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Effects of Tomato Pomace on Baking Properties of Wheat Flour and Bread Quality

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RESEARCH ARTICLE

Abstract

The aim of this study was to investigate the properties of tomato pomace by-products by incorporating them in powder form into new bread products to improve their properties. Tomato pomace was dried, milled and incorporated with different levels (5%, 10%, 15% and 25%) into dough and breads made from wheat white flour. The addition of tomato pomace powder (TMF) influenced farinograph characteristics by increasing water absorption and dough softening, while decreasing dough development time and stability time. However, there were no notable changes observed in the quality of the bread, including baking yield, loss, and crumb moisture. The bread with added TMF showed higher protein and lipid content compared to the control sample. Specifically, the addition of 25% TMF increased fat content by 316.7%, protein content by 43.5%, and ash content by 34.1%. The sensory evaluation revealed that higher levels of TMF (25%) negatively affected overall acceptability of the bread while the bread with medium TMF, to which 15% powder was added, received the highest mean score of 4.82 out of 5, indicating its preference among customers due to its distinctive characteristics. This finding suggests that consumers prefer a moderate amount of TMF in their bread. These results highlight the potential of vegetable by-products, specifically TMF, as beneficial food additions that can improve bread's nutritional value.

Keywords: by-products, tomato pomace, bread quality

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INTRODUCTION

The food industry and research trends aim to implement the concept of zero-waste and its policies. Although the industry is primarily concerned with the disposal of by-products from the production of vegetable food products, these by-products also present a promising source of compounds with nutritional or technological features, and they are currently being investigated as potential sources of functional compounds. A significant number of studies in the field highlight that plant residues generated by the canned vegetable and fruit industry have enormous potential for their reuse in various food products (Zarzycki et al., 2022). The management of by-products from plant food processing can be achieved through various eco-friendly methods, including composting and anaerobic digestion. Composting converts organic waste into nutrient-rich fertilizer, reduces waste volume, kills pathogens, decreases weed germination in agricultural fields, and destroys malodorous compounds (Tiwari & Khawas, 2021). Meanwhile, anaerobic digestion breaks down organic matter, such as food or plant waste, through micro-organisms in the absence of oxygen. This process produces biogas, which can serve as a source of energy, and a bio-fertilizer by-product (Dey et al., 2021). Waste can be recycled or reused by other industries. For example, food waste generated during the production process can be converted into animal feed (Tiwari & Khawas, 2021; Waste Management in the Food Processing Industry). Surplus food can also be donated to those in need (Torres-León et al., 2018).

Tomatoes (*Lycopersicon esculentum*) are the second-largest vegetable harvest in the world after potatoes. They contain lycopene, phenolics, organic acids, vitamins, and other beneficial components (Lu et al., 2019). In 2021, the total number of tomatoes produced worldwide for processing and fresh consumption was just over 189.1 million metric tonnes (mT). This is a 2% increase from the 184.8 million mT grown in 2020 and a 4% increase over the average (182.7 million mT) of the three years prior (2018-2020) (Food and Agriculture Organization (FAO)).

Worldwide, there are many different ways to eat tomatoes: raw or in the form of processed foods like paste, juice, sauce, puree, and ketchup (Kaur et al., 2008). In general, when tomatoes are processed, a by-product known as tomato pomace (TP) is formed, which consists primarily of peels (40%) and seeds (60%). The peel, and seeds are rich in minerals, fatty acids, proteins, lipids, and amino acids, and they also include bioactive antioxidants like lycopene, beta-carotenoids, tocopherols, polyphenols, and terpenes (Lu et al., 2022). Tomato pomace consists of 5–10% of the fresh weight of tomatoes (Baldacchino et al., 2023).

Because industrial processing generates a huge volume of tomato pomace, the disposal or utilization of TP is an unavoidable challenge that is critical to the food sector. On the one hand, due to its high-water content and nutrient richness, TP is prone to spoilage if not properly disposed of, posing an environmental burden and wasting resources; on the other hand, rational TP utilization, to some extent, converts wastes into usable resources such as lycopene, dietary fibers, and tomato seed oil via bio-refinery (Lu et al., 2019). The resulting by-products after processing tomatoes are a rich source of nutrients and biologically active compounds: carotenoids, proteins, phenolic compounds, mineral substances and oils (Fritsch et al., 2017). To improve the nutritional, textural, and sensory qualities of the meals involved, fine powders of tomato pomace and its peel and seed components that contain significant amounts of dietary fiber, significant amounts of minerals, vitamins, proteins, polyphenols and carotenoids (lycopene, beta-carotene and lutein) can be used as functional food ingredients to be included into wheat flour-based foods, meat products, and tomato paste (Lu et al., 2019). Specialized literature suggests that reusing these by-products can benefit consumer' health by providing ways to incorporate them into their daily diets. This is particularly important for middle-aged individuals who wish to maintain their health and reduce the signs of aging (Azabou et al., 2020; Lu et al., 2022).

The increased public interest in the health benefits of food necessitates the development of new food products as well as the modification of classic recipes. These patterns are also applicable to bakery products, such as bread (Almeida et al., 2013; Badjona et al., 2019) or pasta (Lupu et al., 2023). "Functional bread" is bread that has been enhanced with food industry by-products. The addition of these by-products can improve the nutritional value of the bread while also reducing food waste (Amoah et al., 2020).

Introducing extra components to a product recipe can be a challenging task for food manufacturers. Therefore, it is crucial to evaluate the impact of these components on the final product. The present study investigates the potential use of tomato pomace powder in the bakery industry to improve the nutritional value of bread and other bakery products. The study focuses on the quality characteristics of the flour mixture and resulting bread.

MATERIALS AND METHODS

Materials

Flour and other ingredients

The commercial wheat white flour type 550 (fat: 1.3%; carbohydrates: 69%; protein: 11%; dietary fiber: 3%) was provided by a local supplier. Wheat flour type 550 (F550) is a versatile flour that can be used for a variety of baking purposes, including bread. In addition, this type of flour has a greater amount of protein, which is necessary for the development of gluten, and it also has a wet gluten content (the amount of gluten remaining after washing the dough with water to remove starch, water-soluble pentosans, and water-soluble proteins) of 28.5%, which is ideal for elastic doughs (Kulkarni et al., 1987). The ingredients for the bread - iodized salt, dry yeast - were purchased at a nearby market. The national water distribution system provided the tap water used.

Tomato pomace

The tomatoes (2 kg.) were provided by a local supplier. After washing and cleaning, the tomatoes were placed in a juicer (Gulliver O.M.A.C Italia), which extracted all the juice. The tomato pomace (peels and seeds) was dehydrated, for 12 hours at 40 degrees Celsius in the multitray dryer Klarstein. Subsequently, the pomace was shredded using the Thermomix TM5 food processor and divided into size classes using the Analysett 3 Spartan sieves. The mixtures were created based on the percentage of particles smaller than 20 nm.

Flour mixtures

The breads were obtained through the direct method with small changes in fermentation time and temperature, by varying the amount of added tomato pomace powder (TMF) to wheat flour (F550) in proportions of 5%, 10%, 15% and 25% (w/w). A control sample (CB) was also prepared without the addition of TMF.

Therefore, five loaves of bread formulations were prepared. The recipe of the control sample consists of 500 g of wheat flour, 12.5 g of salt, 15 g of compressed yeast and the amount of water needed to form a dough with optimal characteristics. The amount of water added to each formula was based on farinographic water absorption (WA) determined previously (500 Brabender units consistency). In bread recipes with added TMF, the wheat flour was replaced by a mixture of wheat flour and 25 g of tomato pomace powder, 50 g, 75 g and 125 g, respectively. The coding of the bread samples is shown in Table 1.

Table 1. Sample coding

Type	Coding	Wheat flour (g)	TMF (g)
Control sample	CB	500	-
Sample with 5% TMF	BTMF5	475	25
Sample with 10% TMF	BTMF10	450	50
Sample with 15% TMF	BTMF15	425	75
Sample with 25% TMF	BTMF25	375	125

Note: Tomato pomace powder (TMF)

Methods

Breadmaking procedure

The dough was prepared using the Kitchen Aid Artisan 5KSM7580XEER laboratory mixer. All ingredients were accurately measured and mixed for 5 minutes at speed 1. The mixing arm speed was then increased to 8, and kneading continued for 10 minutes to form and fully develop the gluten network. The resulting dough was left to ferment for 60 minutes at 38°C. After 60 minutes, a brief mixing was performed for 30 seconds, followed by manual division of the dough into pieces weighing 250g±5g.

The samples were formed, placed into rectangular baking molds (18x7.5x7cm) and allowed to finish leavening for 30 minutes at 30 °C. The baking process was carried out in a Whirlpool 6th Sense convection oven at a temperature of 220°C for a duration of 30 minutes. The humidity in the baking room was 70-75% during the first 10 minutes and decreased to 60% by the end of baking. The breads were weighed and cooled to room temperature before measuring all parameters. After cooling, the loaves were placed in special bread packaging and stored at 20ºC prior to testing after 24 and 72 hours.

Farinograph analysis

The Farinograph-E (Brabender, Farinograph-AT, model 8110142, Duisburg model 8110142, Germany) equipped with a 50-g bowl was used to determine the water absorption (WA), dough development time (DDT), stability time (ST), and dough softening (DS) of wheat flour and wheat flour with added TMF dough. The American Association of Cereal Chemistry (AACC) Method 54–21 was employed for the determinations of farinograph parameters (AACC International, 2010).

Determination of bread physicochemical properties

The yield of bread (BY) was calculated as the amount of bread that could be produced from a given weight of flour (Zarzycki et al., 2022). The baking loss (BL) was calculated as the difference between the weight of the dough and the weight of the baked bread. The weight of the samples was measured using a balance (Radwag, model WLC 2/A2, Poland) (Miller et al., 2008).

Bread volume (BV) was determined using the rapeseed displacement method according to AACC Method 10.05-01 after cooling the loaves for two hours at room temperature (AACC International, 2010), and specific volume (cm^3/g) was determined through calculation of the bread volume/bread mass ratio.

The moisture content of the samples was determined by AACC Method 44–15.02. The samples were analyzed 24 h and additionally 72 h after baking (AACC International, 2010).

Samples of length, width, and height measuring 1.5 x 1.5 x 1.5 cm from the geometric center of the crumb were obtained for each type of bread in order to determine the porosity (Tsatsaragkou et al., 2012). Helium was used as the displacement fluid for the gas pycnometer (Stereopycnometer SPY-3, Quantachrome, Syosset, N.Y., USA) in order to estimate the volume of solids (V_S, m^3). The formula for expressing the solid density (kg/m^3), which is the ratio of dry solids' mass to volume, is as follows: $\rho_s = m_s/V_s$. The following formula was used to estimate the bulk density from the measurement of the real geometrical properties of the bead sample: $\rho_b = m_s/V_b$. The porosity was calculated from the following equation: $P\ (\%) = 1 - \rho_s/\rho_b$.

Protein, lipids, and ash content were measured using AACC-approved procedures, such as AACC 46-11.02 (using the Kjeldahl method; total nitrogen multiplied by 5.7 protein conversion factor), AACC 30-25.01, and AACC 08-01.01, respectively (AACC International, 2010).

Sensory analysis

To determine consumer preference for the examined bread formula, 40 evaluators (males and females, ages 21-60) were asked to rate the bread on a 5-point hedonic scale from least liked (1- "dislike very much") to most preferred (5- "like very much"). Shape, crust and crumb color, crust thinness, smell, taste, elasticity, porosity, aftertaste, attractiveness and overall acceptability were considered. The bread samples were coded and distributed in a random order. Each participant rated two replications of each bread recipe. A loaf of bread (uncut) was provided for each formula to evaluate shape. Water was offered to clean the palette between bread samples. The sensory examination was conducted in a laboratory with LED lighting and at room temperature. Staff and students of Transilvania University of Brașov were recruited as evaluators.

Statistical analysis

Each bread sample was tested in triplicate and results were collected from three separate tests. All data are presented as the mean of the three replicates followed by the standard deviation (SD). The significance of mean differences was assessed by one-way ANOVA. Tukey's test ($p \leq 0.05$) was used to compare mean differences (JASP Team, 2022).

RESULTS AND DISCUSSIONS

The examination of farinograph curves can yield valuable insights into how TMF affects the dough's mixing properties and water absorption (Table 2).

Table 2. Farinograph analysis of wheat dough with TMF addition

Sample Code	WA [%]	DDT [min]	ST [min]	DS [FU]
CB	58.8±0.5^{c}	2.8±0.3^{a}	13.2±0.3^{a}	29.2±2.1^{c}
BTMF5	59.9±0.5^{c}	2.6±0.3^{a}	12.1±0.1^{b}	52.5±5.6^{ab}
BTMF10	61.2±0.5^{b}	2.55±0.5^{a}	11.7±0.1^{b}	58.3±3.2^{a}
BTMF15	62.2±0.4^{a}	2.65±0.3^{a}	10.±0.2^{c}	60.2±3.2^{a}
BTMF25	62.8±0.3^{a}	2.65±0.5^{a}	10.5±0.3^{c}	58.8±4.0^{b}

Note: Control sample (CB); Bread with 5% tomato pomace powder (BTMF5); Bread with 10% tomato pomace powder (BTMF10); Bread with 15% tomato pomace powder (BTMF15); Bread with 25% tomato pomace powder (BTMF25); Water adsorption (WA); Dough development time (DDT); Stability time (ST); Dough softening (SD); Values are means ± SD of triplicate determinations.; different letters in superscript within the same column indicate significant differences (Tukey test, $p \leq 0.05$).

The data presented in Table 2 provide information on the effect that the addition of tomato pomace has on the water absorption capacity of the dough and, implicitly on the dough forming capacity. As can be seen, the WA value ranges from 58.8 % to 62.8 %, with no significant ($p>0.05$) variation in BTMF5 (59.9 %), but with significant ($p \leq 0.05$) variations in BTMF10 (61.2), BTMF15 (62.2) and BTMF25 (62.8) compared to the control sample (58.8 %). According to previous studies the high concentration of dietary fiber that tomato pomace brings to the dough significantly ($p \leq 0.05$) increases the hydration capacity of the flour and, implicitly, the quality of the dough and its baking properties (Wang et al., 2002). Moreover, good baking performance is generally indicated by significant water absorption (Zečević et al., 2013).

The analysis of the presented data showed that the strength of the dough is given by indicators such as DDT and ST, which that indicate more tenacious doughs at variance values. The tenacity of the dough increased progressively with the amount of tomato pomace powder added, but the stability of the dough over time suffered slightly. The results of this study, summarized as values in Table 1, indicates that the addition of tomato pomace powder does not have a significant ($p>0.05$) effect on the DDT and ST values. The only exception is observed in the case of 25 % TMF addition, when the ST value decreases to 10.5 min. A minimum DDT of 2.65 min. as the amount of TMF added increases can be explained, according to studies by (Dima Gheonea, 2021), by the reduction /dilution of the gluten content in the studied flour mixtures.

In terms of ST, most types of flour on the market have an ST value less than or equal to 10 min. (Mohamed et al., 2006). In the case of this study, this value varies between 10.5 min. and 13.2 min. and is inversely proportional to the amount of tomato pomace added. The lowest value (10.5 min.) was obtained with the highest percentage of TMF added (25 %). The same trend of decreasing the stability over time of doughs with added dietary fiber has been reported by other authors (Codină et al., 2019; Liu et al., 2018).

In our investigation, compared to the control, the addition of TMF increased the degree of dough softening (Table 2). Nawroka's (Nawrocka et al., 2016) addition of carob fiber to the dough resulted in an increase in the degree of softening, which is consistent with the current investigations.

The results mentioned above can be partially explained by the interaction between added dietary fiber and gluten found in flour. In the first phase, dietary fiber absorbs water, preventing the complete hydration of proteins. This leads to incomplete and delayed formation of the gluten network during the dough mixing process (Liu et al., 2018).

Table 3 displays the results of the physical characteristics of the tested bread recipes. All bread samples exhibited good production and acceptable baking loss, consistent with previously reported data in the literature (Dziki et al., 2019; Wirkijowska et al., 2020).

Table 3. Physico-chemical properties of bread with the addition of TMF

Sample Code	BY [%]	BL [%]	Specific volume [cm^3/g]	Crumb moisture after 24h [%]	Crumb moisture after 72h [%]	Crumb porosity [%]
CB	140.1±0.6^c	12.3±0.3^a	301.4±5.3^a	42.7±0.3^a	40.7±0.4^a	78.0±0.3^a
BTMF5	141.8±0.6^b	11.6±0.3^a	290.1±5.1^b	43.5±0.2^c	42.5±0.2^c	76.81±1^b
BTMF10	142.9±0.6^a	11.5±0.5^a	285.7±5.1^b	42.3±0.3^a	41.3±0.3^a	76.11±1^b
BTMF15	144.5±0.5^a	11.0±0.3^a	280.8±2.2^c	42.5±0.1^b	41.5±0.1^b	75.80±0.4^c
BTMF25	141.2±0.6^b	11.9±0.4^a	265.5±2.3^c	42.8±0.4^a	41.8±0.4^a	74.06±1^b

Note: Control sample (CB); Bread with 5% tomato pomace powder (BTMF5); Bread with 10% tomato pomace powder (BTMF10); Bread with 15% tomato pomace powder (BTMF15); Bread with 25% tomato pomace powder (BTMF25); Bread yield (BY); Baking loss (BL); Values are means ± SD of triplicate determinations.; different letters in superscript within the same column indicate significant differences (Tukey test, $p \leq 0.05$).

In this study, it was found that replacing wheat flour with TMF at levels ranging from 5% to 25% resulted in only a slight increase in BY and a slight decrease in BL compared to the control. The BY value ranged from 140.1% (CB) to 144.5% (BTMF15). This increase in BY can be attributed to the increase in WA observed with the addition of TMF, which is consistent with previous studies reported by other researchers (Dziki et al., 2019).

The examined bread samples had a BL value ranging from 11% to 12.3%, slightly lower than values reported by other authors for wheat bread and bread with added dietary fiber components (ranging from 11.0% to 15.8%) (Blicharz-Kania et al., 2023; Kasprzak & Rzedzicki, 2012; Wirkijowska et al., 2020; Zarzycki et al., 2022). Additionally, the overall baking loss was not significantly affected by the inclusion of TMF ($p>0.05$).

The loaf volume is one of the most important variables in determining bread quality as consumers tend to find larger-volume loaves more enticing (Makowska et al., 2023). The addition of vegetable by-products resulted in a decrease in SV, which ranged from 265.5 cm^3/g (BTMF25) to 301.4, with the control sample having the highest value. However, it can be observed that the SV decreased with increasing the percent of TMF added. The specific volume decreased by 11.9% with the addition of 25 TMF, which was the most sensible reduction observed. In their study, (Nour et al., 2015) investigated the effect of adding dry tomato waste on bread volume and reported that the bread with tomato waste added showed a strong decrease in volume compared to the control bread. Furthermore, (Mironeasa et al., 2018) showed a rise in bread volume in their investigation on the impact of tomato seed flour addition, especially when the addition did not surpass 10%.

The moisture content of the crumbs ranged from 42.3% to 43.5% after 24 hours and from 40.7% to 42.5% after 72 hours. The addition of TMF caused a maximum increase in moisture content of 2.84% after 24 hours and 4.42% after 72 hours. Moreover, there were significant variations ($p\leq0.05$) in the moisture content of the crumb after 24h and after 72 amongst the bread samples. In contrast to the control, the TMF-enriched bread showed somewhat more crumb wetness.

Crumb porosity showed the greatest reduction when TMF was substituted for wheat flour among the physical characteristics assessed in the study that was presented (Table 3). For the BTMF25 sample and the control sample, the crumb porosity varied from 78.0 to 74.06%. Other authors report a crumb porosity of 88.4% and 79.8 % for two pan bread samples made from white flour, 64.8% for steamed bread and 79.4% for a French baguette (Falcone et al., 2006; Gao et al., 2015). According to the results, a lower porosity of the bread crumb is correlated with an increased inclusion of vegetable by-products.

TMF can be a valuable resource for producing functional bread due to its substantial higher content of dietary fiber, protein, and fat compared to wheat flour (Table 4).

Table 4. Chemical composition of wheat flour, TMF and bread with addition of TMF

Sample Code	Moisture content [%]	Fat [%]	Protein [%]	Ash [%]
F550	9.4±0,1	1.3±0.2	11±0.3	0.55±0.3
TMF	8.1±0,1	12.2± 0.2	21.7± 0.4	2.5 ± 0.6
CB	43.8±0.6^{b}	0.6±0.3^{a}	11.5±0.1^{b}	2.61±0.1^{a}
BTMF5	41.8±0.6^{b}	1.0±0.3^{a}	12.1±0.1^{b}	2.72±0.2^{c}
BTMF10	42.9±0.6^{a}	1.3±0.5^{a}	13.5.7±0.1^{b}	2.85±0.3^{a}
BTMF15	43.1±0.5^{a}	1.5±0.3^{a}	13.8±0.2^{c}	2.97±0.1^{b}
BTMF25	43.3±0.6^{b}	1.9±0.4^{a}	16.5±0.3^{c}	3.5±0.4^{a}

Note: Wheat white flour type 550 (F550); Tomato pomace powder (TMF); Control sample (CB); Bread with 5% tomato pomace powder (BTMF5); Bread with 10% tomato pomace powder (BTMF10); Bread with 15% tomato pomace powder (BTMF15); Bread with 25% tomato pomace powder (BTMF25); Values are means ± SD of triplicate determinations.; different letters in superscript within the same column indicate significant differences (Tukey test, p≤0.05).

The moisture content in tomato pomace can range from 45% to 80% depending on the processing technology (Vasyliev et al., 2022). In this study, the moisture content of the dried TMF was found to be 8.1%. This value differs from the moisture content of 5.1% reported by other authors (Beglița et al., 2023). The moisture content of the samples with added tomato pomace ranged from 41.8% to 43.3%. Although there was a small increase in moisture content, the maximum being found in BTMF25 (43.3%), these changes were not statistically significant (p>0.05). Ather authors (Nour et al., 2015; Wirkijowska et al., 2023) also noted a change in moisture content with the addition of tomato pomace.

The fat content of tomato pomace may vary depending on the amount of seeds present, as they are richer in protein and fat compared to the peels. According to some authors, the fat content ranged from 85.2 to 244.7 g/kg, with an average of 128.7 g/kg, based on the specific variety of tomatoes and the local processing conditions (Lu et al., 2022). The study found a significant (p≤0.05) increase in fat content in bread samples with added tomato pomace, with the increase being proportional to the amount of pomace added. The maximum increase was observed in the BTMF25 sample, which had a fat content of 1.9%. Compared to the control bread (CB), the fat content increased by 166.7% in the BTMF5 sample and 316.7% in the BTMF25 sample. These results are consistent with previous studies in the literature (Wirkijowska et al., 2020; Zarzycki et al., 2022).

The protein content of dried tomato pomace can vary from 20.77% to 21.9% (Lu et al., 2022). The protein content of the samples with added TMF ranged from 12.1% (BTMF5) to 16.5% (BTMF25) in this study. Compared to CB, we observed an increase in protein content of 5.2% for BTMF5 and 43.5% for BTMF25. Furthermore, we found that the increase was proportional to the amount of TMF added. Other authors have also observed this trend (Wirkijowska et al., 2023).

The addition of tomato pomace did not significantly affect the ash content of the bread samples. The ash content varied slightly based on the percentage of tomato pomace used, which is consistent with previous research by other authors (Wirkijowska et al., 2023). The ash content ranged from 2.72% for the BTMF5 sample to 3.5% for the BTMF25 sample.

Sensory evaluation of bread

The success of a new product or formula is largely dependent on consumer desire and sensory acceptability. In order to ascertain consumer approval and pinpoint any insufficient sensory aspects, a sensory evaluation was carried out in addition to evaluating the bread's other quality elements.

Figure 1 shows the sensory attributes of bread samples with varying percentages of tomato pomace powder, including shape, crust and crumb color, crust thinness, smell, taste, elasticity, porosity, aftertaste, attractiveness and overall acceptability.

The bread with medium BTMF15 tomato pomace powder, to which 15% powder was added, received the highest mean score of 4.82 out of 5, indicating its preference among customers due to its distinctive characteristics. This finding suggests that consumers prefer a moderate amount of tomato pomace powder in their bread. Conversely, samples with 25% powder additions received the lowest score of 4.04 points and were rejected. The samples BTMF15 and BTMF10, which had 5% and 10% tomato pomace powder added, respectively, received ratings of 4.45 and 4.59 points. These ratings were slightly higher than the control sample, which received 4.4 points.

Other authors (Majzoobi et al., 2011; Wirkijowska et al., 2023) reported different findings regarding the use of tomato pomace, which also affected taste. These results are not consistent with the current observations.

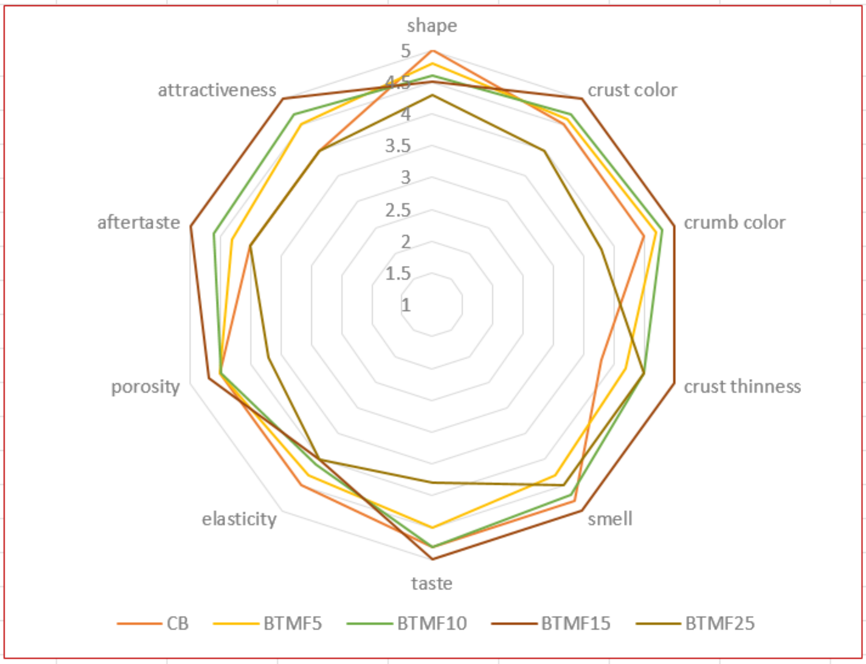

Figure 1. Sensory analysis of the bread samples. Control sample (CB); Bread with 5% tomato pomace powder (BTMF5); Bread with 10% tomato pomace powder (BTMF10); Bread with 15% tomato pomace powder (BTMF15); Bread with 25% tomato pomace powder (BTMF25).

CONCLUSIONS

The addition of tomato pomace powder influenced farinograph characteristics by increasing water absorption and dough softening, while decreasing dough development time and stability time. However, there were no significant changes observed in the quality of the bread, including baking yield, loss, and crumb moisture. The addition of 25% tomato pomace powder resulted in a significant decrease of 11.9% in the specific volume, which was the most notable reduction observed. The study assessed various physical characteristics, and the greatest reduction was observed in crumb porosity, which ranged from 78.0 in control bread to 74.06 in bread with 25% tomato pomace powder. The results indicate that an increased inclusion of vegetable by-products is correlated with a lower porosity of the bread crumb. The incorporation of vegetable processing waste from tomatoes into a bread recipe resulted in significant improvements in the nutritional composition of the bread. The bread with added tomato pomace powder showed higher protein and lipid content compared to the control sample. Specifically, the addition of 25% tomato pomace powder increased fat content by 316.7%, protein content by 43.5%, and ash content by 34.1%. The sensory evaluation revealed that higher levels of tomato pomace powder (25%) negatively affected overall acceptability of the bread while the bread with medium tomato pomace powder, to which 15% powder was added, received the highest mean score of 4.82 out of 5, indicating its preference among customers due to its distinctive characteristics. This finding suggests that consumers prefer a moderate amount of tomato pomace powder in their bread. These results highlight the potential of vegetable by-products, specifically tomato pomace powder, as beneficial food additions that can improve bread's nutritional value. Not only does this support sustainability, but it also aids in lowering food waste when these waste materials are used in food production. In addition, future studies ought to focus on finding new uses and maximizing the use of this vegetable processing waste in a range of food items. It is crucial to concentrate on determining the ideal supplementation levels to enhance the bread's sensory qualities with different percentages of tomato pomace powder while maintaining the intended nutritional advantages. Such initiatives will support a more resource-efficient and sustainable method of producing food, as well as increase the use of vegetable by-products in the food sector.

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Conflicts of Interest

The authors declare that they do not have any conflict of interest.

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