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Incorporation of tomato peel (*Solanum lycopersicum* L.) into scones: effects on nutritional composition, fatty acids, and sensory traits

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Incorporación de cáscara de tomate (*Solanum lycopersicum* L.) en scones: efectos sobre la composición nutricional, ácidos grasos y características sensoriales

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ABSTRACT

Food losses and waste correspond to environmental, economic, ethical, and nutritional problems affecting the world. Since most waste is generated at the household level, developing initiatives to recover and revalue it is essential. The present study evaluated the incorporation of tomato (*Solanum lycopersicum* L.) peels (CT) as an ingredient in scones when replacing milk and part of margarine. Scones were formulated with the addition of CT at 20, 25, and 30% of the weight of the dough, and a control sample (M1) was kept. The prepared samples' nutritional composition, carotenoid content, instrumental color, specific volume, and sensory acceptability were evaluated. The fatty acid profile was analyzed in M1 and another sample with CT. A 9-point hedonic scale per parameter was used for sensory evaluation. Incorporating CT in scones made it possible to produce healthier products, with lower fat content, higher dietary fiber content, carotenoids, and lower caloric intake. The specific volume decreased in the scones with CT. The color acquired red tones and, the luminosity decreased. Sensory acceptability was high, with higher ratings for the sample with 30% CT. In the fatty acid profile, saturated fatty acids increased, monounsaturated and polyunsaturated decreased, compared to M1. It was concluded that the incorporation of CT in the preparation of scones is feasible, healthier products were obtained, and well qualified in sensory acceptability.

Keywords:
Bakery
Sensory
Specific volume
Waste

RESUMEN

Las pérdidas y desperdicios de alimentos son un problema ambiental, económico, ético y nutricional que afectan al mundo. Dado que la mayor parte de los residuos se genera a nivel doméstico, es esencial desarrollar iniciativas para su recuperación y valorización. El presente estudio evaluó la incorporación de cáscara de tomate (*Solanum lycopersicum* L.) (CT) como ingrediente en bollitos en reemplazo de leche y parte de la margarina. Los bollitos se formularon con adición de CT en un 20, 25 y 30% del peso de la masa y se conservó una muestra control (M1). De las muestras preparadas se evaluó la composición nutricional, el contenido de carotenoides, el color por método instrumental, el volumen específico y la aceptabilidad sensorial. El perfil de ácidos grasos se analizó en M1 y otra muestra con CT. Para la evaluación sensorial se aplicó una escala hedónica de 9 puntos por parámetro. La incorporación de CT en scones permitió elaborar productos más saludables, con menor contenido de grasa, mayor contenido de fibra dietética, carotenoides y menor aporte calórico. El volumen específico disminuyó en los bollitos con CT. El color adquirió tonos rojos y la luminosidad disminuyó. La aceptabilidad sensorial fue positiva, con calificaciones más altas para la muestra con 30% de CT. En el perfil de ácidos grasos, aumentaron los ácidos grasos saturados, disminuyeron los monoinsaturados y poliinsaturados, en comparación con M1. Se concluyó que la incorporación de CT en la preparación de bollitos es factible, se obtuvieron productos más saludables y bien calificados en aceptabilidad sensorial.

Palabras clave:
Productos horneados
Sensorial
Volumen específico
Desperdicios

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According to FAO (2019) data, 14% of food, with an estimated value of US$ 400 billion, is lost between harvest and distribution worldwide, and 17% is wasted in distribution and among final consumers (PNUMA 2021). This is an economic, environmental, ethical, and nutritional problem. Consumers can reduce "waste" by taking advantage of what is commonly known as "inedible parts" of some foods, such as vegetable peels. When revaluing these, their nutrients and bioactive compounds are used, since, in several vegetables, the peels contain more nutrients, dietary fiber, polyphenols, and other bioactive compounds than the pulp (Rocha da Costa et al. 2023). Further, its use allows to reduce waste.

Data from a household survey in Santiago, Chile, indicate that the average food waste was 0.96 kg per week per capita, and the main group of wasted food corresponds to fruits and vegetables (Cáceres-Rodríguez et al. 2021). The waste products must be revalued as they contain nutrients, pigments, and bioactive compounds that enhance processed foods, such as bakery products.

Several studies have explored the use of fruits and vegetable peels as partial substitutes for flour in baked products, increasing the content of dietary fiber and bioactive compounds while reducing caloric intake. Some studies have shown an increase in satiety because of the higher dietary fiber content. When vegetable peels are added, the dough changes, and the leavening effect is diminished. The concentrations at which they are added must be carefully monitored as in some cases, the products acquire strong or uncharacteristic residual aroma and flavor (Martins et al. 2017; Santos et al. 2022; Quitral et al. 2022, 2023).

Baked products are a highly consumed food by a large part of the population (Moretton et al. 2023). They are consumed at breakfast as snacks, and to accompany other meals. They are made with flour, butter, margarine or oil, eggs, sugar, milk, and other ingredients. Their caloric intake in general is high, attributed to the fat they contain and carbohydrates. Scones, or English rolls, are characterized by their flavor and soft texture; they are very pleasant and have high acceptability among consumers, despite their high caloric intake.

In this type of product, vegetable peels can be used to replace part of other ingredients and provide nutrients and bioactive compounds. The incorporation of vegetable peels alters the color of baked products (measured instrumentally) in various cases, the specific volume decreases, and the sensory characteristics are favored or harmed depending on the concentration of peels incorporated (Martins et al. 2017).

Tomato peels are interesting to research due to their attractive color produced by carotenoids and their high availability since tomato is a widely consumed vegetable. It is consumed fresh, in culinary preparations, and processed products. It is rich in carotenoids, especially lycopene, which is a powerful antioxidant, and contains tocopherols, polyphenols, organic acids, vitamins, and other components beneficial to health. At an industrial and domestic level, tomato by-products are eliminated, which must be valued and rescued to take advantage of their nutrients and bioactive compounds (Navarro-González et al. 2011).

This study aimed to assess the impact of replacing milk and part of margarine with fresh tomato peel on the nutritional composition, fatty acid profile, carotenoid content, physical properties, and sensory acceptability of scones.

MATERIALS AND METHODS

Formulations

This study employs a quantitative experimental design to formulate scones with tomato peels (CT) at varying concentrations, substituting milk and a portion of the margarine. The independent variable is the concentration of CT in scones. The dependent variables are nutritional composition, total carotenoid content, color, specific volume, sensory acceptability, and fatty acid profile. CT was obtained from household discards through the manual peeling of tomatoes, the inclusion of the red layer attached to the skin. The peels were washed exhaustively with water, dried with absorbent paper, and ground in a manual grinder.

Scones were made for a traditional recipe based on flour, eggs, margarine, milk, sugar, baking powder, and salt. Three formulations were developed in which milk was eliminated; the margarine concentration was reduced by 25, 35, and 50%; and CT was added at 20, 25, and 30% of the total mass. A control sample, without tomato peel, was also prepared. The dough was divided into units of 50 g and baked in an oven at 175 °C for 20 minutes. The formulations are presented in Table 1.

Table 1. Scone formulations with tomato peel (CT).

Ingredients/formulations	M1	M2	M3	M4
Flour (g)	52	52	52	52
Eggs (g)	6	6	6	6
Sugar (g)	3	3	3	3
Baking powder (g)	2	2	2	2
Salt (g)	1	1	1	1
Milk (mL)	25	0	0	0
Margarine (g)	11	8.25	7.15	5.5
Tomato peel (CT) (g)	0	20	25	30
Water (mL)	0	7.75	3.85	0.5

Chemical analysis

The nutritional composition was determined using official methods (AOAC 2012). Humidity was measured by the thermogravimetric oven drying method at 105 °C. Fat content was determined by solvent extraction using the Soxhlet method. Proteins were analyzed according to the Kjeldahl method. Ash content was measured by the thermogravimetric method, with incineration in a muffle furnace at 550 °C. Total dietary fiber (TDF) was determined using a gravimetric enzymatic method, with soluble (SDF) and insoluble fiber (IDF) components assessed separately. Carbohydrates were calculated by difference. Caloric intake was estimated by multiplying the values for proteins, fats, and carbohydrates by the Atwater factors. Total carotenoids were evaluated using a spectrophotometric method, and the fatty acid profile was determined by chromatography (AOAC 2012).

Determination of color

Instrumental color was evaluated for CIELab values with a Hunter colorimeter and specific volume according to the seed displacement method (AACC 2010).

Sensory analysis

Acceptability test with a 9-point hedonic scale for parameters (Abalos et al. 2023; Sugumar and Guha 2022). The test was applied to 93 consumers, 50 women, and 43 men, aged 20 to 60. Single-blind study. Each scone sample was evaluated individually. A sample and the answer sheet were given to the evaluator. Each description was assigned a numerical value from 1 to 9 (1 for “I dislike it too much” and 9 for “I love it”), and the average was calculated for each parameter per sample.

Statistical analysis

The data were analyzed by analysis of variance (ANOVA) and Tukey’s test to establish significant differences between the samples at $P<0.05$. All experiments and analyses were conducted in triplicate to ensure the reliability of the results.

RESULTS AND DISCUSSION

The incorporation of CT in the scone dough was effective, readily integrating with the other ingredients to produce a dough with suitable properties. Consistent with this observation, Gu et al. (2020) reported that CT exhibits high water retention capacity (7.9 g g^{-1}), water solubility (18%), oil retention capacity (4.5 g g^{-1}), and swelling capacity (12.4 mL g^{-1}), due to its dietary fiber content, which likely facilitated its convenient addition and homogeneous mixing with the other components.

As shown in Table 2, the protein and ash content do not exhibit statistically significant differences between the analyzed samples. In contrast, the fat content was significantly higher ($P<0.05$) in the control sample and demonstrated a reduction with increasing CT incorporation. The carbohydrate content was significantly higher ($P<0.05$)

in sample M1. Statistically significant differences ($P<0.05$) were observed in the total dietary fiber (TDF) content, with M1 displaying the lowest value and M4 the highest. A similar trend was observed for soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). The caloric intake is significantly higher in M1 and significantly lower in M4 ($P<0.05$).

Table 2. Nutritional composition and carotenoids in scones in 100-gram dry weight (dw).

	M1	M2	M3	M4
Proteins (g)	10.9±0.367[a]	10.8±0.286[a]	11.3±0.474[a]	11.3±0.242[a]
Fat (g)	10.5±0.345[b]	7.1±0.421[a]	6.5±0.420[a]	6.3±0.227[a]
Ashes (g)	4.1±0.514[a]	4.2±0.188[a]	3.7±0.043[a]	3.7±0.201[a]
Carbohydrates (g)	68.0±0.989[b]	64.5±1.152[a]	64.9±0.834[a]	63.4±0.489[a]
Total dietary fiber (TDF) (g)	6.4±0.303[a]	12.9±0.536[b]	13.6±0.376[b]	15.3±0.324[c]
Soluble dietary fiber (SDF) (g)	1.8±0.220[a]	2.7±0.294[b]	2.9±0.169[b]	4.3±0.179[c]
Insoluble dietary fiber (IDF) (g)	4.6±0.270[a]	10.1±0.406[b]	10.8±0.207[bc]	11.0±0.302[c]
Energy (kcal)	411±4.400[c]	365±2.645[b]	363±2.449[b]	355±1.391[a]
Carotenoid totals (mg)	ND	2.7±0.147[a]	2.9±0.312[a]	3.2±0.310[a]

M1: control sample; M2: sample with 20% of CT, 25% margarine reduction; M3: sample with 25% of CT, 35% margarine reduction; M4: sample with 30% of CT, 50% margarine reduction; ND: not detected. The detection limit is $\leq$0.60 mg 100 g^{-1}. Different letters indicate significant differences between the samples ($P<0.05$).

Eliminating milk from formulations and substituting part of the margarine with tomato peels resulted in a significant decrease in fat content of 32, 38, and 40% in M1, M2, and M3, respectively, compared to M1. The incorporation of CT also led to a reduction in caloric intake in M2, M3, and M4 by 11, 12, and 14%, respectively. Furthermore, a significant increase in dietary fiber, primarily in IDF, was observed. A negative correlation was found between the CT content in scones and both fat and energy (R^2=0.994, 0.960, and 0.780, respectively). From a nutritional perspective, scone formulations incorporating CT appear healthier due to their lower fat, carbohydrate, and caloric content, coupled with a higher DF contribution. These findings align with other studies demonstrating that the addition of vegetable peels can reduce caloric intake while enhancing dietary fiber content (Martins et al. 2017; Quitral et al. 2022).

The carotenoid content in CT was measured at 15.5 mg 100 g^{-1}, and its concentration in the scone samples increased with higher CT concentrations in the formulations. No statistically significant differences in carotenoid content were observed among the scone samples containing CT. Notably, the total carotenoid concentration in CT is higher than that reported by Beltrán et al. (2012) for common raw tomato (2.66 mg 100 g^{-1}) and by Pataro et al. (2018) for tomato skin (10 mg 100 g^{-1}). It is important to note that the carotenoid content in tomatoes is generally higher in the peel than in the pulp (Meléndez-Martínez et al. 2023).

Carotenoids are susceptible to degradation by heat; the baking temperature of 175 °C is relatively high, likely to affect the carotenoid concentration in the scone samples. Burešová et al. (2021) reported a 26% loss of carotenoids in bread baked al 220 °C. Elevated temperatures can induce degradation, isomerization, and oxidation of carotenoids (Shen et al. 2015). Conversely, thermal processing of food can lead to interaction with other lipophilic constituents, potentially modifying the quantity of carotenoids released from the food matrix (Kotíková et al. 2016).

The incorporation of tomato peels into flour-based products increases the carotenoid concentration, offering potential health benefits due to their antioxidant properties and provitamin A activity. Furthermore, they impart reddish hues to foods, which can be a desirable attribute (Salanţă and Fărcaş 2024). The addition of peels or other fruit and vegetable by-products to baked goods introduces bioactive compounds, such as polyphenols and carotenoids, thereby enhancing the antioxidant capacity of the products (Santos et al. 2022).

Table 3 presents the luminosity (L*), which shows no significant differences between the samples. However, the a* (redness) and b* (yellowness) values increased noticeably with CT incorporation. Chroma (C*) and hue angle (H*) were also higher in samples containing CT. The color difference (∆E*) compared to the control sample did not show significant differences between among the CT-containing samples.

The instrumental color analysis results are consistent with a study on bread incorporating tomato pomace, which also reported an increase in a* and b* values (Martins et al. 2017). The intense red color of tomatoes and their peels contributes to this coloration in the final products. The observed increase in a* and b* aligns with the findings of Bhat and Ahsan (2015) in cookies containing tomato pomace powder (OTP). However, their study reported a decrease in L* with OTP addition, which the authors attributed to the reduced flour concentrations as OTP concentration increased.

By incorporating CT in scones, the specific volume decreases proportionally, as seen in Table 3 and Figure 1. Tomato peel contains dietary fiber, which weakens the structure of gluten, causing less CO_2 retention in the scones (Bora et al. 2019).

Table 3. Instrumental color and specific volume of scone samples.

	M1	M2	M3	M4
L*	66±4.00^{a}	68±4.36^{a}	68±6.08^{a}	69±6.56^{a}
a*	0.3±0.20^{a}	8.2±0.46^{b}	7.8±0.53^{b}	9.1±1.99^{b}
b*	23.4±1.60^{a}	35.6±2.29^{b}	36.0±3.04^{b}	35.1±1.05^{b}
∆E*	-	14.8±0.21^{a}	16.5±5.17^{a}	16.7±3.44^{a}
C*	23.4±1.60^{a}	36.5±2.13^{b}	36.8±3.10^{b}	36.3±0.79^{b}
H*	0.01±0.01^{a}	0.23±0.03^{b}	0.21±0.01^{b}	0.25±0.06^{b}
Specific volume ($cm^3 g^{-1}$)	2.28±0.07^{a}	2.23±0.11^{a}	2.20±0.10^{a}	2.17±0.21^{a}

M1: control sample; M2: sample with 20% of CT, 25% margarine reduction; M3: sample with 25% of CT, 35% margarine reduction; M4: sample with 30% of CT, 50% margarine reduction. Different letters indicate significant differences between the samples (*P*<0.05).

Figure 1 presents the differences in color and shape of the samples. The color differences in the crumb are more noticeable than in the crust. The specific volume of

M1 M2 M3 M4

Figure 1. Scones samples. M1: control sample; M2: sample with 20% of CT, 25% margarine reduction; M3: sample with 25% of CT, 35% margarine reduction; M4: sample with 30% of CT, 50% margarine reduction.

the samples is lower than the values reported by other researchers for bread, which typically exceed 3 cc g^{-1} (Mudgil et al. 2016; Ding et al. 2019). However, the results of this study are comparable to those observed in gluten-free bread and muffins by Gostin (2019) and Bora et al. (2019). According to Burton and Lightowler (2006), this reduction in specific volume could be advantageous as it is associated with a lower glycemic index and increased satiety.

A strong negative correlation (-0.946) was observed between the specific volume of the scones and increasing CT concentration. This phenomenon can be attributed to the incorporation of dietary fiber from CT. Specific volume is a critical characteristic of baked products, influencing the perception of a light and spongy texture. It is primarily determined by gas production and retention during baking, a process largely dependent on gluten development. The samples containing CT exhibited significantly higher DF content, and increasing its concentration in the dough has been shown to reduce the rate of hydration and gluten development (Xu et al. 2021), consequently affecting the specific volume. Furthermore, the reduction in fat content, which plays a crucial role in air bubble incorporation and contributes to increased volume and a porous structure, also likely influenced this result. Fat also aids in moisture retention, leading to a moist and tender crumb, and interacts with starch to form lipid-amylose complexes, thereby inhibiting retrogradation (Garvey et al. 2020).

Overall, the samples demonstrated high sensory acceptability, as illustrated in Figure 2. Appearance was rated significantly higher (P<0.05) in M1 and M4. No significant differences were found in the color of the samples. Regarding aroma, significant differences (P<0.05) were observed, with M4 receiving the highest acceptability score and M2 the lowest. Flavor acceptability was significantly higher (P<0.05) in M1, M2, and M4. Texture was also rated significantly higher (P<0.05) in M1 and M4.

Despite the variations in individual attributes, all samples exhibited high overall sensory acceptability. No significant correlation was found between the amount of CT incorporated into the samples and the ratings of the sensory attributes evaluated using a 9-point hedonic scale. Based on the overall evaluation, sample M4 was the preferred formulation.

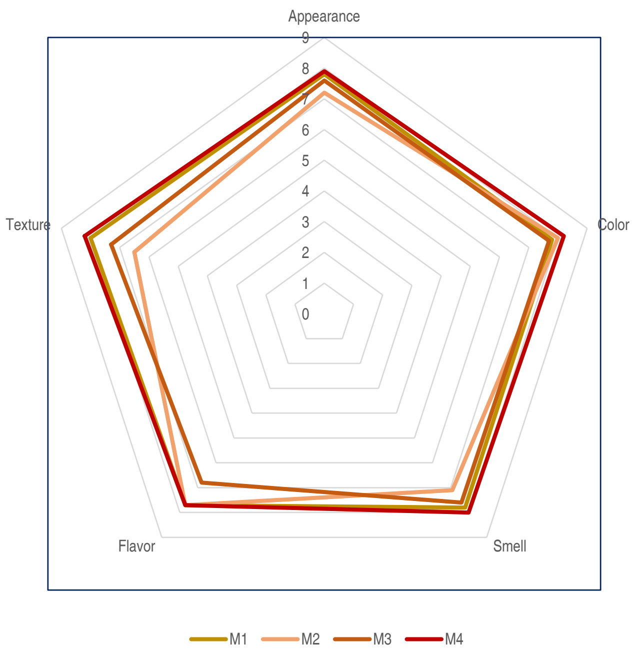

Figure 2. Sensory test radial graph – 9-point hedonic scale. M1: control sample, M2: sample with 20% of CT, 25% margarine reduction, M3: sample with 25% of CT, 35% margarine reduction, and M4: sample with 30% of CT, 50% margarine reduction.

In contrast to the results obtained in this study, Bhat et al. (2015) reported that the incorporation of tomato pomace powder negatively impacted the sensory parameters of appearance, color, texture, and flavor in cookies, recommending a maximum addition of 5%. In this study, the addition of fresh tomato peel, without dehydration, as a substitute for milk and part of margarine, yielded more favorable sensory outcomes.

Based on the results presented in Table 4, sample M4 exhibits a higher proportion of saturated fatty acids compared to M1. The amount of monounsaturated fatty acids is similar between the samples, while polyunsaturated fatty acids are present at a slightly higher concentration in M1. Notably, sample M4 contains linolenic acid, whereas trans fatty acid content is below 0.1% in both samples.

Table 4. Fatty acid profile of scone samples.

Fatty acid	M1	M4
Saturated (%) methyl esters	-	-
C6:0 caproic	0.21	-
C8:0 caprilic	0.63	0.37
C10:0 capric	0.77	0.33
C12:0 lauric	7.34	5.52
C14:0 miristic	3.72	2.35
C15:0 pentadecanoic	0.13	0.04
C16:0 palmitic	14.19	24.91
C17:0 heptadecanoic	0.14	0.13
C18:0 stearic	8.89	9.07
C22:0 docosanoic	0.43	0.33
C24:0 tetracosanoic	0.12	-
The sum of saturated fatty acids	36.58	43.18
Monounsaturated % methyl esters	-	-
C14:1 ω 5 miristoleic	0.11	-
C16:1 ω 7 palmitoleic	0.51	0.39
C18:1 ω 9 oleic	25.39	28.10
C18:1 ω 7 oleic	1.24	0.84
C20:1 ω 15 eicosaenoic	3.98	-
C20:1 ω 9 eicosaenoic	0.39	0.25
The sum of monounsaturated fatty acids	31.62	29.59
Polyunsaturated (%) Methyl esters	-	-
C18:2 ω 6 linoleic acid	31.63	25.27
C18:3 ω 3 linolenic acid	-	1.87
C20:4 ω 6 eicosatetraenoic acid	0.17	0.10
The sum of polyunsaturated fatty acids	31.80	27.23
Isomers trans (%) methyl esters	<0.1	<0.1

M1: Control sample, M4: sample with 30% of CT, 50% margarine reduction.

The fatty acid profile reveals that in M4, saturated fatty acids increased by 18% compared to the control sample, while monounsaturated and polyunsaturated fatty acids decreased by 6.4 and 14.4%, respectively. Different results might have been anticipated, given that M4 is formulated without milk, a significant source of saturated fatty acids, and relatively low in polyunsaturated fatty acids. However, margarine, an ingredient in M4, does contribute saturated fatty acids. Consequently, while the concentration of SFAs in M4 is lower compared to milk-containing formulations, their presence is still attributable to the inclusion of margarine. Linolenic acid was detected in sample M4 but not in M1. Sample M4 had a lower margarine content and did not contain milk; the primary lipid source in this formulation was eggs. Among individual fatty acids, palmitic acid and oleic acid concentrations were 75 and 11% higher in M4 compared to M1, respectively. These fatty acids are constituents of eggs, an ingredient present at a higher ratio to margarine in M4 (1.1:1) than in M1 (0.5:1). The concentration of palmitic acid, oleic acid, and linolenic acid were significantly elevated in M4. According to Elbadrawy and Sello (2016), tomato peel contains 15.2% palmitic acid, 19.1% oleic acid, and 4.3% linolenic acid. The latter two are particularly beneficial for health: oleic acid is associated with a reduced incidence of cardiovascular disease, and linolenic acid is an essential fatty acid and a precursor to EPA and DHA. Tomato peel also contains linoleic acid, another essential fatty acid.

A key strength of this study is its demonstration that vegetable peels can be utilized at the consumer level with minimal processing (simply washing) and still yield positive nutritional and sensory outcomes. Common baked goods like scones often have a high fat content, which can be effectively reduced through the incorporation of vegetable peels, leading to healthier products.

CONCLUSION

Incorporating fresh tomato peels as an ingredient in scones, substituting part of the margarine and all the milk, yielded favorable outcomes. From a nutritional standpoint, this approach effectively reduced total fat content and caloric intake while increasing dietary fiber. Furthermore, carotenoids were successfully incorporated into the scones. The addition of CT influenced the color, resulting in predominantly red tones and a decrease in luminosity. However, the specific volume was negatively affected, indicating a need to explore alternative strategies to mitigate this issue. Scone samples containing CT demonstrated high sensory acceptability, with sample M4 (containing 30% CT and 50% margarine reduction) identified as the most promising formulation. This sample exhibited significantly high levels of TDF, SDF, and IDF, along with a lower caloric content and a distinct fatty acid profile compared to the control sample M1, notably including linolenic acid. This study contributes to the growing body of knowledge regarding the utilization of vegetable peels, specifically fresh tomato peels, in this case, as functional ingredients in flour-based foods. Future research should focus on investigating methods to enhance the specific volume of scones incorporating CT, determining their shelf life, and evaluating their potential for industrial-scale applications.

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CONFLICT OF INTERESTS

The authors have no conflict of interest.

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