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# Utilization of Tomato and Strawberry Processing By-Products in The Production of Health-Beneficial Bakery Products

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## ABSTRACT

Tomato pomace is the leftover by-product from processing tomatoes into juice, sauce, and paste. It includes peels, seeds, pulp, stems, and other plant parts. Similarly, strawberry pomace is the byproduct from processing strawberries for juice, jam, or puree. Strawberry pomace powder (SPP) and tomato peel powder (TPP) are rich in dietary fiber, antioxidants, and bioactive compounds, offering various health benefits. This study sought to ascertain how the addition of TPP or SPP affected the technological, nutritional, and chemical properties of biscuits, crackers, and rusks. We substituted the wheat flour (72%) with TPP and SPP at 10, 20, 30, and 40% (w/w) ratios. Following prepare and bake the final products. Total dietary fibers, total phenolics, total flavonoids, Mg, Ca, and K levels, and antioxidant activity values were significantly increased ($p < 0.05$) with the addition of TPP or SPP. Hardness, cohesiveness, polyphenol content, and antioxidant capacity also rose when TPP and SPP concentrations rose, but water activity fell. The addition of SPP also intensified the sweetness of the cookies, indicating that the biscuits develop a flavor enhancer role while crackers and rusks have a bitter taste. Based on the sensory and compositional characteristics, it was detected that 20 % and 30% of TPP or SPP substitutions may be used to enhance biscuits, crackers, and rusks quality. In addition, they are a good source of anthocyanin, lycopene, and dietary fiber

***Keywords:*** Tomato peel powder, Strawberry pomace powder, Antioxidant, texture profile analysis, Sensory analysis

## 1. Introduction

Fruits and vegetables are the most commonly wasted food, accounting for over 30% of the food produced for human consumption each year, according to the Food and Agriculture Organization (Kultys and Moczkowska-Wyrwisz 2022). Food waste has become an important global problem that impacts not only the economy but also the environment and public health, especially when it comes to fruits and vegetables, which are highly perishable and prone to quality loss at every stage of manufacturing, resulting in significant losses while being a valuable source of biologically active chemicals (Kaur *et al.,* 2022). Nonetheless, there is a lot of potential for use of waste generated during the processing of fruits and vegetables, such as the pomace from the production of juice, which contains high concentrations of advantageous bioactive compounds. As stated in the Sustainable Food Production and Consumption Goals of the 2030 Sustainable Development Agenda, food waste needs to be addressed, particularly with regard to fruit and vegetable waste. Food waste has a major influence on the environment, society, and economy (Manuel, 2023).

Among vegetable crops, tomatoes (*Lycopersicon esculentum L.*) are the second most important crop worldwide. In the world, tomatoes are one of the most widely produced crops. It is a nutritional component that humans must consume, and its production is constantly expanding. FAOSTAT (2021)

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reports a steady shift in tomato production from 1980.It produced over 189 million tons of tomatoes in 2021. Global output is expected to surpass 222 million tons by 2030, according to the predicted growth rate (3.22) from 1980 to 2020. Navarro-González *et al.,* (2011) state that an estimated one-third of all tomatoes are processed annually. Tomato pomace is the by-product left over after the processing of tomatoes for products like juice, sauce, ketchup, or paste. It is composed of various parts of the tomato that are discarded during processing. The key components of tomato pomace include Peels: The skin of the tomato is often separated during processing. It makes up a significant portion of the pomace. Seeds: The seeds are another major component, which are usually removed during juicing or sauce-making. Pulp: the leftover pulp or flesh, which may still contain some of the juice and pulp fibers and. Stems and Other Minor Parts: In some cases, small pieces of the stem or other plant parts may be included in the pomace, though they are typically minimal. Tomato pomace is rich in dietary fiber, antioxidants, and other bioactive compounds and is often used in animal feed, as a source of fiber in human food products, or as a base for making tomato powder. It can also be processed for its potential health benefits, such as its lycopene content, which has antioxidant properties. A wet by-product of processing tomatoes in an industrial setting is tomato pomace. This latter comprises peel, pulp, and seeds and accounts for around 5-30% (w/w) of the original raw material (Saini *et al.,* 2018). In light of this, food companies worldwide generate 5.4 to 9.0 million tons of tomato pomace each year (Lu *et al.,* 2019). Previous studies have shown that tomato peel is one of the primary food sources of carotenoids, mainly ß-carotene and lycopene, which can be up to five times more plentiful in tomato peel than in tomato flesh (Szabo *et al.,* 2018), especially in ripened tomatoes. Actually, throughout the ripening stage, several physiological activities occur, including the synthesis and storage of flavonoids, mainly rutin, kaempferol-3-rutinoside, and naringenin chalcone, as well as carotenoids. These phytochemicals mostly accumulate in the tomato peel, where they serve as molecules that offer defense against biotic and abiotic stresses, because their production pathway is not active in the fruit flesh (Ballester *et al.,* 2009). Several studies have attempted to use tomato peel and pomace waste as functional ingredients to produce nutritionally enhanced and value-added foods such as bread, pasta, sausages, and cookies with higher levels of dietary fiber and minerals, antioxidant activity, and carotenoid content (Szabo *et al.,* 2018).

One berry that is very well-liked is the strawberry (*Fragaria ananassa*). Europe produces more than half of the world's strawberries, with Poland, Serbia, Germany, Ukraine, and Italy leading the pack (Tumbas Šaponjac *et al.,* 2015). The manufacturing of strawberry-based products generates a lot of agro-waste. Numerous technical waste management solutions are required to address this environmental problem in the generating locations. The industrial strawberry press cake, which is left over after juice processing, makes up around 4% of the raw material's initial weight, according to Sójka *et al.,* (2013). Recovering, recycling, and upgrading wastes that can be turned into a range of products—including bio-fuels, multipurpose food ingredients, nutrients, food flavors, fodder, feed, and operational supplies like bio-adsorbents for waste water treatment has received a lot of attention lately (Laufenberg *et al.,* 2003). However, there is a notable phenolic concentration in strawberry pomace (Amatori *et al.,* 2016). Strawberry pomace is the by-product left after processing strawberries, such as for making juice, jam, puree, or other strawberry-based products. It consists of the parts of the strawberry that are not used in the final product. The key components of strawberry pomace include peels, seeds, pulp, stems, and leaves. Strawberry pomace is rich in dietary fiber, antioxidants, vitamins, and other bioactive compounds and is sometimes used in animal feed, as a natural food additive, or for creating products like strawberry powder or jam. It can also be used as a source of dietary fiber or in composting. Therefore, it is believed that strawberry pomace contains polyphenols with antioxidant activity that could be used as functional food additives (Volf and Popa, 2004). Vitamins, proteins, lipids, carbohydrates, pectins, and fiber are all abundant in pomace. In addition to its nutritional advantages, dietary fiber offers technological and practical applications (Djilas *et al.,* 2009).

The aim of the present study is to enhance the levels of dietary fiber, total polyphenols, and antioxidant activity in rusks, crackers, and biscuits by using tomato peel and strawberry pomace, a by-product of the tomato and strawberry industries. To do this, we assessed the technological, nutritional, and sensory attributes of our products which were checked at four distinct substitution levels (10, 20, 30, and 40%) each.

## 2. Materials and Methods

### 2.1. Methods

Tomato pomace and strawberry pomace, two by-products from the tomato concentrate and strawberry juice that were a combination of cultivars from the 2020 season, were gathered from P&J for Juice and Paste. A market leader in tomato paste and fruit pulp production. Sadat city, Menoufia, Egypt. Wheat flour (72% ex.) was purchased from the local market at Cairo, Egypt.

### 2.2. Raw materials

10 kg of strawberry pomace were dried in a hot-air drying oven for 24 hours at 50 ºC (resulting in 4.7 kg), and the pomace was followed by sieves using an Analysette 3 sifter and grinding in a food mill to a powder consistency. The powder was stored in a deep freezer at -18 ºC for storage.

10 kg of tomato pomace was dried in an oven at 50 ºC for 24 hours, until the moisture content was below12%. The dried pomace (4.9kg) was passed through sieves with a 2- and 5-mm mesh diameter using an Analysette 3 sifter to separate seeds, and the peel was followed by grinding and powder after that, kept in polyethylene bags, and stored at -18 ºC until used (tomato peel powder TPP).

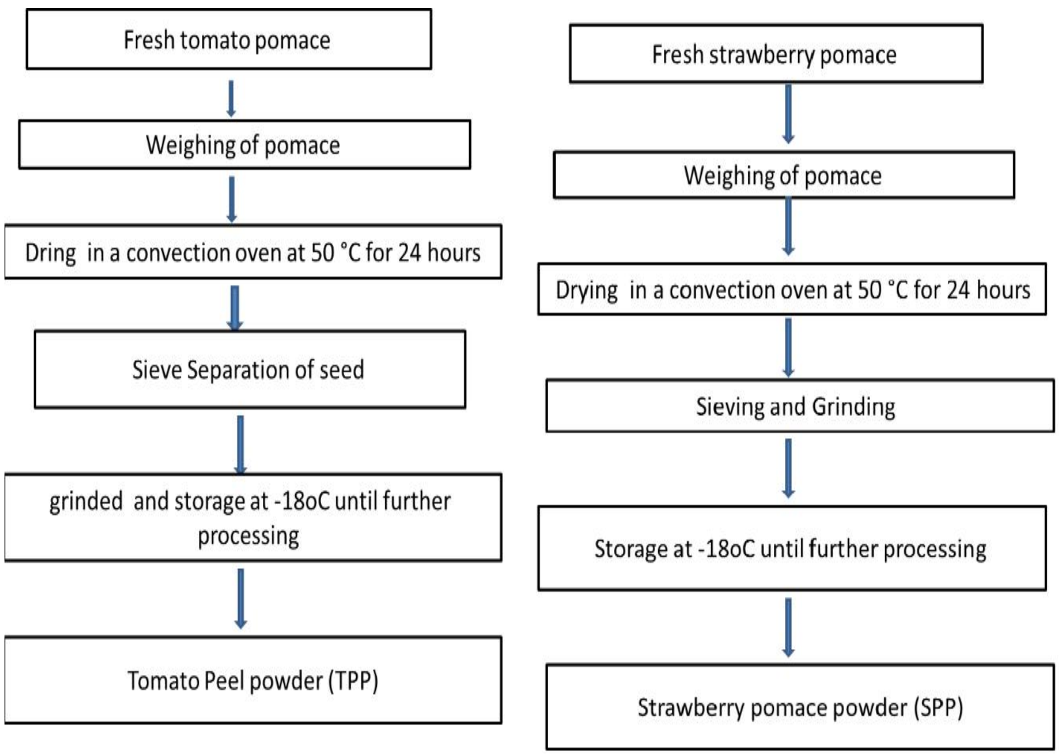


**Fig. 1:** Sample preparation flow chart.

#### 2.2.1. Preliminary formulation

Preliminary palatability tests were conducted to determine the optimal taste ratio and the possibility of conjugation to an acceptable sensory ratio of TPP and SPP for biscuits, crackers, and rusk. For biscuits, rusks, and crackers, this combination includes TPP (10, 20, 30, and 40%) and SPP (10, 20, 30, and 40%) (results not reported). The study employed acceptable ratios of SPP in conjunction with biscuits (10, 20, 30, and 40% SPP) and rusks and crackers (10, 20, 30, and 40% TPP) to achieve the sensory characteristics.

#### 2.2.2 Preparing biscuits

The wheat (72% ex.) flour and SPP ratios that were used to make the composite biscuits were 100:0 (control biscuit), 90:10, 80:20, 70:30, and 60:40, respectively. Ingredients for the biscuit formulation included 500 g wheat flour, 40 mL sunflower oil, and 250 mL water. After two minutes of kneading, the cohesive dough was rolled to a thickness of 2 mm using a rolling pin, and it was then cut using a square plastic frame. The dough pieces were carefully placed on a baking pan lined with buttered, baked for 30 minutes at 160 ±2 ºC in a preheated oven, and then allowed to cool for a further 30 minutes at room temperature. The biscuits were stored at 4±2 ºC and were sealed in thick, airtight zip-seal food bags before being placed in low-density polyethylene bags (Nabil *et al.,* 2020).

**2.2.3. Preparing crackers**

Crackers were prepared using Han *et al.,* (2010) process with a few modifications. The formulations were changed to contain 10, 20, 30, and 40% of TPP. The crackers with 0% TPP were used as control crackers. Among the ingredients used in the cracker formulation were corn starch (50 g), wheat flour 72% (450 g), corn oil (75 g), sugar (17.5 g), salt (5.5 g), and baking powder (5 g). To make the dough, the liquid and dry ingredients were mixed together for three to four minutes. After ten minutes of rest, the dough was sheeted and laminated three times via a set of revolving, smooth stainless-steel drums. The dough sheet was then cut into crackers that were square in shape. Crackers were baked at 200°C for 10 minutes in a convection oven. The crackers were baked for an additional two minutes, with forced air circulation and the heat turned off. This process simulated the drying and cooling stages of a tunnel-shaped professional baking oven. Subsequently, the baked crackers were removed from the oven and allowed to reach room temperature.

**2.2.4. Rusk preparation**

The process described by Filipovic *et al.,* (2012) to make rusks. At levels 10, 20, 30, and 40%, TPP was substituted instead of wheat flour, accordingly. The rusk with no TPP was the control rusk. A mixture of 500 g wheat flour/TPP blends, 80 g sunflower oil, 80 g sugar, 4 g salt, 16 g yeast, and water was used to produce the dough. The dough was then mixed in a room-temperature mixer set to speed 2 for three minutes. The dough was completely mixed for approximately two minutes at speed 2 and one minute at speed 4. It was then covered with a plastic sheet and allowed to rest for five minutes at room temperature. The dough was then carefully sliced into tiny, round pieces. Slice the dough into pieces that are 9 cm thick. Baked at 200 ºC for approximately ten minutes, or until light brown, using the standard baking procedure. Before being used for the analysis, it was put in low-density polyethylene bags and allowed to cool to room temperature.

**2.3. The Proximate composition analysis and energy value**

The composition of raw materials and products, including their moisture, fat, and protein, and ash was evaluated (AOAC, 2005). To calculate carbohydrates, the difference calculation approach was applied. The energy value was calculated on DW, using the Atwater factor, as follows:

Energy value (Kcal) = (%Protein×4) + (%Fat×9) + (% Carbohydrate×4). The energy value was also multiplied by 4.184 to get the result in kilojoules in accordance with Prosky *et al.* (1984), the total dietary fiber content has been determined.

**2.4. Water activity (WA)**

Measurements of water activity (WA) were obtained with an Aqua Laboratory device (AQUALAB 4TE, Pullman, USA). Our product was partially poured into the sample plastic cups before being put in the measurement chamber. WA readings were instantly captured from the digital display at room temperature.

**2.5 Mineral determination**

The amount of minerals was examined. Agilent Technologies, Inc. (2021) states that a microwave digestor (Multiwave GO Plus 50 HZ) was utilized before the samples were subjected to spectrophotometric analysis by MPAES4210 (Microwave Plasma Atomic Emission Spectroscopy) (Agilent, Mulgrave, Victoria, Australia).

**2.6. Organoleptic evaluation of products:**

Organoleptic evaluation of rusk, crackers, and biscuits was done in comparison to a control group that didn't contain any SPP or TPP. Three different product baking types, each with four different TPP or SPP concentrations, were displayed on the panel. A panel of semi-trained judges, comprising female and male members of the Food Technology Research Institute, Egypt (n = 50; age range: 25–60 years), completed the evaluation. A nine-point hedonic scale was used to measure character traits (Agrahar-Murugkar and Jha, 2011).

Furthermore, the sensory evaluation was finished in compliance with Regulation No. 1924/2006. None of the panelists indicated having any food allergies, and they were all aware of the product's components.

**2.7. Determination of lycopene**

The method of Rao *et al.* (1998) was used to determine the lycopene content (mg/100 g) in our new products (rusk and cracker fortified with TPP and control without TPP). The 500 mg of homogenized samples were utilized. 5 mL of 2.5% butylated hydroxytoluene with a 2:1:1 ratio of hexane, methanol, and acetone was combined with the homogenate. The measured pectrophotometer (Labomed, Inc., Los Angeles, CA, USA) with a wavelength of 472 nm.

**2.8. Analysis of anthocyanins**

Anthocyanin in the new products (the crackers, biscuits, and rusk fortified % TPP or SPP) and control items were extracted using 1.5 N. HCL and 85 mL of 95% ethanol. Lee *et al.* (2005) reported that the color of the clear extract was measured at 510 and 700 nm.

**2.9. Analyses Physicochemicals**

**2.9.1 Color analysis**

By mixing each product sample, a homogenous sample was produced. Every sample was subjected to five measurements using the Konica Minolta CR-400 chromameter (Pathare *et al.,* 2013). The $L^*$ value in the color system represents the degree of lightness, with 0 indicating total darkness and 100 indicating total lightness. The green versus red and yellow versus blue intensities were measured in the range of 0 to 100 and -100 to 0, respectively, by the $a^*$ and $b^*$ values. Furthermore, the formula is used to estimate the delta E (ΔE), which represents the color difference.

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

**2.9.2 Analyses of Texture Profiles (TPA).**

Texture analyzer (Stable Micro System Ltd., Scarsdale, NY) was used to examine the texture of the rusk, crackers, and biscuits. A set of three cookies were chosen, and their center and two side points were measured. Analysis of texture was done three hours after baking. The information was recorded and Texture Expert Version 1.22 Software (Stable Micro System Ltd., Scarsdale, NY) was used to analyze the texture profile. The test parameters were as follows: a trigger force of 5.0 g, a target value of 4 mm (the distance reached by the test piece in the sample), and a total of 2 cycles at a speed of 2 mm/s. According to Bourne (2002), the texture, hardness (N), adhesiveness (mj), cohesiveness, springiness (mm), gumminess (N), resilience (%) and chewiness (mj) were calculated. Hardness (the peak maximum force on the first compression, N), Cohesiveness (the ratio of positive areas in the two compression cycles representing the work required to compress the food again as compared with that which was necessary to compress it for the first time, dimensionless), Springiness (the height that the food recovers after the first compression), and Chewiness (the product of hardness × cohesiveness × springiness) were the parameters that were evaluated. The product of the down stroke energy of the initial compression (Area 3) and the upstroke energy (Area 4) determines resilience. For every treatment, at least three measurements were made, and the averages were reported.

**2.10. Phytochemical extraction**

**2.10.1. Extraction of active compounds**

Using the Collar *et al.* (2014) method, the phytochemical components of the raw material and our new products were extracted. The following method was used to create the methanol extract: A combination was centrifuged for 10 minutes at 3000 rpm (Sigma 3–18 K, Osterode and Harz, Germany) after 1 gram of each sample product was combined with 10 mL of an 80:20 MeOH and water mixture, homogenized with 1% HCl, and stored at 4°C for 24 hours. During the analysis, the recoverable supernatants were collected and stored at -20°C in the dark.

**2.10.2. Total phenolic content (TPC)**

Using the Singleton *et al.,* (1999) approach, the TPC in the previously collected supernatant was assessed. The steps were as follows: 0.1 mL of the Folin-Ciocalteu phenol reagent (1:1), 1.5 mL of distilled water, and 0.1 mL of the sample or the standard dilutions (100–500 µg/mL) were combined. This was homogenized for five minutes, and then 0.3 mL of a 20% $Na_2CO_3$ solution was vortexed. The following sixty minutes were spent at room temperature and out of the light. Finally, each solution at 740 nm was examined in respect to an acidified methanol blank using a Spectro 23 digital spectrophotometer (Labomed, Inc., Los Angeles, California, USA). Three repeats of the experiment were conducted. Gallic acid equivalents (GAE) were calculated as mg / 100 g of dry weight using a standard curve of 25–2500 mg/L.

**2.10.3. Total flavonoids content (TFC)**

Zhishen *et al.,* (1999) used their colorimetric method to determine TFC.1 mL of extract solution was mixed with four milliliters of distilled water. The latter mixture was supplemented with a 0.3 mL solution of 5% $NaNO_2$. 0.3 milliliters of 10% $AlCl_3$ were added after five minutes. 2 mL of 1 M NaOH were added after six minutes. Dist. $H_2O$ was then added to bring the total amount to 10 mL, and everything was thoroughly mixed. The absorbance of solutions at 510 nm was measured in comparison to a newly prepared blank. mg of quercetin equivalent per 100g of dry matter, or mg QE/100g, was used to express the TFC. The mean of three replicates was used to represent the results.

**2.10.4. Antioxidant activity (AOX):**

The antiradical activity of the raw components and the baking of our products were measured using the methodology outlined by Sánchez-Moreno *et al.,* (1998). Thus, 3.9 mL of DPPH (1,1-diphenyl-2-picryl hydrazyl, 0.025/L methanol) was mixed with 0.1 mL of each extracted sample. The absorbance was measured at 515 nm using a Vis spectrophotometer against a blank after mixing and storing for 15 minutes in a dark place. The scavenging activity was computed as a percentage of inhibition for each sample. The concentration ranges of trolox, which was used as the standard, was 0.50 to 5.0 mM. Calibration curves were used to quantify the antiradical activity, and they showed good linearity (R2 ≥ 0.998). Milligrams (mg TE/100 g) of Trolox equivalents (TE) per 100 g of material were used to express the results.

**2.10.5. HPLC determination of phenolic and flavonoid components of raw materials and products**

The standards of phenolic and flavonoid components were obtained from Sigma-Aldrich (USA). After homogenizing 2.5 g of the sample with 20 mL of 70% (v/v) HPLC-grade methanol, it was allowed to stand at room temperature in an ultrasonic bath for an hour in order to aid in the extraction process. This was done in order to determine the phenolic compound profile of TPP, SPP, rusk, crackers, biscuit control, or fortified with 20% TPP or SPP via chromatography (Mattila *et al.,* 2000). Centrifuging each extract at 8.832 × g for 15 minutes at 4 °C, it was then filtered through filter paper. The phenolic compounds were estimated using gradient elution with a mobile phase of solvent A (2% acetic acid) and solvent B (0.5% acetic acid: acetonitrile (1:1)). For flavonoids, gradient elution was performed with a mobile phase of solvent A (2% acetic acid) and solvent B (methanol). The flow rate was 1 mL/min. UV absorption was measured at nm 280 (phenolic)-330 (flavonoid) Phenolic compounds were identified and quantified by comparing them to a standard sample in terms of retention duration and peak area. The results were expressed as mg/100 g of sample.

**2.11. Statistical analyses**

The statistical analysis system, SPSS, was used to evaluate the related results statistically (2017). The significance of the difference at p<0.05 was determined using Duncan's multiple range analysis. The significance is indicated by different superscript series (e.g., a, ab, b,.. z). To ascertain the relationship between different parameters, Excel was utilized.

## 3. Results

The raw materials' composition (strawberry pomace powder, tomato peel powder, and wheat flour) was determined by chemical analysis and can be seen in the Table 1. Strawberry pomace powder had the highest fat level (12.60%), whereas wheat flour had the lowest fat content (2.37%). TPP and SPP showed higher protein contents, whereas wheat flour had the lowest. Furthermore, SPP had the greatest ash content and wheat flour the lowest. TPP and SPP had the highest percentage of dietary fiber, whereas wheat flour had the lowest percentage (Table 1). Additionally, the tomato peel and strawberry pomace used in our study had moisture percentages (wet basis) of 72% and 77.33%, respectively. Consequently, there is a high chance that these products will cause microbial growth. For this reason, a lot of things need to be dried before being stored for subsequent use. The Table (1) displays the mineral composition of tomato peel powder, strawberry pomace powder, and wheat flour. TPP and SPP are good sources of vitamins and certain mineral elements, some of which have antioxidant qualities. Our data revealed the highest concentrations of Ca, Mg, Zn, and Cu in TPP. Strawberry pomace powder also had the highest concentrations of P, Fe, and Mn. These results show that TPP could be considered a good source of Mg, and Ca, Zn, and Cu and SPP also a good source of P, Fe, and Mn. In addition, this property is interesting from a nutritional point of view, because TPP and SPP could be used as a food supplement.

**Table 1:** Pomace and wheat flour proximate analysis was used in the study.

| Parameters | Tomato peel powder (TPP) | Wheat flour | Strawberry pomace powder (SPP) |
|---|---|---|---|
| **Ash (%)** | $3.52^{b}\pm0.47$ | $0.88^{c}\pm0.28$ | $4.72^{a}\pm0.46$ |
| **Protein (%)** | $19.08^{a}\pm1.54$ | $12.70^{b}\pm1.32$ | $18.37^{a}\pm0.95$ |
| **Fat (%)** | $7.98^{b}\pm0.56$ | $2.37^{c}\pm0.46$ | $12.60^{a}\pm1.39$ |
| **Total dietary fiber (%)** | $35.14^{a}\pm3.27$ | $1.22^{b}\pm0.35$ | $38.18^{a}\pm1.46$ |
| **Carbohydrate (%)** | $69.42^{b}\pm1.82$ | $84.05^{a}\pm2.01$ | $64.31^{b}\pm1.13$ |
| **Total energy (kcal/100 g)** | $425.82^{b}\pm0.92$ | $408.33^{c}\pm1.16$ | $444.12^{a}\pm5.99$ |
| **Total energy (kj/100 g)** | $1781.63^{b}\pm3.85^{b}$ | $1708.46^{c}\pm4.87$ | $1858.21^{a}\pm25.07$ |
| **K(mg/kg)** | $2426.43^{b}\pm13.38$ | $4249.47^{a}\pm76.25$ | $2679.67^{b}\pm10.33$ |
| **Ca (mg/kg)** | $3656^{c}\pm16.28$ | $656.47^{b}\pm28.34$ | $2542.67^{a}\pm22.81$ |
| **P (mg/kg)** | $3640.70^{b}\pm13.23$ | $1562.70^{c}\pm29.92$ | $4408.67^{a}\pm85.67$ |
| **Mg(mg/kg)** | $2858.40^{a}\pm16.10$ | $574.77^{c}\pm24.39$ | $1172.67^{b}\pm8.76$ |
| **Fe (mg/kg)** | $37.46^{b}\pm1.00$ | $18.96^{c}\pm0.699$ | $362.67^{a}\pm7.36$ |
| **Mn (mg/kg)** | $36.55^{b}\pm2.16$ | $20.47^{c}\pm1.28$ | $44.67^{a}\pm1.77$ |
| **Zn(mg/kg)** | $38.70^{a}\pm1.62$ | $12.23^{c}\pm0.83$ | $22.98^{b}\pm1.61$ |
| **Cu(mg/kg)** | $8.51^{a}\pm0.64$ | $3.69^{b}\pm0.41$ | $7.56^{a}\pm0.57$ |

Each value in the table was obtained by calculating the average of three triplicates, and the data are presented as mean ± Standard error of the mean within the same row. Statistical significance was accepted at the $p < 0.05$ level. The superscript letters a, b, etc. denote the significance of one parameter between tomato peel powder (TPP), Strawberry pomace powder (SPP), and wheat flour.

The addition of TPP and SPP had a significant impact on the chemical composition of biscuits, crackers, and rusks. Ash, crude protein, total dietary fiber, and mineral contents of biscuits, crackers, and rusks increased significantly ($p < 0.05$) with peel and pomace powder addition (Table 2). The reason is most likely that pomace and peel powder, which substituted wheat flour in rusk, cracker, and biscuit production, had higher ash, crude protein, total dietary fiber, and mineral contents than wheat flour. The results indicate that rusks, crackers, and biscuits exhibit significant differences when fortified with SPP or TPP in regard to ash. The high ash content of TPP and SPP resulted in higher ash content of fortified biscuits, crackers, and rusks, and this is consistent with the detailed results from the individual mineral content (Table 3). Subsequently, biscuits incorporating 30 and 40% of SPP have the highest ash content compared to other types biscuits. The results for total dietary fiber are much higher for biscuit fortified with 30 and 40% SPP and rusk and crackers fortified with 40% because the peel and pomace powder are enriched in total dietary fiber. The fat content of both TPP and SPP is considerably low and is slightly higher in rusk, crackers, and biscuits fortified with TPP or SPP, respectively. Protein and total dietary fiber contents of rusk, cracker, and biscuits fortified with TPP and SPP are higher compared to those of control products. The high protein and total dietary fiber content of TPP and SPP resulted in higher it content of fortified biscuits, crackers, and rusks.

Carbohydrates were calculated as the difference for the other compounds, and the value was markedly higher for control products. When SPP or TPP were incorporated into the rusk, cracker, and biscuit, the carbohydrate content showed statistically significant differences for each product. Carbohydrate content ranged from 58.34 to 67.62% (for biscuits fortified with SPP), from 74.43 to 82.05% (for rusks fortified with TPP), and from 64.89 to 72.71% (for crackers fortified with TPP) in new products. A decreasing trend was, in general, observed along with increasing TPP and SPP incorporation levels. This is due to the high content of complex carbohydrates such as dietary fiber in the TPP and SPP. The results show that all of our baked products fortified with TPP or SPP have high total energy compared to the control products. However, out of all the fortified samples, crackers supplemented with TPP had the highest total energy, ranging from 481.94 to 484.96 kcal/100 g. Due to crackers' high fat content is responsible for this.

It has been observed that Aw exhibits an inverse correlation with the substitution of TPP or SPP in biscuits, crackers, and rusks. Additionally, we found that our innovative items had lower water activity than the control (Figure 2).

Evaluating the mineral composition shown in the Table 3. Additionally, adding TP and SP powder to the rusks, crackers, and biscuits increased their mineral element content ($p<0.05$) in the following ways: Mg, Ca, K, P, Mn, Cu, Zn, and Fe. When 40% of the wheat flour was replaced with TPP, the mineral levels in the crackers increased to 59.22% (K), 516.8% (Ca), 179% (Zn), and 137.5% (Cu). In rusk fortified with 40% TPP, we also noticed rising levels, with a ratio of 771.75% for P and 181.97% for Mn. Lastly, a biscuit that was fortified with 40% SP had iron (Fe) content of 760.42%. According RDA by consuming 100g of cracker fortified with 20% TP, an adult female (aged 31 to 50) can consume approximately 40.22% of K, 91.69% of Ca, 216.67% of Mg, 367.70% of P, 864.81 of Mn, 182.50% of Zn, 82.96% of Fe, and 379.63% of Cu every day, according to our calculations (Figure 3).

A crucial part of describing the quality of food products is sensory analysis. Results of sensory analysis of rusks, crackers, and biscuits fortified with TPP or SPP have shown that the addition of this functional ingredient in their composition has no negative effect on sensory characteristics (Table 4). So, the analyzed products were tested by an expert panel receiving qualifying. All the products were acceptable; additionally, panelists preferred products that have color produced from addition TPP or SPP, which registered the highest score for general acceptability (overall acceptability). A number of panelists reported that rusk and crackers fortified with TPP (10, 20, 30%) had a little bitterness. Following the sensory analysis by a panel of tasters, the products received the following high scores and the qualification: control, rusk, and crackers fortified with 10 and 20% TPP. Furthermore, rusk and crackers with TPP had a natural reddish color (natural additive), which avoids the addition of other synthetic red colors.

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**Table 2:** Proximate analysis of the products fortified with tomato peel or strawberry pomace

| Products | Protein % | Fat % | Carbohydrate % | Ash % | Total dietary fiber % | Total energy (Kcal/100 g) | Total energy (kj/100 g) |
|---|---|---|---|---|---|---|---|
| **Rusk control** | 10.10$^{e}$±0.15 | 3.81$^{e}$±0.17 | 84.57$^{a}$±0.36 | 1.52$^{e}$±0.07 | 1.07$^{e}$±0.088 | 412.99$^{d}$±0.67 | 1727.94$^{d}$±2.80 |
| **Rusk +10% TPP** | 11.67$^{d}$±0.15 | 4.44$^{d}$±0.16 | 82.05$^{b}$±0.35 | 1.83$^{d}$±0.07 | 4.27$^{d}$±0.088 | 414.87$^{cd}$±0.66 | 1735.82$^{cd}$±2.77 |
| **Rusk +20% TPP** | 13.23$^{c}$±0.14 | 5.06$^{c}$±0.17 | 79.56$^{c}$±0.35 | 2.15$^{c}$±0.07 | 7.47$^{c}$±0.088 | 416.73$^{bc}$±0.66 | 1743.60$^{bc}$±2.76 |
| **Rusk +30% TPP** | 14.77$^{b}$±0.15 | 5.68$^{b}$±0.17 | 77.09$^{d}$±0.37 | 2.46$^{b}$±0.07 | 10.67$^{b}$±0.088 | 418.58$^{ab}$±0.68 | 1751.35$^{ab}$±2.79 |
| **Rusk +40% TPP** | 16.30$^{a}$±0.16 | 6.30$^{a}$±0.17 | 74.43$^{e}$±0.22 | 2.98$^{a}$±0.13 | 13.87$^{a}$±0.088 | 419.56$^{a}$±1.20 | 1755.46$^{a}$±5.04 |
| **Crackers control** | 7.61$^{e}$±0.08 | 16.83$^{c}$±0.32 | 74.30$^{a}$±0.42 | 1.26$^{d}$±0.03 | 1.17$^{e}$±0.088 | 479.09$^{b}$±1.46 | 2004.53$^{b}$±6.11 |
| **Crackers++10% TPP** | 9.15$^{d}$±0.08 | 17.40$^{bc}$±0.31 | 72.71$^{b}$±0.14 | 1.26$^{d}$±0.03 | 4.37$^{d}$±0.088 | 481.94$^{ab}$±1.43 | 2016.44$^{ab}$±5.97 |
| **Crackers+20% TPP** | 10.68$^{c}$±0.07 | 17.94$^{ab}$±0.31 | 69.51$^{c}$±0.40 | 1.88$^{c}$±0.03 | 7.57$^{c}$±0.088 | 482.17$^{ab}$±1.40 | 2017.39$^{ab}$±5.87 |
| **Crackers+30% TPP** | 12.19$^{b}$±0.09 | 18.48$^{a}$±0.31 | 67.15$^{d}$±0.41 | 2.18$^{b}$±0.03 | 10.77$^{b}$±0.088 | 483.67$^{ab}$±1.41 | 2023.67$^{ab}$±5.91 |
| **Crackers+40% TPP** | 13.65$^{a}$±0.10 | 18.97$^{a}$±0.33 | 64.89$^{e}$±0.44 | 2.48$^{a}$±0.04 | 13.97$^{a}$±0.088 | 484.96$^{a}$±1.48 | 2029.05$^{a}$±6.20 |
| **Biscuit control** | 12.66$^{d}$±0.46 | 14.78$^{c}$±0.34 | 70.54$^{a}$±0.65 | 2.02$^{e}$±0.06 | 1.98$^{d}$±0.072 | 465.80$^{c}$±1.92 | 1948.92$^{c}$±8.05 |
| **Biscuit +10%SPP** | 14.28$^{c}$±0.46 | 15.65$^{c}$±0.65 | 67.62$^{b}$±0.86 | 2.45$^{d}$±0.06 | 3.25$^{d}$±1.03 | 468.46$^{bc}$±3.42 | 1960.04$^{bc}$±14.32 |
| **Biscuit +20%SPP** | 14.86$^{c}$±0.44 | 17.18$^{b}$±0.35 | 65.03$^{c}$±0.56 | 2.93$^{c}$±0.06 | 9.05$^{c}$±0.11 | 474.20$^{ab}$±1.98 | 1984.05$^{ab}$±8.30 |
| **Biscuit +30%SPP** | 17.54$^{b}$±0.48 | 17.87$^{ab}$±0.29 | 61.22$^{d}$±0.66 | 3.37$^{b}$±0.06 | 13.01$^{b}$±0.96 | 475.89$^{ab}$±1.66 | 1991.11$^{ab}$±6.95 |
| **Biscuit +40%SPP** | 19.06$^{a}$±0.38 | 18.82$^{a}$±0.43 | 58.34$^{e}$±0.62 | 3.79$^{a}$±0.05 | 16.24$^{a}$±0.199 | 478.931$^{a}$±2.35 | 2003.85$^{a}$±9.83 |

Control: rusk, crackers, and biscuit free from TPP or SPP. rusk, crackers, and biscuit fortified with TPP or SPP. Values are expressed as means ± standard errors (a,b,c, etc.) donated the significant difference (p<0.05) between all treatments in the same column for one parameter. Means sharing similar letters within a raw are statistically nonsignificant (p > 0.05). The statistical analysis carried out for individual products with respect to each component. TPP : tomato peel powder, SPP: strawberry pomace powder.

**Table 3:** Minerals content in the products fortified with tomato peel or strawberry pomace powder

| Products | K(mg/kg) | Ca (mg/kg) | P (mg/kg) | Mg(mg/kg) | Fe (mg/kg) | Mn (mg/kg) | Zn(mg/kg) | Cu(mg/kg) |
|---|---|---|---|---|---|---|---|---|
| **Rusk control** | $6719^{d}\pm3.79$ | $1511.53^{e}\pm1.30$ | $155.49^{e}\pm2.85$ | $1236.03^{e}\pm1.13$ | $113.07^{c}\pm1.09$ | $7.82^{e}\pm0.56$ | $31.04^{d}\pm1.29$ | $8.83^{b}\pm0.40$ |
| **Rusk +10% TPP** | $6721^{d}\pm2.08$ | $1818.20^{d}\pm4.39$ | $465.49^{d}\pm8.62$ | $1446.03^{d}\pm6.90$ | $116.24^{c}\pm1.18$ | $10.95^{d}\pm0.48$ | $33.14^{cd}\pm2.15$ | $9.16^{b}\pm0.36$ |
| **Rusk +20% TPP** | $7189^{c}\pm5.57$ | $2216.53^{c}\pm4.17$ | $858.82^{c}\pm5.95$ | $1746.03^{c}\pm6.90$ | $120.07^{b}\pm1.09$ | $14.72^{c}\pm0.58$ | $38.043^{bc}\pm1.37$ | $9.26^{ab}\pm0.34$ |
| **Rusk +30% TPP** | $7417.33^{b}\pm1.45$ | $2518.2^{b}\pm5.71$ | $1160.49^{b}\pm4.94$ | $2050.67^{b}\pm8.97$ | $123.07^{b}\pm0.52$ | $18.08^{b}\pm0.55$ | $41.54^{ab}\pm1.23$ | $9.73^{ab}\pm0.20$ |
| **Rusk +40% TPP** | $7629^{a}\pm8.02$ | $2762.53^{a}\pm85.34$ | $1355.49^{a}\pm2.85$ | $2245.67^{a}\pm3.93$ | $127.24^{a}\pm1.43$ | $22.05^{a}\pm0.52$ | $45.54^{a}\pm1.23$ | $10.26^{a}\pm0.36$ |
| **Crackers control** | $1480.37^{e}\pm7.88$ | $206.40^{e}\pm4.05$ | $1865.60^{e}\pm3.42$ | $178.33^{e}\pm4.41$ | $8.13^{e}\pm0.41$ | $9.07^{e}\pm0.35$ | $8.10^{e}\pm0.38$ | $2.40^{d}\pm0.21$ |
| **Crackers++10% TPP** | $1685.37^{d}\pm5.19$ | $519.73^{d}\pm7.43$ | $2180.60^{d}\pm0.60$ | $441.67^{d}\pm39.19$ | $11.23^{d}\pm0.35$ | $12.23^{d}\pm0.30$ | $10.93^{d}\pm0.23$ | $3.07^{c}\pm0.19$ |
| **Crackers+20% TPP** | $1890.37^{c}\pm2.91$ | $916.40^{c}\pm8.21$ | $2573.93^{c}\pm6.99$ | $693.33^{c}\pm4.41$ | $14.93^{c}\pm0.54$ | $15.57^{c}\pm0.54$ | $14.60^{c}\pm0.67$ | $3.42^{c}\pm0.19$ |
| **Crackers+30% TPP** | $2170.37^{b}\pm10.76$ | $1193.07^{b}\pm10.53$ | $2855.60^{b}\pm8.23$ | $930^{b}\pm60.07$ | $17.33^{b}\pm0.22$ | $18.57^{b}\pm0.07$ | $17.93^{b}\pm0.52$ | $4.53^{b}\pm0.12$ |
| **Crackers+40% TPP** | $2357.03^{a}\pm46.03$ | $1273.07^{a}\pm29.62$ | $3148.93^{a}\pm17.30$ | $1296.67^{a}\pm11.67$ | $21.63^{a}\pm0.70$ | $22.57^{a}\pm0.54$ | $22.60^{a}\pm0.31$ | $5.70^{a}\pm0.06$ |
| **Biscuit control** | $3490^{d}\pm5.77$ | $1290^{e}\pm5.78$ | $400.50^{e}\pm3.33$ | $986.67^{e}\pm8.82$ | $16.00^{e}\pm0.58$ | $18.20^{e}\pm0.76$ | $10.17^{c}\pm0.60$ | $4.60^{b}\pm0.21$ |
| **Biscuit +10%SPP** | $3576.67^{d}\pm86.86$ | $1453.33^{d}\pm76.88$ | $811.30^{d}\pm2.89$ | $1083.67^{d}\pm8.99$ | $43.67^{d}\pm1.76$ | $22.20^{d}\pm0.74$ | $11.87^{c}\pm0.54$ | $5.10^{bc}\pm0.23$ |
| **Biscuit +20%SPP** | $4000^{c}\pm5.77$ | $1790^{c}\pm5.77$ | $1193.83^{c}\pm4.53$ | $1196.67^{c}\pm8.82$ | $77.67^{c}\pm1.76$ | $25.70^{c}\pm0.96$ | $13.90^{b}\pm0.55$ | $5.60^{b}\pm0.23$ |
| **Biscuit +30%SPP** | $4280^{b}\pm10$ | $2013.33^{b}\pm6.67$ | $1419.33^{b}\pm6.43$ | $1295^{b}\pm7.64$ | $104.33^{b}\pm4.26$ | $29.20^{b}\pm0.61$ | $16.33^{a}\pm0.17$ | $6.47^{a}\pm0.23$ |
| **Biscuit +40%SPP** | $4470^{a}\pm17.32$ | $2200^{a}\pm5.77$ | $1950.50^{a}\pm25.55$ | $1396.67^{a}\pm8.82$ | $137.67^{a}\pm4.06$ | $33.20^{a}\pm1.11$ | $18.00^{a}\pm0.87$ | $6.73^{a}\pm0.15$ |

Control: rusk, crackers, and biscuit free from TPP or SPP. Values are expressed as means ± standard errors (a,b,c, etc.) donated the significant difference ($p<0.05$) between all treatments in the same column for one parameter. Results are expressed as the mean of trireplicates. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$). The statistical analysis carried out for individual products with respect to each component. TPP : tomato peel powder, SPP: strawberry pomace powder.

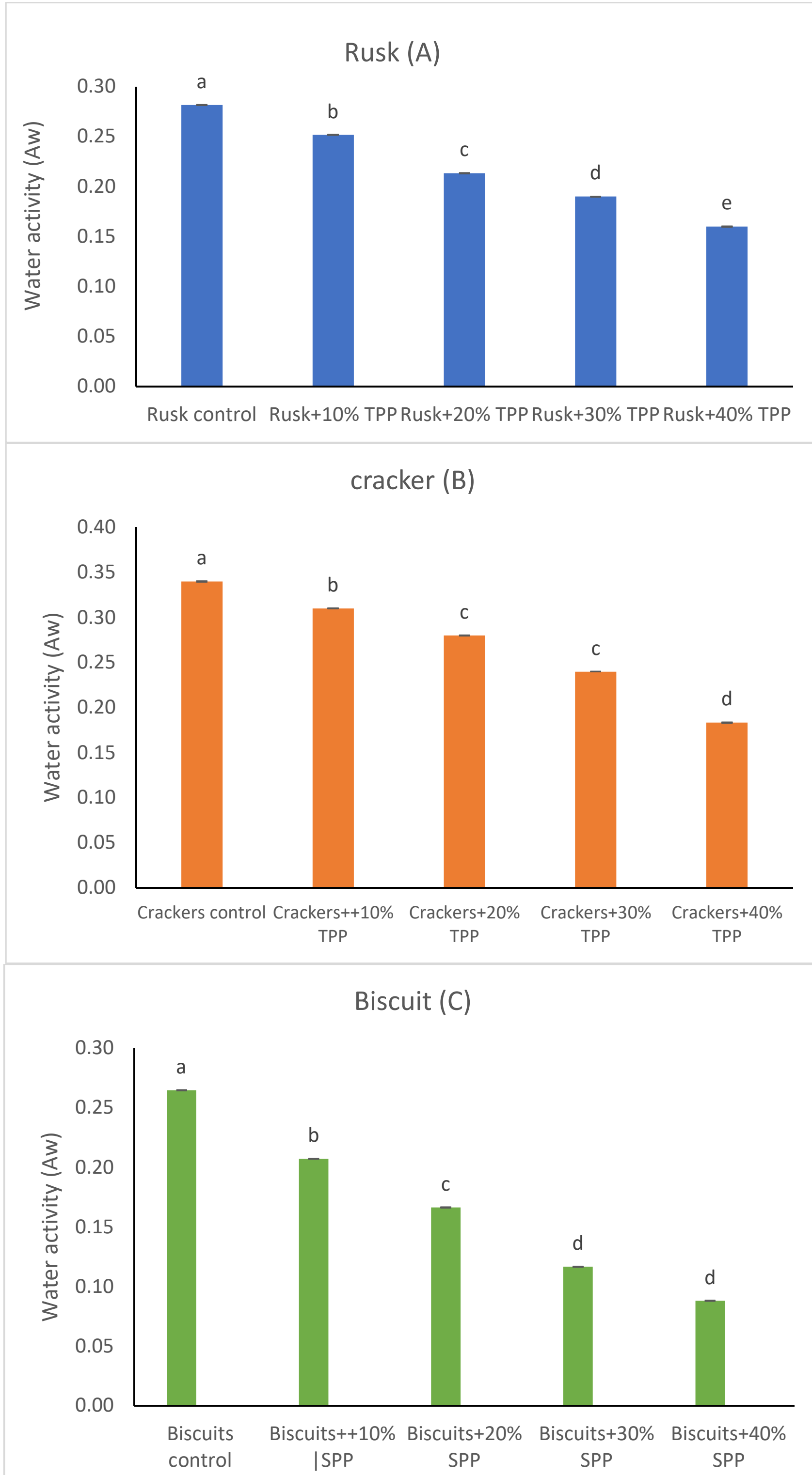


**Fig. 2:** Water activity covered by each Control: rusk, crackers, and biscuit free from TPP or SPP. rusk, crackers, and biscuit fortified with TPP or SPP. Results are expressed as the mean of three replicates. Significant differences ($p < 0.5$) are shown by (a, b, c, etc.) between products types in the same parameter. Water activity in rusks, crackers, and biscuits was indicated by A, B, and C, respectively. TPP : Tomato peel powder, SPP: Strawberry pomace powder.

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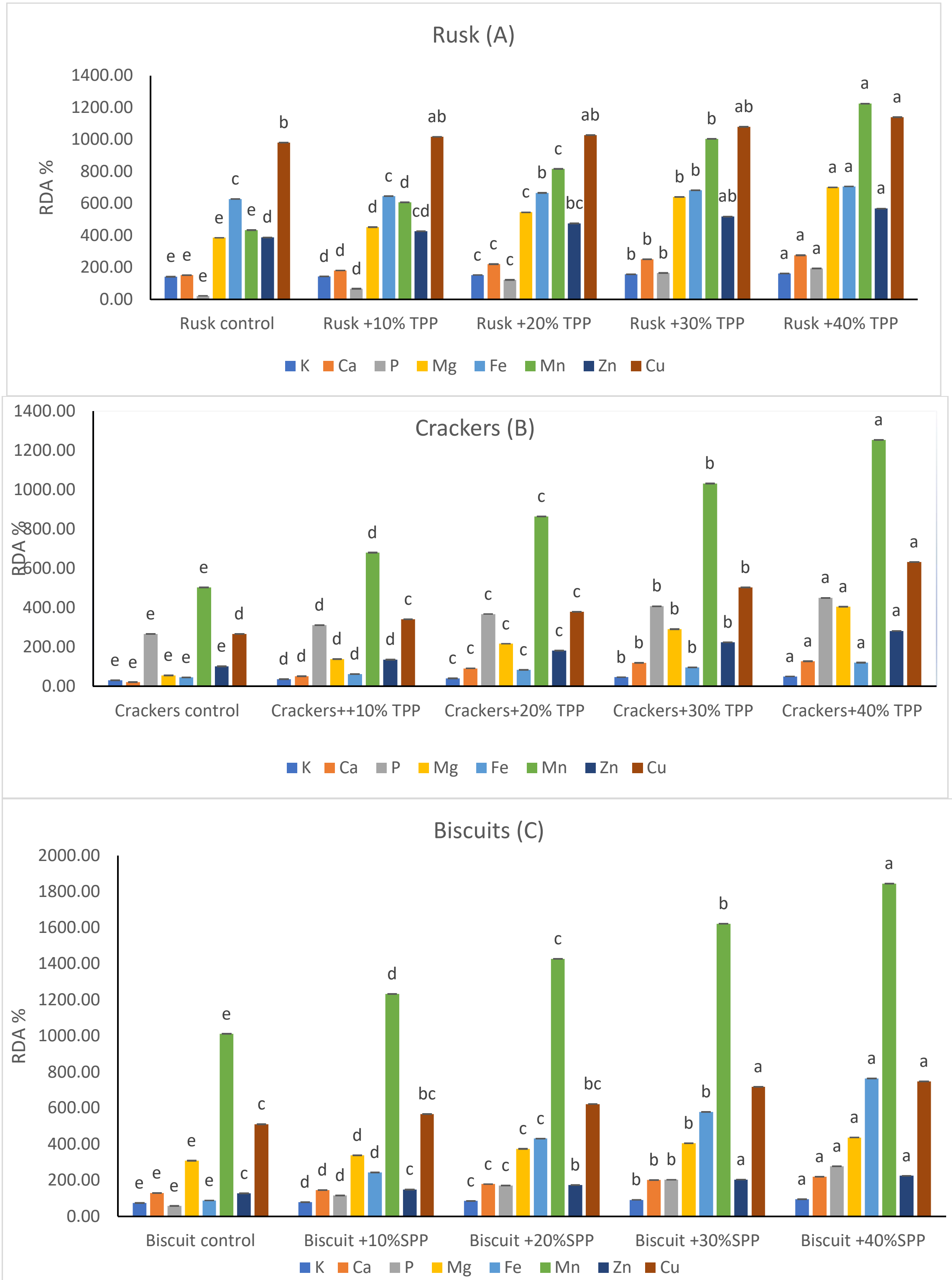


**Fig. 3:** Minerals expressed as a percent of the Recommend Daily allowance (RDA **%**) covered by each Control: rusk, crackers, and biscuit free from TPP or SPP. rusk, crackers, and biscuit fortifiedwith TPP or SPP . Results are expressed as the mean of triplicates. Significant differences (p < 0.5) are shown by (a, b, c, etc.) between products types at the same parameter. RDA in rusks, crackers, and biscuits was indicated by A, B, and C, respectively TPP : Tomato peel powder,SPP: Strawberry pomace powder.

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**Table 4:** Sensory attributes of control, and rusks, crackers, biscuits supplemented with TPP or SPP

| Products | Appearance | Color | Flavor | Texture | Crispiness | Overall acceptability |
|---|---|---|---|---|---|---|
| **Rusk control** | $8.20^{b}\pm0.47$ | $8.40^{b}\pm.34$ | $8.30^{b}\pm0.37$ | $8.30^{b}\pm0.43$ | $8.30^{a}\pm0.40$ | $8.60^{a}\pm0.40$ |
| **Rusk +10% TPP** | $8.30^{b}\pm0.34$ | $8.30^{b}\pm0.34$ | $8.40^{b}\pm0.43$ | $8.50^{a}\pm0.401$ | $8.40^{a}\pm0.45$ | $8.60^{a}\pm0.31$ |
| **Rusk +20% TPP** | $8.40^{b}\pm.34$ | $8.40^{b}\pm.34$ | $8.80^{a}\pm0.23$ | $8.20^{b}\pm0.49$ | $8.20^{b}\pm0.49$ | $8.45^{b}\pm0.49$ |
| **Rusk +30% TPP** | $6.90^{c}\pm0.38$ | $6.95^{c}\pm0.4$ | $7.10^{c}\pm0.48$ | $7.05^{c}\pm0.46$ | $7.15^{c}\pm0.5$ | $7.15^{c}\pm0.4$ |
| **Rusk +40% TPP** | $6.10^{d}\pm0.38$ | $6.35^{c}\pm0.47$ | $6.40^{d}\pm0.45216$ | $5.60^{d}\pm0.22$ | $5.40^{d}\pm0.27$ | $5.60^{d}\pm0.22$ |
| **Crackers control** | $8.20^{a}\pm0.34$ | $8.15^{b}\pm0.48^{e}$ | $8.15^{b}\pm0.483$ | $8.20^{b}\pm0.66$ | $7.80^{b}\pm0.55$ | $7.80^{b}\pm0.55$ |
| **Crackers++10% TPP** | $8.10^{a}\pm0.41$ | $7.94^{c}\pm0.47^{e}$ | $7.40^{c}\pm0.53$ | $7.70^{c}\pm0.597$ | $7.00^{c}\pm0.47$ | $7.00^{c}\pm0.47$ |
| **Crackers+20% TPP** | $7.95^{b}\pm0.700$ | $8.80^{a}\pm0.389$ | $8.60^{a}\pm0.37$ | $8.65^{a}\pm0.483$ | $8.70^{a}\pm0.42$ | $8.70^{a}\pm0.42$ |
| **Crackers+30% TPP** | $7.45^{c}\pm0.37$ | $7.25^{d}\pm0.39^{d}$ | $6.00^{d}\pm0.42$ | $7.00^{d}\pm0.494$ | $6.80^{d}\pm0.29$ | $6.80^{d}\pm0.29$ |
| **Crackers+40% TPP** | $7.45^{c}\pm0.598$ | $7.10^{d}\pm0.43$ | $6.20^{d}\pm0.47$ | $6.20^{e}\pm.389$ | $6.50^{e}\pm0.45$ | $6.50^{e}\pm0.45$ |
| **Biscuit control** | $7.60^{b}\pm0.60$ | $8.20^{b}\pm0.42^{e}$ | $8.40^{b}\pm0.34$ | $7.65^{b}\pm0.55$ | $7.95^{b}\pm0.45$ | $7.95^{b}\pm0.45$ |
| **Biscuit +10%SPP** | $7.30^{c}\pm0.58$ | $7.80^{c}\pm0.44$ | $7.90^{c}\pm0.46$ | $6.90^{c}\pm0.38$ | $7.65^{c}\pm0.29$ | $7.65^{b}\pm0.30$ |
| **Biscuit +20%SPP** | $8.60^{a}\pm0.62$ | $8.85^{a}\pm0.38$ | $9.15^{a}\pm.25874$ | $8.90^{a}\pm0.48$ | $9.20^{a}\pm0.33$ | $9.20^{a}\pm0.33$ |
| **Biscuit +30%SPP** | $7.20^{c}\pm0.60$ | $7.70^{c}\pm0.42$ | $7.40^{d}\pm0.37$ | $6.40^{d}\pm.31$ | $7.10^{d}\pm0.18$ | $7.10^{c}\pm0.181$ |
| **Biscuit +40%SPP** | $6.40^{d}\pm0.65$ | $7.10^{d}\pm0.53$ | $6.70^{e}\pm0.47$ | $5.80^{e}\pm0.33$ | $6.50^{e}\pm0.27$ | $6.50^{d}\pm0.23$ |

Control: rusk, crackers, and biscuit free from TPP or SPP. Values are expressed as means ± standard errors (a,b,c, etc.) donated the significant difference ($p<0.05$) between all treatments in the same column for one parameter. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$). The statistical analysis carried out for individual products with respect to each component. TPP : Tomato peel powder, SPP: Strawberry pomace powder.

According to the results of the sensory evaluation, "biscuits fortified with SPP have a sweet and pleasant, characteristic taste; they are well baked and tender, and they have a natural chocolate color and aroma." Differences in color were noticed in the biscuits supplemented with SPP having a darker color. The dark color increased with added SPP. The biscuit fortified with 30% SPP was preferred, considering all the parameters evaluated, while the biscuit fortified with 40% SPP showed the lowest scores for appearance, color, texture, crispiness, and overall acceptability due to their softer texture. Scores were lower for our products supplemented with SPP or SPP, probably due to the notable differences in color, flavor, texture, crispiness, and appearance of these products as a result of the original properties of the SPP and TPP. Results also showed that as the amount of TPP or SPP increased to 40%, products were less acceptable.

Our results showed that SPP contains higher anthocyanin than TPP (Figure 4A). effects of anthocyanins When comparing rusks, crackers, and biscuits, there are several significant differences. The products fortified with TPP or SPP had the highest anthocyanin content, whereas the unfortified control products, rusk, crackers, and biscuits had the lowest. The values were 0.25, 0.23, and 0.21 µg/100 g, respectively. In novel products fortified with TPP or SPP, anthocyanin values have risen. They range from 8.77 to 17.23 µg/100 g for rusks, from 9.77 to 17.50 µg/100 g for crackers, and from 38.43 to 49.17 µg/100 g for biscuits, respectively (Figure 4 B,C, and D). The data shown in figure 5 (A, B) indicated that TPP has 62 mg/100 g of lycopene. As a result, rusks and crackers supplemented with TPP had a higher lycopene content than the control products. For rusk fortified TPP, the corresponding values ranged from 8.73 to 20.87 mg/100 g. Similarly, crackers. The corresponding results ranged between 8.40 and 20.13 mg/100 g.

*L* a*, and b** scales were used to express the color characteristics of rusk, crackers, and biscuit products (Table 5). The table's findings revealed When fortified with TPP or SPP, the three novel products (biscuits, crackers, and rusks) showed significant variations. The brightness coordinate *L** indicated that the products without pomace or peel powder in the bakery were the brightest rusk, crackers, and biscuits; when comparing the different product types, the lightest products were those with 10% TPP (rusk and crackers), and the darkest was for the product fortified with SPP (40% SPP biscuit). Analyzing the red color's, *a** value revealed that products with a higher pomace and peel powder content exhibited deeper red colors. A more intense yellow color was produced in the products with a reduced pomace content, according to the assessment of the *b** value for yellow color. In products of color intensity, 40% strawberry pomace powder produced the darkest biscuits, whereas 40% tomato pomace produced the more reddish crackers.

When conducting texture measurements, the properties of hardness, adhesiveness, cohesiveness, gumminess, springiness, resilience, and chewiness should be taken into consideration because they most properly describe the texture of rusks, crackers, and biscuits (Table 6). These qualities are essential because they communicate the freshness and quality of the product. When TPP or SPP is added, rusks, crackers, and biscuits' TPA properties show a significant ($p < 0.05$) impact. Hardness rose considerably ($p < 0.05$) when TPP or SPP were used. This rise may be connected to the products' lower "springiness" values in the study when compared to the control products.

Furthermore, studies have demonstrated that TPP or SPP improves the adhesiveness, cohesiveness, gumminess, resilience, and chewiness of rusks, crackers, and biscuits. The results of the present investigation The hardness value, which is related to the force needed to break the products, rises with the addition of TPP or SPP. The hardness values of rusk fortified with 40% TPP, crackers fortified with 40% TPP, and biscuits fortified with 40% SPP were 209.30, 248.31, and 130.2 N, respectively, whereas the control products exhibited values of 99.38, 20.58, and 13.81 N, respectively.

The cohesiveness of our products increased further with the addition of SPP or TPP, while the control items showed significantly lower values. The range of results for crackers was 2.26 to 3.50; for rusk, it was 0.75 to 1.31; and for biscuits, it was 0.79 to 1.08. Although resilience values change when TPP or SPP are added, Gumminess, which is "the product of hardness and cohesiveness," exhibited a trend that was very equivalent to that of hardness. In the end, the results showed a significant improvement in the textural characteristics of our products that contained either SPP or TPP.

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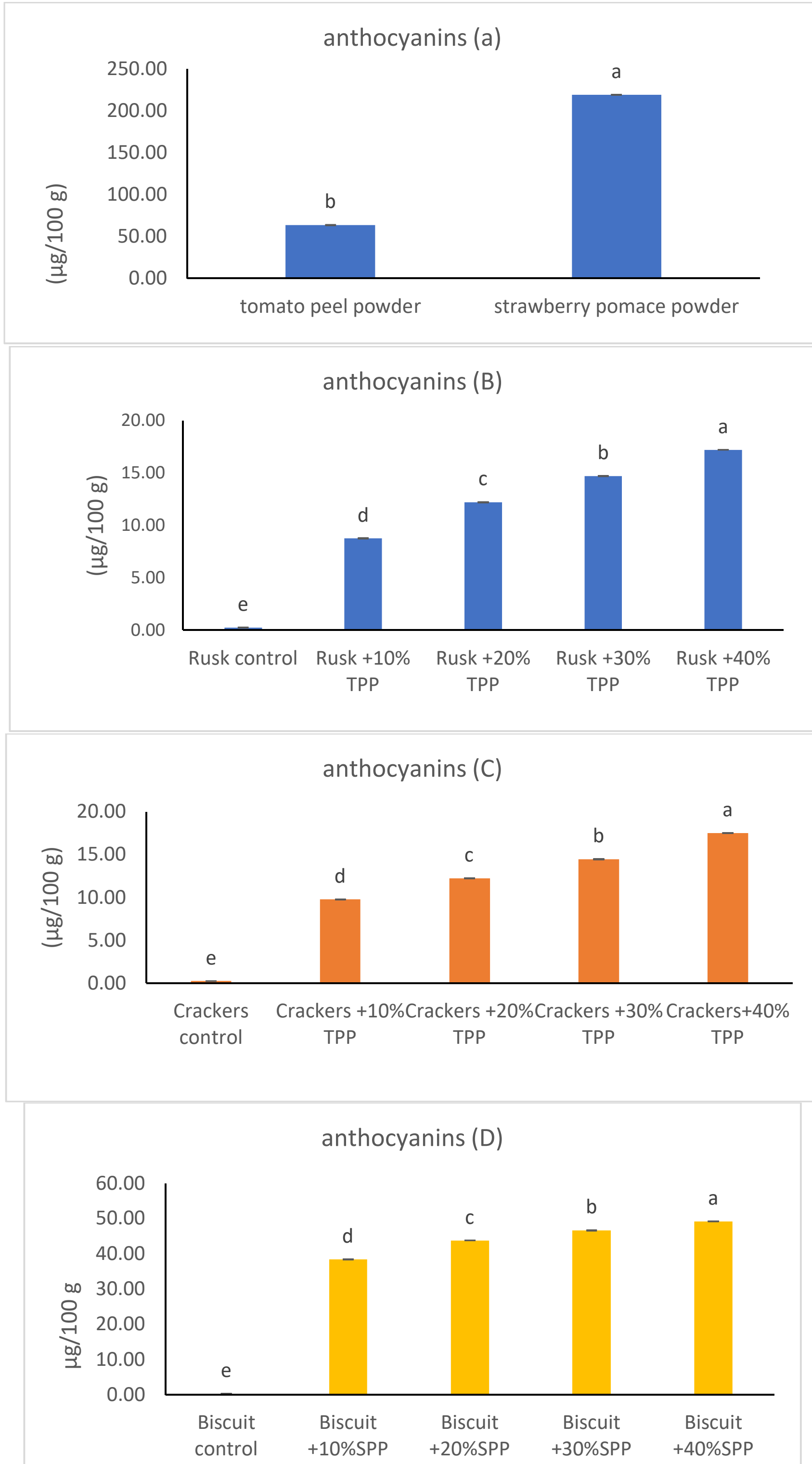
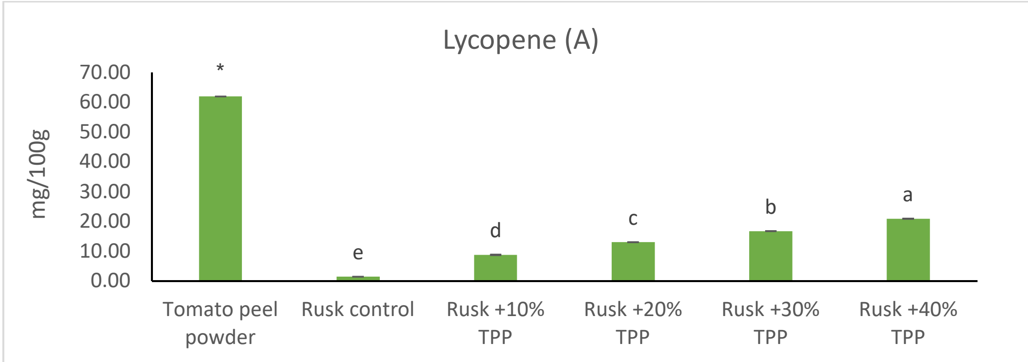



**Fig. 4:** Anthocyanins (µg/100 g) Control: rusk, crackers, and biscuit free from TPP or SPP. rusk, crackers, and biscuit fortified with TPP or SPP . Results are expressed as the mean of triplicates. Significant differences ($p < 0.5$) are shown by (a, b, c, etc.) betweenproducts types in the same parameter. The statistical analysis carried out for individual products with respect to anthocyanins. Anthocyanins in TPP, SPP, rusks, crackers, and biscuits was indicated by A, B, C, and D respectively. TPP : Tomato peel powder, SPP: Strawberry pomace powder.



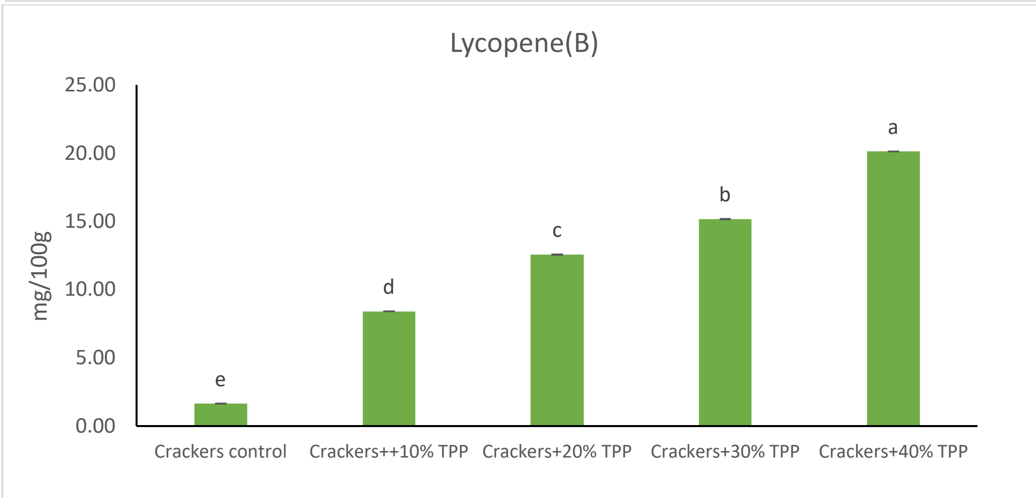




**Fig. 5:** Lycopene(mg/100g) Control: rusk, crackers, and biscuit free from TPP or SPP. rusk, crackers, and biscuit fortified with TPP or SPP . Results are expressed as the mean of triplicates. Significant differences ($p < 0.5$) are shown by (a, b, c, etc.) between products types in the same parameter. The statistical analysis carried out for individual products with respect to lycopene. Lycopene in TPP, rusks, and crackers, was indicated by A, and B, respectively TPP : Tomato peel powder, SPP: Strawberry pomace powder.

**Table 5:** Colour parameters of products expressed in terms of the CIELab scale parameters:

| | **Color parameters** | | | |
|---|---|---|---|---|
| **Treatments** | ***L**** | ***a**** | ***b**** | **ΔE*** |
| **Rusk control** | 76.39$^{a}$±6.2 | 6.46$^{e}$±0.66 | 28.67$^{a}$±0.58 | 81.95$^{a}$±5.59 |
| **Rusk +10% TPP** | 61.56$^{b}$±0.75 | 11.32$^{d}$±0.63 | 25.83$^{b}$±0.40 | 67.73$^{b}$±0.70 |
| **Rusk +20% TPP** | 58.61$^{c}$±0.55 | 11.99$^{c}$±0.58 | 24.21$^{c}$±0.50f | 64.55$^{c}$±0.26 |
| **Rusk +30% TPP** | 54.77$^{d}$±0.40 | 12.48$^{b}$±0.42 | 19.52$^{d}$±0.41 | 59.37$^{d}$±0.40 |
| **Rusk +40% TPP** | 51.99$^{e}$±0.91 | 14.44$^{a}$±0.71 | 14.55$^{e}$±0.86 | 55.91$^{e}$±0.72 |
| **Crackers control** | 69.43a±0.57 | 6.96±0.21 | 22.40$^{a}$±0.45 | 73.30$^{a}$±0.42 |
| **Crackers++10% TPP** | 61.51$^{b}$±0.82 | 12.15$^{c}$±1.04 | 17.75$^{b}$±0.88 | 65.40$^{b}$±0.04 |
| **Crackers+20% TPP** | 56.54$^{c}$±0.40 | 12.80$^{b}$±0.90 | 13.15$^{c}$±1.14 | 59.48$^{c}$±0.34 |
| **Crackers+30% TPP** | 53.00$^{d}$±0.98 | 13.00$^{a}$±0.73 | 9.34$^{d}$±0.86 | 55.39$^{d}$±1.11 |
| **Crackers+40% TPP** | 51.03$^{d}$±0.86 | 13.30$^{a}$±0.68 | 6.38$^{e}$±0.72 | 52.87$^{e}$±0.90 |
| **Biscuit control** | 69.26$^{b}$±0.57 | 4.20$^{e}$±0.20 | 27.64$^{a}$±0.45 | 74.69$^{a}$±0.69 |
| **Biscuit +10%SPP** | 47.63$^{a}$±0.74 | 7.62$^{d}$±0.80 | 24.77$^{b}$±1.08 | 54.25$^{b}$±1.05 |
| **Biscuit +20%SPP** | 41.07$^{c}$±0.9 | 10.50$^{c}$±0.57 | 19.39$^{c}$±0.87 | 46.64$^{c}$±0.74 |
| **Biscuit +30%SPP** | 36.56$^{d}$±0.43 | 11.57$^{b}$±0.40 | 16.77$^{d}$±0.48 | 41.87$^{d}$±0.29 |
| **Biscuit +40%SPP** | 33.70$^{e}$±0.68 | 12.48$^{a}$±0.20 | 13.48$^{e}$±1.00 | 38.41$^{e}$±0.79 |

Control: rusk, crackers, and biscuit free from TPP or SPP. Values are expressed as means ± standard errors (a,b,c, etc.) donated the significant difference ($p<0.05$) between all treatments in the same column for one parameter. Results are expressed as the mean of triplicates. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$). The statistical analysis carried out for individual products with respect to each component. TPP : Tomato peel powder, SPP: Strawberry pomace powder.

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**Table 6:** Texture profiles analysis of various product types

| Products | Hardness (N) | Adhesiveness (mj) | Springiness (mm) | Gumminess (N) | Chewiness (mj) | Resilience % | Cohesiveness |
|---|---|---|---|---|---|---|---|
| **Rusk control** | 99.38$^{e}$±0.69 | 8.67$^{a}$±0.88 | 122.33$^{a}$±1.45 | 76.74$^{e}$±0.94 | 9771.52$^{d}$±0.58 | 0.05$^{d}$±0.003 | 0.77$^{b}$±0.006 |
| **Rusk +10% TPP** | 147.96$^{d}$±1.12 | 6.00$^{c}$±0.58 | 114.89$^{c}$±1.06 | 114.19$^{d}$±1.32 | 13597.77$^{c}$±1.39 | 0.27$^{b}$±0.009$^{c}$ | 0.75$^{b}$±0.03 |
| **Rusk +20% TPP** | 159.28$^{c}$±0.83 | 3.00$^{d}$±0.58 | 119.00$^{b}$±0.58 | 124.07$^{c}$±0.64 | 15025.04$^{b}$±0.61 | 0.16$^{c}$±0.005 | 0.77$^{b}$±0.005 |
| **Rusk +30% TPP** | 198.31$^{b}$±0.86 | 0.73$^{b}$±0.12 | 88.67$^{d}$±0.88 | 241.67$^{b}$±0.33 | 21782.2$^{a}$±2.43 | 0.73$^{a}$±0.32 | 1.10$^{a}$±0.06 |
| **Rusk +40% TPP** | 209.30$^{a}$±0.85 | 0.77$^{b}$±0.12 | 76.31$^{e}$±0.65 | 280.07$^{a}$±0.64 | 21629.60$^{a}$±1.14 | 0.16$^{c}$±0.03 | 1.31$^{a}$±0.02 |
| **Crackers control** | 20.58$^{e}$±0.71 | 12.67$^{a}$±1.20 | 38.33$^{a}$±0.88 | 24.13$^{e}$±0.69 | 1014.07$^{c}$±0.64 | 0.35$^{c}$±0.03 | 1.22$^{d}$±0.03 |
| **Crackers++10% TPP** | 147.81$^{d}$±0.42 | 8.00$^{b}$±0.58 | 35.79$^{b}$±0.91 | 345.10$^{d}$±0.67 | 12591.40$^{b}$±0.95 | 0.45$^{b}$±0.03 | 2.26$^{c}$±0.04 |
| **Crackers+20% TPP** | 162.04$^{c}$±0.62 | 3.00$^{c}$±0.58 | 32.11$^{c}$±0.68 | 395.06$^{c}$±0.63 | 13203.92$^{b}$±1.09 | 0.35$^{c}$±0.03 | 2.36$^{c}$±0.04 |
| **Crackers+30% TPP** | 174.02$^{b}$±0.59 | -1.67$^{d}$±0.33 | 26.09$^{d}$±0.66 | 628.13$^{b}$±0.59 | 17136.92$^{a}$±0.96 | 0.29$^{d}$±0.02 | 3.50$^{a}$±0.05 |
| **Crackers+40% TPP** | 248.31$^{a}$±0.43 | - 8.00$^{e}$± 0.58 | 23.33$^{e}$±0.88 | 693.08$^{a}$±0.65 | 17354.27$^{a}$±0.82 | 0.57$^{a}$±0.05 | 2.79$^{b}$±0.05 |
| **Biscuit control** | 13.81$^{e}$±0.74 | 0.31$^{a}$±0.01 | 135.12$^{a}$±0.69 | 8.91$^{e}$±0.22 | 1259.22$^{a}$±0.77 | 0.06$^{c}$±0.005 | 0.70$^{c}$±0.03 |
| **Biscuit +10%SPP** | 74.28$^{d}$±1.81 | -1.00$^{b}$±0.58 | 121.00$^{b}$±1.00 | 57.12$^{d}$±0.69 | 7002.22$^{d}$±0.78 | 0.04$^{d}$±0.003 | 0.79$^{c}$±0.05 |
| **Biscuit +20%SPP** | 97.34$^{c}$±0.88 | -4.00$^{c}$±0.58 | 98.00$^{c}$±1.53 | 94.07$^{c}$±0.58 | 9420.18$^{c}$±0.74 | 0.07$^{c}$±0.003 | 0.94$^{b}$±0.02 |
| **Biscuit +30%SPP** | 118.03$^{b}$±0.55 | -6.00$^{d}$±0.58 | 86.96$^{d}$±1.53 | 121.13$^{b}$±0.70 | 10879.05$^{b}$±0.62 | 0.10$^{b}$±0.003 | 1.04$^{a}$±0.005 |
| **Biscuit +40%SPP** | 130.20$^{a}$±1.40 | -11.00$^{e}$±0.58 | 70.33$^{e}$±0.88 | 139.11$^{a}$±0.59 | 9752.31$^{c}$±0.65 | 0.70$^{a}$±0.007 | 1.08$^{a}$±0.006 |

Control: rusk, crackers, and biscuit free from TPP or SPP. Values are expressed as means ± standard errors (a,b,c, etc.) donated the significant difference ($p<0.05$) between all treatments in the same column for one parameter. Results are expressed as the mean of triplicates. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$). The statistical analysis carried out for individual products with respect to each component. TPP : tomato peel powder, SPP: Strawberry pomace powder.

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The collected data indicate that there is a difference in resilience between the three study products and the control. The resilience of the TPP-fortified rusks increases as the concentration of TPP rises, with the rusks fortified by 40% exhibiting the maximum resilience when compared to the control. Similarly, for the crackers that were TPP-fortified, the values exceeded the control, with the exception of the 30%TPP-fortified crackers. Regarding the biscuits fortified with SPP, the values grew as the concentration of SPP did as well, with the exception of the biscuits fortified with 10% SPP, where the value was 0.04%.

Due in large part to their antioxidant qualities, secondary metabolites have garnered attention. The total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity of raw materials and products fortified with TPP or SPP are shown in Table 7. According to our research, SPP has higher levels of total phenolic content, flavonoid content, and antioxidant activity than TPP. Comparing our new products to control products, we found that adding SPP or TPP boosted TPC, TFC, and antioxidant activity. Furthermore, the TPC for biscuits fortified with SPP ranged from 161.61 to 415.58mg GAE/100g; for rusks fortified with TPP, it ranged from 130.77 to 242.21mg GAE/100g; and for crackers fortified with TPP, it ranged from 94.2 to 215.30 mg GAE/100 g. TFC was detected in lower concentrations and exhibited a similar pattern as phenolic acids. Our findings demonstrated that TPP or SPP powder, when substituted for wheat flour, raised the TPC, TFC, and antioxidant activity values of rusks, crackers, and biscuits. The DPPH and trolox method's measurements of the antioxidant activity of samples demonstrated the important ability for free-radical scavenging possessed by the supplemented samples. There were significant variations in the antiradical power between products that were fortified with TPP or SPP, raw materials, and control products. The TPP and SPP meal's greater TPC, TFC, and antioxidant activity value than wheat flour is most likely the cause of these results.

The distribution of polyphenols in tomato peel powder, strawberry pomace powder, rusk, strawberry, and biscuit control or fortified with TPP or SPP was investigated further using HPLC (phenolic acids and flavonoids) analysis, with the results shown in the Table 8. HPLC analysis revealed differences in phenolic acid and favonoid composition between TPP and SPP. The SPP contained a high concentration of phenolic substances such as Protocatchoichuic acid, gallic acid, Catechin, Chlorogenic, Vanillic, Ellagic Acid, and P- Coumaric, whereas the TPP contained a high concentration of Caffeic Acid, Chlorogenic, Ferulic acid, gallic acid, Syringic, and P- Coumaric. Similarly, our results showed that rutin is the most abundant flavonoid in TPP, followed by quercetin, kaempferol, and naringenin. The most frequent compound in the SPP was rutin, followed by naringin, luteolin, quercetrin, and apegenin. The TPP and SPP concentrations in crackers, rusk, and biscuits increased, as did the phenolic and flavonoid content of products fortified with 20% SP or TP (sensory acceptable).

## 4. Discussion

The existence of naturally occurring and physiologically active compounds like TPP and SPP, which are important in preventing the harmful effects of free radicals, has received a lot of attention in recent years. Along with carotenoids and polyphenols, vitamins A, C, and E should be listed among the many compounds that have antioxidant effects (Pieszka *et al.,* 2015; Isik and Topkaya 2016). When compared to the nutritional composition of wheat flour, examined TPP, and SPP exhibits differences in the amounts of basic components such as protein, ash, total dietary fiber, and fat. The raw material we use to create dried pomaces determines its chemical composition, which is influenced by agricultural practices, fertilization, and weather. The drying process, the kind of dryer, and the drying parameters are the second crucial component that affects the quality of the dried material that is obtained. As demonstrated, modifications to the original formulation will impact the final products' characteristics based on variations in protein, fat, and carbohydrate content.

These two basic ingredients, TPP and SPP, are present in varying amounts in biscuit, cracker, and rusk formulations and may have an impact on the dry base compositions of our products. Carbohydrates were the most prevalent nutrient in both TPP and SPP, followed by total dietary fiber, proteins, fat, and ash. Therefore, all of our new products contain these components in the same order. As a result, this raises these new products' nutritional value. The main cause is probably because TPP and SPP, which were used to make rusks, crackers, and biscuits instead of wheat flour, had higher

**Table 7:** Phytochemicals content and antioxidant activity of rusks, crackers, and biscuits

| Products | Total phenolic content (mg Gallic acid /100g) | Total flavonoids content ( mg/100 g) | Total antioxidant activity (µmol TE/100g) | Antioxidant activity (%) as DPPH |
|---|---|---|---|---|
| **Tomato peel powder** | 444.34$^{b}$±8.49 | 97.74$^{c}$±4.36 | 53.26$^{b}$±2.74 | 30.63$^{b}$±1.58 |
| **Strawberry pomace powder** | 859.87$^{a}$±2.23 | 275.70$^{a}$±3.19 | 69.70$^{a}$±2.16 | 40.09$^{a}$±1.24 |
| **Flour wheat 72%** | 116.26$^{c}$±6.28 | 181.96$^{b}$±4.23 | 44.59$^{c}$±3.75 | 25.65$^{c}$±2.16 |
| **Rusk control** | 88.07$^{e}$±1.40 | 13.30$^{e}$±1.17 | 23.03$^{d}$±1.27 | 13.24$^{d}$±0.73 |
| **Rusk +10% TPP** | 130.77$^{d}$±1.40 | 17.82$^{d}$±0.97 | 23.16$^{d}$±0.78 | 13.32$^{d}$±0.45 |
| **Rusk +20% TPP** | 164.57$^{c}$±2.14 | 28.71$^{c}$±0.97 | 33.92$^{c}$±1.40 | 19.51$^{c}$±0.80 |
| **Rusk +30% TPP** | 198.53$^{b}$±4.33 | 34.88$^{b}$±1.42 | 37.793$^{b}$±3.44 | 21.74$^{b}$±1.98 |
| **Rusk +40% TPP** | 242.21$^{a}$±3.31 | 42.86$^{a}$±1.21 | 46.37$^{a}$±2.59 | 26.67$^{a}$±1.49 |
| **Crackers control** | 55.53$^{e}$±1.63 | 18.74$^{e}$±1.42 | 13.23$^{e}$±1.20 | 7.61$^{e}$±0.69 |
| **Crackers++10% TPP** | 94.2$^{d}$±1.05 | 23.54$^{d}$±1.34 | 15.12$^{d}$±0.68 | 8.70$^{d}$±0.39 |
| **Crackers+20% TPP** | 132.21$^{c}$±1.43 | 40.68$^{c}$±1.68 | 25.36$^{c}$±1.67$^{e}$ | 14.58$^{c}$±1.01 |
| **Crackers+30% TPP** | 171.03$^{b}$±2.17 | 52.05$^{b}$±2.25 | 31.68$^{b}$±1.70 | 18.22$^{b}$±0.98 |
| **Crackers+40% TPP** | 215.30$^{a}$±3.07 | 66.08$^{a}$±2.18 | 38.18$^{a}$±1.72 | 21.96$^{a}$±0.99 |
| **Biscuit control** | 69.68$^{e}$±2.19 | 35.90$^{e}$±2.03 | 24.13$^{e}$±1.45 | 13.88$^{e}$±0.83 |
| **Biscuit +10%SPP** | 161.61$^{d}$±6.73 | 65.97$^{d}$±3.03 | 30.05$^{d}$±1.71 | 17.28$^{d}$±0.98 |
| **Biscuit +20%SPP** | 212.34$^{c}$±4.35 | 86.32$^{c}$±0.73 | 38.20$^{c}$±1.88 | 21.97$^{c}$±1.08 |
| **Biscuit +30%SPP** | 294.67$^{b}$±2.54 | 116.18$^{b}$±1.96 | 48.08$^{b}$±2.16 | 27.65$^{b}$±1.24 |
| **Biscuit +40%SPP** | 415.58$^{a}$±1.31 | 142.95$^{a}$±1.30 | 57.68$^{a}$±1.95 | 33.17$^{a}$±1.12 |

Control: rusk, crackers, and biscuit free from TPP or SPP. Values are expressed as means ± standard errors (a,b,c, etc.) donated the significant difference ($p<0.05$) between all treatments in the same column for one parameter. Results are expressed as the mean of triplicates. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$). The statistical analysis carried out for individual products with respect to each component. TPP : Tomato peel powder, SPP: Strawberry pomace powder.

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**Table 8:** HPLC analysis for phenolic and flavonoid profile of raw material and products

| Compounds | SPP | TPP | Rusk control | Rusk + 20% TPP | Crackers control | Crackers+20 % TPP | Biscuit control | Biscuit +20% SPP |
|---|---|---|---|---|---|---|---|---|
| **Phenolic profile mg/100g** | | | | | | | | |
| **Gallic acid** | 679.1 | 83.98 | 9.60 | 26.396 | 9.93 | 26.726 | 161.79 | 297.61 |
| **Pyrogallol** | 0.70 | 0.20 | 0.002 | 0.042 | 0.10 | 0.14 | 0.18 | 0.32 |
| **Caffeic Acid** | 6.00 | 55.20 | 19.19 | 30.23 | 11.90 | 22.94 | 23.00 | 24.20 |
| **Protocatchoichuic acid** | 1938.31 | 19.00 | 2.30 | 6.10 | 5.80 | 9.60 | 11.00 | 398.662 |
| **Chlorogenic** | 48.00 | 75.00 | 0.32 | 15.32 | 0.09 | 15.09 | 1.20 | 10.80 |
| **Epi-Catechin** | 13.93 | 15.00 | 1.80 | 4.80 | 2.30 | 5.30 | 2.90 | 5.686 |
| **Catechin** | 264.01 | 19.00 | 3.60 | 7.40 | 5.70 | 9.50 | 6.50 | 59.302 |
| **Caffeic Acid** | 6.75 | 0.83 | 0.30 | 0.466 | 0.50 | 0.666 | 0.80 | 2.15 |
| **P-OH.Benzoic** | 16.00 | 12.00 | 0.66 | 3.06 | 87.60 | 89.50 | 1.06 | 4.26 |
| **Vanillic** | 47.85 | 18.50 | 3.10 | 6.80 | 2.50 | 6.20 | 4.20 | 13.77 |
| **Ferulic acid** | 12.40 | 28.22 | 4.20 | 9.844 | 2.55 | 8.194 | 8..26 | 10.48 |
| **Catechol** | 0.23 | 0.09 | 0.20 | 0.218 | 0.40 | 0.418 | 0.04 | 0.086 |
| **E- Vanillic** | 0.98 | 0.75 | 0.80 | 0.95 | 0.90 | 1.05 | 1.20 | 1.396 |
| **Ellagic Acid** | 45.39 | 13.25 | 1.80 | 4.45 | 2.00 | 4.65 | 3.20 | 12.278 |
| **Benzoic** | 17.00 | 10.00 | 5.00 | 7.00 | 5.30 | 7.30 | 5.90 | 9.30 |
| **Salycillic** | 2.30 | 2.70 | 0.02 | 0.56 | 0.30 | 0.84 | 0.40 | 0.86 |
| **3,4,5 Methoxy Cinnamic** | 1.90 | 2.70 | 0.50 | 1.04 | 0.83 | 1.34 | 0.90 | 1.28 |
| **Coumarin** | 8.18 | 6.84 | 0.31 | 1.678 | 0.36 | 1.728 | 0.58 | 2.216 |
| **P- Coumaric** | 44.26 | 49.97 | 0.07 | 10.064 | 0.19 | 10.184 | 3.76 | 12.612 |
| **Cinnamic** | 5.80 | 3.40 | 0.038 | 0.718 | 0.04 | 0.72 | 0.094 | 1.254 |
| **Syringic** | 15.00 | 42.53 | 13.00 | 21.506 | 12.80 | 21.306 | 1.37 | 4.37 |
| **Flavonoid (mg/100g)** | | | | | | | | |
| **Luteolin** | 39.31 | 0.92 | 0.26 | 0.444 | 0.53 | 0.714 | 0.59 | 8.452 |
| **Naringin** | 82.80 | 39.02 | 3.20 | 11.004 | 2.96 | 10.764 | 3.10 | 19.66 |
| **Rutin** | 563.49 | 489.26 | 16.74 | 114.592 | 9.81 | 107.662 | 10.80 | 123.498 |
| **Quercetrin** | 31.22 | 9.80 | 0.15 | 2.11 | 0.38 | 2.34 | 0.40 | 6.644 |
| **Quercetin** | 6.00 | 56.74 | 0.90 | 12.248 | 1.86 | 13.208 | 1.99 | 3.19 |
| **Kaempferol** | 0.99 | 48.90 | 2.80 | 12.58 | 3.80 | 13.58 | 3.90 | 4.098 |
| **Hespertin** | 5.70 | 3.60 | 0.90 | 1.62 | 0.99 | 1.71 | 1.28 | 2.42 |
| **Apegenin** | 22.90 | 1.70 | 0.07 | 0.41 | 0.08 | 0.42 | 0.09 | 4.67 |

Control: rusk, crackers, and biscuit free from TPP or SPP. rusk, crackers, and biscuit fortified with TPP or SPP. TPP: tomato peel powder, SPP: strawberry pomace powder.

levels of nutritional total dietary fiber, protein, fat, ash, carbohydrates, and minerals. According to Fernandez-Gines *et al.,* (2004), dietary fiber consumption has several health advantages, such as a decreased risk of cancer, heart disease, obesity, and gastrointestinal disorders. The U.S. Food and Drug Administration (FDA) states that people on a diet of 2000 kcal should consume 25 g of dietary fiber daily. Therefore, a 100 g portion of our new products fortified with TPP or SPP can provide 17.08 to 55.48 % of an adult's daily dietary fiber needs for rusk, 17.48 to 55.88% for crackers, and 13 to 64.96% for biscuits, respectively. The control group's corresponding dietary fiber needs are 1.07%, 1.17%, and 1.98%. Another study found that when Topkaya and Isik (2016) used up to 12% tomato pomace instead of wheat flour to make crackers, the amount of dietary fiber was around four times higher than the control. Our findings support the findings of Mehta *et al.,* (2018) and Pieszka *et al.,* (2015), which suggest that SPP and TPP by-products have been reported as a good source of dietary fiber and protein. The reason for the slight variations in fat content between the majority of the fortified products and the control is that the fat from the TPP and SPP changed the fat of the wheat flour. However, there is a notable change in the amount of carbohydrates in our new products when TPP or SPP are added. This could be because of the Maillard reaction, which breaks down carbohydrates, or caramelization, which may occur while cooking at 180 °C (Salari *et al.,* 2024).

SPP contains manganese, which is a cofactor of antioxidant enzymes and plays a crucial part in the defense mechanisms by scavenging free radicals. TPP also contains trace minerals, such as copper and zinc. It is well recognized that minerals are necessary to sustain the body's metabolic processes. Minerals are essential for controlling the activity of the skeletal, muscular, neurological, and circulatory systems. Muscle contraction, regular heartbeat, nerve impulse transmission, oxygen transport, oxidative phosphorylation, enzyme activation, immunological responses, antioxidant activity, bone health, and blood acid-base balance are only a few of the numerous bodily processes for which they are beneficial (Lakshmi, 2014). A woman between the ages of 31 and 50 should take 4700 mg of potassium and 1000 mg of calcium every day according to FDA. Our calculations show that 1.14 times K and 1.83 times Ca can be obtained from a 100 g portion of rusk fortified with TPP 40%, 1.59 times K and 6.17 times Ca can be obtained from crackers fortified with TPP 40%, and 1.28 times K and 1.70 times Ca can be obtained from biscuits fortified with SPP 40% than from a single portion of control products. These results indicate that SPP and TPP have a high potential for nutritional value and could be a significant addition to human meals. Gava (2010) states that since the water activity (Aw) of all of our bread items was less than 0.6, they are all classified as microbiologically stable foods. Fellows (2017) states that meals with an Aw between 0.40 and 0.70 don't need to be refrigerated, but they should be stored in packs that prevent moisture loss or absorption. Both SPP and TPP are known to have significant levels of total dietary fiber. Aw decreases as a result of enhanced water retention brought on by the fiber's excellent water absorption and swelling power properties. In new products, there is a noticeable decrease in water activity when TPP or SPP increases. This could result in longer shelf life for the dietary fiber-enriched products.

This is in line with Pieszka *et al.,* (2015), Chabi *et al.,* (2024), and Isik and Topkaya (2016). The findings indicated that all products with TPP or SPP fell within the acceptable range based on the mean scores of overall acceptability. Either TPP or SPP significantly impacted the quality of the finished product in terms of appearance, color, flavor, and taste. acceptability of the products overall. Judges liked the rusks, crackers, and biscuits fortified with TPP or SPP at varying concentrations; however, the best points were awarded for concentrations of 20 and 30%. However, when the quantity of SPP was increased, the biscuits fortified with 30% SPP tasted like chocolate and received the highest ratings from the testers. One of the most crucial factors in biscuit, cracker, and rusk acceptability is taste. Additionally, it might be claimed that the combination of TPP or SPP also ranged high because the fat content of TPP or SPP makes the sample taste better when consumed in excess. The crispness of the product is undoubtedly impacted by the increase in dietary fiber and protein content, which can lead to an increase in hardness. However, some variance in textural qualities was noted in all combinations as a result of an increase in TPP or SPP percentage. The product's color finally became darker in biscuits and redder in crackers and rusks as the TPP or SPP percentage rose. All of the studies above showed that baking TPP or SPP with wheat flour can result in baked products that are acceptable (biscuits, crackers, and rusks). Furthermore, the most significant factor influencing our new items' sensory qualities was their TPP and SPP content. The addition of TPP to bakery goods (bread and muffins) improved their color, according to Mehta *et al.,* (2018).

Similar sensory trends have previously been noted in cookies and crackers made with tomato peel and strawberry pomace (Tarasevičienė *et al.,* 2021; Nakov *et al.,* 2022; Garzoli *et al.,* 2020; and Bhat and Ahsan, 2015).

Our findings revealed that the increased content of anthocyanins in biscuits, as well as the increased content of anthocyanins and lycopene in rusks and crackers, is attributable to the high amount of these compounds in SPP and TPP, respectively. Furthermore, our results indicate that anthocyanins are the main flavonoid pigments present in TPP and SPP currants. They can readily enter cells since they are very soluble in water. According to Ramirez-Tortosa *et al.,* (2001), they also possess noteworthy antioxidant and anti-inflammatory qualities. The results of this study corroborate several studies' claims that the anthocyanins, flavonoids, and phenolic compounds present in chokeberries and black currants inhibit the overproduction of free radicals, which can be harmful to the body (Wang and Jiao, 2000). Lycopene is also present in significant concentrations in TPP. Among common carotenoids, lycopene has the strongest antioxidant activity. It also makes up around 83% of the pigments present and gives tomatoes their vibrant red color (Kamiloglu *et al.,* 2013; Kamiloglu *et al.,* 2014). The most prevalent anthocyanin in strawberry pomace was calledistephin, or pelagonidin-3-glucoside (Giampieri *et al.,* 2012; Tumbas Šaponjac *et al.,* 2015). Pelargonidin-3-glucoside and cyanidin-3-glucoside are the primary pigments present in wild strawberries. However, strawberry pomace did not contain any second compounds. According to Tumbas Šaponjac *et al.* (2015), strawberry anthocyanin pigments are less stable and might have been harmed during juice processing. For this reason, adding lycopene and anthocyane from natural sources to food products in general and bakery products in particular is of great interest.

Since color is the first sensory aspect of food that consumers perceive and can have an impact on their preferences, color is an extremely significant food attribute. When we added TPP and SPP, we measured the color variations in the rusk, crackers, and biscuits using $L^*$, $a^*$, $b^*$, and $\Delta E^*$. The redness $a^*$ values among the color parameters changed significantly as a result of the TPP addition. Due to the lycopene pigment in TPP, a rise in tomato pomace powder concentrations in the product raised the samples' "a" values as predicted. In regard to color intensity, biscuits enriched with SPP had the darkest $L^*$ value. This might be because SPP has a higher amount of reducing sugars, which could give the biscuits a darker color and cause the Maillard process, as shown in biscuits containing 40% strawberry pomace, according to findings from other researchers (Tarasevičienė *et al.,* 2021). Our findings demonstrated that increasing the pomace concentration in all products decreased lightness ($L^*$) and increased red color ($a^*$). Because its pigment becomes unstable when cooked, the 40%SP biscuit has the least color difference ($\Delta E^*$). Additionally, there was a difference ($p<0.05$) in the color change ($\Delta E^*$) between treatments. In contrast to traditional products (control), products enhanced with pomace may have a different color. Pomace addition was found to enhance all product darkness (Manuel, 2023). Conversely, a strawberry's high anthocyanin concentration accounts for its high redness value.

Given these findings, it is difficult to identify a general behavior because the textural characteristics are solely dependent on the elements that were substituted for the original formulation. Nonetheless, it appears that the high fiber content of the resultant compounds tends to make the baked products harder. Accordingly, when TPP and SPP were added to our product research, the influence on hardness, cohesiveness, and gumminess was greatest at the highest concentration of pomace, whereas a decrease in springiness was observed with increasing pomace concentrations. Food products' acceptability, particularly those from bakeries, is greatly influenced by their hardness. Our findings demonstrated that adding a fiber-rich food, such as TPP or SPP, instead of wheat flour causes a decrease in springiness and an increase in hardness. These findings concurred with those previously published by other writers (Bamal and Dhull 2024 and Topkaya and Isik 2018). Our products' high cohesiveness in this investigation was caused by a rise in fibers, as demonstrated by the results. Products that are cohesive are more resilient to the strains of packaging and shipping, guaranteeing that they reach customers in the desired condition. A weak and fragile structure may result from gluten's reduction of the network (Silva *et al.,* 2013). Partially substituting TPP or SPP could cause the whole wheat protein (gluten) to dilute, altering the gluten-starch interface and preventing the development of springiness in our products. This finding is consistent with the research conducted by Gonelimali *et al.,* (2021). These findings are thought to be connected to the reduction in total gluten content of the crackers, rusks, and biscuits caused by the substitution of SPP or TPP. Researchers that substituted pomegranate peel powder for wheat flour in biscuits and tomato seed and Jerusalem artichoke powders for wheat flour in crackers (Urganci and Isik 2021; Ozgoren *et al.,* 2019; and Topkaya and Isik 2018) came to similar conclusions. In addition to the apple pomace, other factors that affect biscuit hardness include the water content, the grain size of the flours used, the sweetener, the fat, and the ways in which the ingredients interact. Low water content prevents some starch grains from gelatinizing and leaving them in their original form, which causes the biscuit to harden (Kulp *et al.,* 1991). According to studies by Gu *et al.,* 2020; Elleuch *et al.,* 2011; and Hotchkiss *et al.,* 2024, dietary fiber from tomato and strawberry byproducts (57.4,54.7%, respectively) has a stronger affinity for water and oil than does dietary fiber from cereal derivatives. The hardness of the baked muffins was subsequently increased due to the higher dietary fiber content and the higher water and oil-holding ability of the pomegranate peel (Topkaya and Isik 2018). According to Mildner-Szkudlarz *et al.,* (2016), the cohesiveness of baked products, which measures the food's internal resistance and sticking power, is typically considered to have good textural qualities. calculating cohesiveness, which is done by dividing the work area of the second compression by that of the first. As per Atta *et al.,* (2023), a product that is less cohesive is more likely to break easily, which may affect the product's acceptance by consumers. Resilience, or the sample's elasticity or ability to return to its initial state once a force is applied, was enhanced by the addition of TPP or SPP to the products (Atta *et al.,* 2023). By breaking up the gluten network, adding SPP or TPP results in a stiffer texture and greater resilience (Weng *et al.,* 2021).

Numerous biotic and abiotic stressors produce oxidative damage, which plants' antioxidants protect them from. Tomato's beneficial activity is attributed to the presence of antioxidant components as well as its ability to suppress ROS-mediated processes. The red color of tomatoes is caused by the presence of lycopene, which has greater antioxidant action than other carotenoids due to the presence of conjugated double bonds in its structure (Chandra *et al.,* 2012). Strawberry pomace contains phytochemicals such as antioxidants, flavonoids, phenols, and anthocyanins that can be used in food supplements or fortification (Tumbas Šaponjac *et al.,* 2015). In our study, TPP and SPP were found to be high in bioactive compounds such as TPC, TFC, and antioxidants. Its integration in rusk, cracker, and biscuit provides favorable health effects to the human body. Our findings are consistent with those of Isik and Topkaya (2016) and Tumbas Šaponjac *et al.*(2015). TPP and SPP by-products may be a healthier option to wheat flour in bakery production (Ivanova *et al.,* 2021; Isik and Topkaya 2016; Tarasevičienė *et al.,* 2021). Findings of this study show that adding TPP or SPP during the production process of rusks, crackers, and biscuits raised the products' TPC, TFC, and antioxidant activity. This enhanced the products' nutritional value, making them more acceptable for consumption by a wide range of societal groups. For instance, adding strawberries pomace caused the percentage of antioxidants (µmol TE/100g) to increase from 1.25 to 2.39 times. By substituting it for wheat flour in the products, we were able to utilize the byproducts and obtain their benefits. The antioxidant activity of SPP and TPP currants appears to be determined not only by the level of anthocyanins, but also by the presence of flavonoids and other phenols in significant proportions, as confirmed in this study. According to our data, TPP and SPP contain an important quantity of phenolic compounds, such as phenolic acids and flavonoids, which have a very high ability to neutralize free radicals and hence potentially demonstrate a strong antioxidant potential. This is consistent with the line of several authors (Pieszka *et al.,* 2015; Tumbas Šaponjac *et al.,* 2015). They also concluded that higher overall phenolic contents result in greater antioxidant activity in cookies.

Our results showed that the high polyphenol content of the rusk, crackers, and biscuits increased total phenol and flavonoid levels. The partial replacement of wheat flour with TPP or SPP altered the phenolic and flavonoid components of rusk, crackers, and biscuits. Most compounds showed an increase in levels after adding TPP or SPP. Our innovative products have been shown to have a diverse range of phytochemicals, which explains their high total phenol content when compared to control rusk, crackers, and biscuits. These results are congruent with those published by Tumbas Saponjac *et al.,* (2015) and Kumar *et al.,* (2024). Despite the fact that heat treatment can alter the phenolic profile depending on the phenolic acid and baked product, adding additional TPP or SPP to all products increased the amount of all components. TPP and SPP have significant quantities of phenolic components, including phenolic acids and flavonoids, which can neutralize free radicals and provide antioxidant properties (Pieszka *et al.,* 2015; Tumbas Šaponjac *et al.,* 2015). Ivanova *et al.,* (2021) and Tarasevičienė *et al.,* (2021) noticed that mixing TPP and SPP considerably increased antioxidant activity compared to the control product. These findings show that TPP and SPP include a range of flavonoids that are beneficial to human health. Rutin, for example, has been associated with significantly decreased hepatic and cardiac triglyceride levels (Fernandez *et al.,* 2010) and may have anti-inflammatory properties (Guardia *et al.,* 2001). Naringenin has been identified as an antioxidant, anti-inflammatory, and regulator of fat and sex hormone metabolism. In addition, quercetin has been found to have antioxidant, anticarcinogenic, anti-inflammatory, anti-aggregation, and vasodilating properties (Navarro-González 2011).

Isik and Topkaya (2016) discovered that replacing wheat flour with 4%, 8%, or 12% dried tomato pomace meal in cracker production increased total polyphenol content (TPC) by 52.52 to 127.58 mg GAE/100 g.

Yagci *et al.,* (2020) discovered that incorporating tomato pomace powder into extruded snacks significantly increased the amount of individual free phenolics such as gallic acid, protocatechuic acid, 2,5-dihydroxybenzoic acid, chlorogenic acid, rutin, and quercetin.

## 5. Conclusion

A by-product with superior nutritional composition (high levels of ash, fat, and protein) is TPP and SPP. It is a good source of dietary fiber, lycopene, and anthocyanin, according to the findings of chemical composition analysis of TPP and SPP. The physical and nutritional properties of biscuits enriched with varying quantities of SPP (10%, 20%, 30%, and 40%) and rusk and crackers enriched with varying amounts of TPP were superior to those of the control, and these advantages were directly connected to the TPP or SPP content. Our products with 20 and 30% TPP or SPP were the most well-liked by panelists, according to the sensory study. The utilization of various nutrient-rich food industry by-products in the creation of novel functional foods may be encouraged by these findings. The products' texture profile was also impacted by the addition of TPP and SPP. However, the specific textural characteristic determined the extent of influence. Additionally, TPP and SPP will be marketed as human feed, which will increase their worth more than they would as waste. Additionally, using SPP and TPP will contribute to a reduction in pollution in the environment. We believe TPP can be utilized in bitter baked goods and SPP can be employed in other meals, particularly in sweet baked products and sweeter products like biscuits. Furthermore, a deeper comprehension of TPP and SPP's composition and characteristics in connection to other compounds can lead to improved exploitation of these compounds. Waste from the manufacturing of strawberry juice and tomato concentrate could be converted into byproducts through the use of efficient and effective waste treatment technology.

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**Availability of data and materials**

All data generated or analysed during this study are included in this published article

**Competing interests**

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**Authors' contributions**

The experiment was designed and conducted by Hanaa, Nahed, and Zein. Hanaa explained the results. The work was written, drafted, and reviewed by Hanaa.

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