84±0.03^c	0.92±0.01^{ab}	7.96±0.02^a	10.20±0.01^{ab}
T_4	109.77±0.02^c	0.95±0.01^a	7.98±0.01^a	10.25±0.01^a

Values in the column showing different letters are significantly different at P< *0.05.*

Table 5. TPC, DPPH, FRAP and ABTS activity of tarts

Treat.	TPC (mg GAE/g DM)	DPPH (µmol TE/g DM)	ABTS (µmol TE/g DM)	FRAP (µmol TE/g DM)
	BP	BP	BP	BP
T_0	0.48± 0.01^e	0.42± 0.05^e	0.39± 0.05^e	0.21± 0.02^e
T_1	1.02± 0.01^d	0.92± 0.01^d	0.91± 0.02^d	0.87± 0.05^d
T_2	1.28± 0.01^c	1.04± 0.01^c	1.05± 0.04^c	1.08± 0.07^c
T_3	1.46± 0.01^b	1.14± 0.01^b	1.25± 0.03^b	1.50± 0.04^b
T_4	1.69± 0.00^a	1.25± 0.03^a	1.37± 0.03^a	1.71± 0.04^a

Values in the column showing different letters are significantly different at P< *0.05***.**

Table 6. Aerobic count of tarts produced from broccoli sprouts powder

Treatment	0 Day	7 Day	14 Days	21 Days	Means
T_0	1.41±0.04^i	5.44±0.20^{ef}	6.49±0.20^b	7.15±0.10^a	5.12±2.23^a
T_1	1.03±0.03^{ij}	4.95±0.07^{fg}	6.12±0.09^{bcd}	6.42±0.15^{bc}	4.63±2.15^b
T_2	0.99±0.02^{ij}	4.87±0.10^g	5.96±0.06^{cd}	6.04±0.06^{bcd}	4.47±2.05^c
T_3	0.86±0.03^j	4.65±0.06^g	5.46±0.30^e	5.74±0.12^{de}	4.18±1.96^c
T_4	0.74±0.03^j	3.33±0.20^h	4.74±0.08^g	5.46±0.13^e	3.57±1.80^d
Means	1.01±0.23^d	4.45±0.59^c	5.76±0.61^b	6.16±0.59^a	

Values in the column showing different letters are significantly different at P< *0.05.*

Table 7. Mold count of tarts produced from broccoli sprouts powder

Treatment	0 Day	7 Day	14 Days	21 Days	Means
T_0	6.02±0.02[fg]	6.73±0.13[cd]	7.15±0.13[b]	7.61±0.26[a]	6.88±0.59[a]
T_1	5.21±0.08[h]	6.12±0.09[efg]	6.48±0.09[de]	6.96±0.06[bc]	6.19±0.64[b]
T_2	4.97±0.02[h]	5.84±0.12[g]	6.34±0.09[def]	6.43±0.14[de]	5.89±0.58[c]
T_3	4.56±0.05[i]	5.05±0.04[h]	5.99±0.02[fg]	6.28±0.19[ef]	5.47±0.69[d]
T_4	4.03±0.03[j]	5.00±0.02[h]	5.07±0.11[h]	5.79±0.08[g]	4.97±0.62[e]
Means	4.96±0.66[d]	5.75±0.66[c]	6.20±0.68[b]	6.61±0.62[a]	

Values in the column showing different letters are significantly different at P< *0.05.*

Table 8. Stability of tarts produced from broccoli sprouts powder

Treatment	0 Day	7 Day	14 Days	21 Days	Means
T_0	0.98±0.005 [a]	0.97±0.008 [ab]	0.95±0.005 [abc]	0.93±0.008 [b-e]	0.96±0.02 [a]
T_1	0.97±0.008 [ab]	0.94±0.012 [bcd]	0.93±0.012 [cde]	0.89±0.017 [def]	0.93±0.03 [b]
T_2	0.95±0.012 [abc]	0.90±0.012 [def]	0.88±0.012 [fg]	0.87±0.008 [fg]	0.90±0.03 [c]
T_3	0.93±0.008 [cde]	0.89±0.012 [ef]	0.88±0.012 [fg]	0.86±0.012 [fg]	0.89±0.03 [c]
T_4	0.90±0.008 [def]	0.88±0.012 [fg]	0.87±0.008 [fg]	0.85±0.012 [g]	0.87±0.02 [d]
Means	0.94±0.03[a]	0.91±0.03 [b]	0.90±0.03 [c]	0.88±0.03 [d]	

Values in the column showing different letters are significantly different at P< *0.05.*

Table 9. pH of tarts produced from broccoli sprouts powder

Treatment	0 Day	7 Day	14 Days	21 Days	Means
T_0	6.79±0.01[a]	6.74±0.01[ab]	6.75±0.01[ab]	6.72±0.01[b]	6.75±0.03[a]
T_1	5.71±0.03[c]	5.72±0.01[c]	5.68±0.02[cd]	5.66±0.01[cde]	5.69±0.02[b]
T_2	5.64±0.02[def]	5.65±0.02[def]	5.62±0.02[efg]	5.63±0.02[def]	5.63±0.01[c]
T_3	5.64±0.02[def]	5.63±0.01[def]	5.61±0.01[efg]	5.59±0.01[fg]	5.61±0.02[c]
T_4	5.57±0.02[gh]	5.53±0.02[hi]	5.53±0.01[hi]	5.50±0.01[i]	5.53±0.03[d]
Means	5.87±0.46[a]	5.85±0.45[ab]	5.84±0.46[bc]	5.82±0.45[c]	

Values in the column showing different letters are significantly different at P< *0.05.*

Table 10. Sensory characteristics of tarts produced from broccoli sprouts powder

Treatment	T_0	T_1	T_2	T_3	T_4
Creamy Color	8.43±0.33[a]	7.80±0.29[b]	6.63±0.29[bc]	5.73±0.17[c]	5.03±0.21[d]
Green Color	0.00±0.00[e]	5.27±0.21[d]	6.48±0.08[c]	7.43±0.33[b]	8.35±0.19[a]
Grassy odour	0.00± 0.00[e]	5.30± 0.22[d]	6.23± 0.21[c]	7.37± 0.25[b]	8.13± 0.21[a]
Broccoli Odour	0.00± 0.00[e]	5.43± 0.17[d]	6.30± 0.29[c]	7.23± 0.21[b]	8.10± 0.16[a]
Broccoli flavour	0.00± 0.00[e]	5.40± 0.22[d]	6.20± 0.16[c]	6.87± 0.17[b]	7.77± 0.21[a]
Sweet flavour	8.00± 0.16[a]	7.07± 0.21[b]	6.33± 0.17[c]	5.80± 0.16[c]	5.10± 0.22[d]
Grassy flavour	0.00± 0.00[d]	6.27± 0.17[c]	7.43± 0.25[b]	8.10± 0.16[a]	8.53± 0.21[a]
Adhesiveness	4.43±0.21[c]	5.77±0.12[b]	6.13±0.12[b]	6.67±0.12[a]	7.07±0.12[a]

Hardness	7.03± 0.17[a]	6.72± 0.05[b]	6.63± 0.08[bc]	6.40± 0.08[c]	6.30± 0.08[d]
Aftertaste	5.23± 0.12[d]	6.17± 0.17[c]	6.47± 0.12[bc]	6.77± 0.12[ab]	7.07± 0.12[a]

Values in the column showing different letters are significantly different at P< *0.05.*