Valorization strategies of dietary fiber and carotenoids from a by-product of organic tomato processing as potential ingredients in functional food formulations

Yhonattan Nicolás López Bermúdez, Juan Felipe Aldana Heredia, Andrea del Pilar Sánchez-Camargo, María Hernández Carrión

Grupo de Diseño de Productos y Procesos (GDPP), Departamento de Ingeniería Química y de Alimentos, Universidad de los Andes, Bogotá (Colombia)

ABSTRACT
Production of tomato-based products generates a percentage of waste of 5%, composed mainly of peel. This has a significant source of carotenoids, such as lycopene, and an appropriate amount of total dietary fiber (TDF). Both carotenes and dietary fiber are known to have functional effects on the human body. Therefore, the aim of this research work was mainly divided into two parts. Firstly, characterization of organic tomato peel obtained by a local processing industry in terms of percentage of macronutrients as dietary fiber, protein, and ash, as well as total carotenoid content, was done. Secondly, two valorization alternatives of these compounds as potential functional additives in food processing were proposed. The first one included a carotenoid extraction using UAE and the encapsulation of the enriched-carotenoids extract using spray-drying technology and its subsequent analysis of powder properties. The second one evaluated the potential use of TDF tomato peel as a replacement of fat and flour in the four formulations of cookies. Each formulation was assessed using physicochemical, texture, sensory, and theoretical proximal analyses. For the results, UAE optimization was performed using a solvent ratio of 80 Ethyl Acetate:20 Ethanol and 2.5% w/v of biomass – solvent ratio. A recovery percentage of total carotenoid content of 89.08% was obtained. The content of TDF was 49.46 ± 3.91 (g/100g) on a dry basis. For encapsulation, the drying yield and encapsulation efficiencies were 67.3% ± 0.5 and 58.1% ± 0.8, respectively. Sensory analysis showed no significant difference between the means for the control cookie and 30% fat replacement cookie. Thus, these cookies were the most purchase intention by the consumers. Consequently, this study presented a solution towards unused tomato peel industrial by-product promoting the design of new functional food products with high content of carotenes and dietary fiber, increasing nutritional and health benefits to consumers.

Keywords: β-carotene, Functional food products, Lycopene, Sustainability, Total dietary fiber, Ultrasound-assisted extraction.

1. Introduction

Nowadays, food-processing industries produce a significant volume of liquid and solid wastes, which have a potential value in nutrients and biomass [1]. Adding the fact that those wastes can also be a source of pollution, it is relevant to find other ways to enhance the harvesting of these resources[1]. Even though most food-processing industries are trying to use these wastes in a circular economy framework, there is still an opportunity for their potential use.

Tomato is one of the most consumed fruits around the world, with a global production of 177 million tons [2] and a local (Colombia) production of 527 thousand tons [3]. When processing tomatoes (for juice, sauces, soups or ketchup), a significant amount of waste is produced, composed of peel and seed mainly, that are only used for animal feeding or composting [2], [4]. Therefore, there is an opportunity to effectively reuse this waste and add value to other food matrices.

Tomato’s red hue is given by the presence of lycopene. The lycopene amount found on the peel portion is about five levels more than the peel [5], [6]. This carotenoid is known to have functional effects on the human body, namely, the reduction of cardiovascular diseases and the improvement of skin health because of the increase in antioxidant activity [6],[7]. Despite the decision of the European Food Safety Authority (EFSA) of not being able to conclude if there is a cause-relation effect between lycopene consumption and those health claims [8], more studies are demonstrating the opposite. However, EFSA’s health claim discussion states that the amount of lycopene that should be consumed for an adult is 6 mg/day [8].

Even though lycopene is the main carotene in tomato peel, it also contains a significant amount of β-carotene [9],[10]. This chemical compound is formed by the action of the enzyme lycopene beta-cyclase (β-Lcy), which transforms lycopene through a cyclization method [10], [11]. β-carotene gives tomato a characteristic orange color as well. Nonetheless, the presence of lycopene is higher, and therefore tomato color is mainly red [9]. β-carotene is known to be a precursor of retinol or vitamin A as it is commonly known [11] (see Figure 1). Retinol is known to claim effects in eye, skin and cognitive health [12]. Those health claims are confirmed by the EFSA as a favorable outcome ensuring the statements [12]. This organization also studies the effects of β-carotene in human health and has concluded that it improves skin health as it increases the physiological immune response to UV radiation and contributes to collagen formation [13]. The recommended dose of β-carotene for an adult is about 60 mg/day [12], [13].
Lycopene and β-carotene can be found as natural pigments in different plants and fruits. Despite this, chemical pigments are chosen as the main color agents in the food processing industry [14]. Some of them, such as tartrazine, are known to have a harmful impact on human and environmental health to the extent of being prohibited in some countries [15]. Therefore, there is a real motivation in food processing for the replacement and transition from chemical origin colorants to plant-based natural pigments [14]. Seeing that, numerous amount of emerging green processes of natural pigment extraction are being analyzed, such as ultrasound-assisted extraction (UAE), microwave-assisted extraction (MWE) and supercritical fluid extraction (SCE) [16]. UAE bases its method on the use of high-frequency sound waves (generally prolonged in a material medium), which exceeds the human hearing limits [17]. When the medium is liquid due to their diffusion, sound waves produce little bubbles. This phenomenon is known as cavitation [5]. This process is beneficial for extraction because it can help to overcome some physicochemical barriers in mass transport phenomena through micro-turbulence, micro-streaming, microjets, and shock waves [18]. Hence, the process of extraction can be optimized.

Considering other compounds of interest, tomato peel is also a good source of total dietary fiber (TDF) and consists of about 8.9% soluble dietary fiber (SDF) and 48.5% insoluble dietary fiber (IDF) [19]. Food with dietary fiber tends to have good sensory and nutritional properties as well as beneficial health effects such as preventing colon cancer, lowering the risk of cardiovascular disease and reducing blood sugar [19]-[20]. However, the EFSA states that this cause-effect relation can vary due to the unique physical and chemical characteristics of the fiber component, in addition to the dose and mode of administration [21].

The local government perceives an important need to create a culture built up through sustainability and a circular economy. The urge to contribute to the achievement of Sustainable Development Goal (SDG) number 12 and develop industries based on the usage of residues is changing the mindset of people regarding the potential of by-products [22]. Therefore, the main objective of this project was to evaluate the inclusion of functional compounds in a further formulation of a new product that maintains all the functional characteristics. Therefore, the study was divided into two major parts. First, it aims to characterize tomato peel obtained by a local processing industry in terms of total carotenoid and TDF content. Secondly, the objective sought the valorization of these compounds as a potential functional additive in food processing. Thus, a green extraction process of carotenoids compounds and their encapsulation was carried out. Besides, the powder properties were analyzed. The potential use of TDF as a replacement of fat and flour in four formulations of cookies was assessed. Texture analyses for both dough and baked cookies were also carried out. A consumer sensory analysis was held to determine the acceptance of the different formulations of cookies. This study shows relevant data in the valorization of tomato processing industries residues and could mean a starting point for the complete usage of these residue applying concepts of sustainability and circular economy.

2. Materials and methods

2.1. Reagents and standards

Tomato peels were obtained as a by-product from the processing production of tomato paste of the company “Tomates Villa Santos S.A.S., TOVISA,” located in Santa Sofía – Boyacá. During the tomato paste processing, hot – water blancher was used to ease the peeling process. β-carotene standard 97.0% of purity (Sigma-Aldrich, 7235-40-7). Absolute ethanol C₂H₅OH (99.8% v/v), ethyl acetate C₃H₅O₂ (99.5% v/v), acetone C₃H₅O (99.5% v/v), hydrochloric acid (37.0% v/v) and sodium hydroxide (98.0% w/w), were produced by Panreac [23]–[27]. For the determination of TDF, it was used heat-stable α – amylose (Reactifs RAL), protease (Sigma® Life Science), and amyloglucosidase (Fluka®) for enzymatic digestions. For phosphate butter used in TDF quantification, it was used di-sodium hydrogen phosphate anhydrous Na₂HPO₄ (99.0% v/v) and sodium di-hydrogen phosphate anhydrous NaH₂PO₄ (99.0% v/v) also produced by Panreac [28], [29].

2.2. Raw materials and sample preparation

Tomato peels provided by Tomates Villa Santos S.A.S., TOVISA, were collected in buckets and stored in an ultra-freezer at -86 °C until further sample preparation. Firstly, moisture content (MC) was determined by a moisture analyzer (Precisa, Series 330 XM) (87.47% ± 0.1). Secondly, tomato peels were located on aluminum foil sheets and freeze-dried using a lyophilizer FreeZone (Labconco, 6 Liter Benchtop Freeze Dry System) operating under vacuum (0.007 mBar) and a temperature of -50 °C during 72 hours [30]. Next, freeze-dried peels were ground until a particle size of 1 mm by using the cutting mill (Fritsch, pulverisette 19) [31]. Ground peels were stored in Ziploc bags wrapped in aluminum foil at – 20 °C until their analysis. Further on, this will be considered as the pretreated sample.

2.3. Characterization of tomato peel
2.3.1. Color assessment

Tomato peels before (that is, fresh fruit) and after the hot-water blanching process were analyzed to compare the carotenoid degradation resulting from this thermal process. For this, a color evaluation of both tomato peels was carried out. Color treatments were assessed using a hand-held colorimeter (CR-20, Minolta Co., Osaka, Japan) with an 8° visual angle and D65 illuminant [32]. For each sample, results were obtained as an average of six measurements in different parts of the ground tomato peels.

In addition, chromatic coordinates of the CIELAB were used for ΔE* estimation following Equation 1. This parameter stipulates the magnitude of the total difference of color in two samples. Were L* is brightness, a* is green – red coordinates, and b* is yellow – blue coordinates.

Equation 1. CIELAB formula for a total difference of color (ΔE*).

\[ \Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \]

2.3.2. Dietary fiber quantification

The total dietary fiber content was determined according to the AOAC 991.43 by subtracting the total weight residue with the determination of ash and protein [33]. The buffer solution was adapted according to the Operative Standard Process of Universidad Nacional de Colombia [34] by using phosphate buffer. A water bath orbital shaker (MaxQ™ 7000, ThermoFisher Scientific) was used for enzymatic digestions by heat-stable α – amyrase, protease, and amyloglucosidase to remove starch and protein [33]. For total dietary fiber (TDF), duplicate samples of enzyme digestate were treated with ethanol to precipitate soluble dietary fiber before filtering, using a 30 mL filter crucible of borosilicate glass. Then, TDF residues were washed with ethanol (76% and 98%) and acetone 98%, dried and weighed. Finally, one residue was analyzed for protein using the total nitrogen Kjeldahl method, and the second residue of the duplicate was analyzed for ash using a benchtop muffle furnaces (5313C10, Thermo Scientific™ Thermolyne™), for 5 hours at 525°C.

2.3.3. Total carotenoid extraction and quantification with UV-VIS spectrophotometer

A conventional extraction (CE) was carried out using acetone as a solvent to extract the total carotenoid content in tomato peel samples, following the methodology reported by Biswas and Sahoo’s investigation [35]. 1.0 g of pretreated samples were weighed on a test tube. Then 5 mL of chilled acetone were added to the sample, and the tube was vortexed for 10 min. Finally, samples were centrifuged at 4500 RPM for 10 min using a refrigerated centrifuge (IEC CL40R, Thermo Electron Corporation), and the supernatant was collected in a separate test tube. The pellet was re-extracted by using 5 mL of chilled acetone followed by vortex and centrifugation once again as above. Re-extractions were made until the supernatant became translucent. Solutions of all extractions were pooled, and absorbance was measured at 450 nm by using a UV-VIS spectrophotometer (T80+, PG Instruments).

For the quantification, the maximum absorbance wavelength of a known concentration of standard β-carotene dissolved in solvents used in this investigation (ethyl acetate (EA) and ethanol (EtOH)) was estimated by scanning from 400 nm to 500 nm using a UV-VIS spectrophotometer (T80+, PG Instruments).

For both mixtures of solvents (see Table 1), the maximum absorbance wavelength was 453 nm. The experimental runs' absorbances were measured at 453 nm, diluting the initial solution at different concentrations until ensured that absorbance was between 0.2 and 0.9 [36]. Finally, calibration curves were used to estimate the total carotenoid content (TCC) at μg of β-carotene equivalent per gram. The calibration curve for 80 EA: 20 EtOH (% v/v) was \( y = 0.028 x + 0.0612 \rightarrow R^2 = 0.9964 \), while for 20 EA: 80 EtOH (% v/v) was \( y = 0.0268 x + 0.0538 \rightarrow R^2 = 0.9985 \). For CE, the calibration curve of acetone at 450 nm was \( y = 0.0245x + 0.0435 \rightarrow R^2 = 0.9932 \).

2.4. Strategies proposed for the valorization of tomato peels

2.4.1. Ultrasound-assisted extraction (UAE) of carotenoids from tomato peels

The experimental procedure was adequate with minimal exposure to light. 1 g of ground tomato peels was added into a glass amber bottle jar. A solvent mixture of ethanol-ethyl acetate (EtOH-EA) was chosen and added to the glass amber bottle according to the solvent-biomass ratio and ethanol – ethyl acetate ratio established in the experimental design (See Table 1). For UAE, an ultrasonic cleaner was used (2510-DTH, Branson) at 40°C and 45 min considering Lee-Sie’s study [5]. Frequency and power of ultrasonic were set at 40 kHz and 130 W. The glass amber bottle was taken out and cooled at room temperature. The mixture was centrifuged (IEC CL40R, Thermo Electron Corporation) and filtered at 4500 RPM and 10°C for 20 min to separate the phases. Finally, the supernatant of each run was dried using a rotary evaporator (RE604/801, Yamato) at 30°C under vacuum to obtain the extracts, also named oleoresins. Each run was performed in duplicate.

Table 1. Independent variables of the experimental design using 40 °C and 45 minutes of UAE

<table>
<thead>
<tr>
<th>Run</th>
<th>Solvent – biomass (w/v)</th>
<th>Solvent ratio (% v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.025</td>
<td>80:20</td>
</tr>
<tr>
<td>2</td>
<td>0.025</td>
<td>20:80</td>
</tr>
<tr>
<td>3</td>
<td>0.05</td>
<td>80:20</td>
</tr>
<tr>
<td>4</td>
<td>0.05</td>
<td>20:80</td>
</tr>
</tbody>
</table>

The quantification of total carotenoid content was carried out by using the calibration curve prepared as described in section 2.3.3. The percentage of recovery of total carotenoid content was estimated using the results obtained in ultrasound-assisted extraction (UAE) and conventional extraction (CE), as shown in Equation 2.
2.4.2. Statistical analysis of experimental design

The UAE of carotenoids was optimized using an experimental design of two factors and two levels to determine the recovery percentage of total carotenoid (response variable). Solvent – biomass ratio and ethyl acetate – ethanol ratio was used as independent variables, as seen in Table 1. Minitab® was used as a statistical program. A Tukey key test was used to create confidence intervals for all pairwise differences between factor level means, and a Dunnett test was performed to compare the mean of each factor level (UAE) with the mean of control (CE) [37].

2.4.3. Microencapsulation of Tomato peel UAE extract

Microencapsulation of tomato peel extract with the highest recovery percentage (0.025 solvent – biomass ratio (w/v) and 80 AE:20 EtOH solvent ratio) was performed by spray-drying according to Szabo’s study [38], with some modifications. The extract obtained from the UAE was dissolved in 35 mL of commercial sunflower oil. Wall material was composed of maltodextrin (Cimpa S.A.S) and gum Arabic from acacia tree (Sigma-Aldrich, 9000-01-5) using a ratio of 1:3 (w/v) for each polymer. Wall material was dissolved with distilled water under continuous stirring at 5000 RPM for 10 minutes using a homogenizer (Dispermat®, VMA – Getzmann gmbh D-51580 Reichshof). The aqueous solution was stored for 2 h to assure complete rehydration of the polymers. The emulsion (O/W) was completed by adding drop-by-drop the sunflower oil enriched by the oleoresins to the wall material. The solution used had a ratio of 2:1 wall material: oil, and it was homogenized using the dispersat at a speed of 10000 RPM. After the oil was thoroughly mixed, the homogenization continued for another three minutes.

The spray-drying process was performed using a spray dryer (Buchi B290, Switzerland). A co-current spraying nozzle of 0.7 mm in diameter was used. The emulsion feed rate was 12.5 mL/min using an inlet and outlet temperature of 140°C and 100°C, respectively. The airflow feed was 473 L/h. The inlet temperature of the airflow was set at 120°C. The vacuum cleaner was set at 30 m³/h. The achieved microcapsules were collected intro Ziploc bags hermetically sealed, wrapped with aluminum foil, and stored at 25°C on a desiccator until further analysis.

2.4.3.1. Characterization of encapsulated extract

- **Moisture content**

Moisture content (MC) was determined by a moisture analyzer (Precisa, Series 330 XM) at 105°C until they reached a constant weight. Results were expressed on a wet basis percentage. This method was made in duplicate.

- **Dissolution rate**

The dissolution rate method was based on Duran et al. study [39]. 2.0 g of powder was incorporated with 50 mL of distilled water. The mixture was agitated with a magnetic stirrer (CIMAREC, SP131015Q) at 900 RPM. The dissolution rate was estimated as the time required to completely dissolve the macroscopical particles of the mixture. This method was made in duplicate.

- **Tapped density**

The tapped density was estimated according to Duran et al. study [39]. 4.0 g of powder sample were poured into a 25 mL graduated cylinder (with readable 1 mL). The graduated cylinder was constantly tapped manually until there was a negligible difference in volume between readings observed in the graduated cylinder. The tapped density in (g/mL) was determined as the relation between the mass of powder sample (g) and the volume of tapped powder (mL). Also, the emulsion density was calculated using a 10 mL pycnometer by weight difference. Both methods were estimated in duplicate.

- **Drying yield**

The yield of the spray drying process was expressed in percentage (%) as the relation between the mass of powder obtained and the mass of solids in the emulsion fed into the spray drying. The drying yield (DY) was calculated using Equation 3 [39]:

\[
DY(%) = \frac{mass \ of \ total \ powder \ obtained \ (g)}{mass \ of \ solids \ in \ feed \ emulsion \ (g)} \times 100
\]

- **Encapsulation efficiency**

The encapsulation efficiency was estimated as the relation between the total carotenoid content in the powder (mg/g of powder obtained) and the total carotenoid content of the extract (mg/g of sunflower oil) using Equation 4:

\[
EE(%) = \frac{TCC \ in \ the \ powder}{TCC \ in \ the \ extract} \times 100
\]

For the TCC of the powder, the methodology described in section 2.4.1 for the conventional extraction was carried out.

2.4.4. Formulation of functional food with the inclusion of


2.4.4.1. Cookie’s formulation and preparation

Only the dried ground peels were considered for cookie preparation. Four formulations were performed using the same quantity of all ingredients except flour and butter. The ingredients used for dough preparation were wheat flour (Haz de oros tradicional®), unsalted butter (Alpina®), AAA egg (Kikes®), vanilla essence (Levepan®), salt (Refisal®), baking powder (Royal®), white sugar (Manuelita®), and dried ground tomato peel (TOVISA S.A.S.).

For doughs preparation, it was considered the four formulations shown in

Table 2. The first one consisted of control without the addition of pretreated tomato peel, the second one had a 30% unsalted butter to pretreated tomato peel replacement (E1), the third one also had a 30% of replacement but in wheat flour (E2), and the last one had a 15/15% replacement of wheat flour and unsalted butter.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Control</th>
<th>E1a</th>
<th>E2b</th>
<th>E3c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>45.7</td>
<td>45.7</td>
<td>32.0</td>
<td>38.9</td>
</tr>
<tr>
<td>Unsalted butter</td>
<td>23.5</td>
<td>16.5</td>
<td>23.5</td>
<td>20.0</td>
</tr>
<tr>
<td>Egg</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Vanilla essence</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Salt</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Baking powder</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>White sugar</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Dry ground tomato peel</td>
<td>-</td>
<td>7.1</td>
<td>13.7</td>
<td>10.4</td>
</tr>
</tbody>
</table>

* 30% unsalted butter replacement. a 30% wheat flour replacement. c 15% unsalted butter and 15% wheat flour replacement.

A Six Quart Bowl-lift Stand Mixer manufactured by Kitchenaid® was used for dough preparation. Butter, sugar and vanilla essence were introduced in the mixer for 1 min at a stir speed of 4 (mode: mixing, beating). Considering the owner’s manual of the mixer, this speed is for mixing semi-heavy batters, such as cookies [40]. After that, half of the flour and half of pretreated tomato peel (for E1 to E3) were added to the mixer in continuous stirring for 1 min. Then, the rest of the flour and pretreated tomato peel was added. Afterwards, egg, salt and baking powder were added in continuous stirring for another minute. The mixture of ingredients was kneaded to heat the dough and stretch the gluten chains until obtaining an elastic dough. Then the doughs were wrapped and stored at 4°C for 1 hour. Once time had passed, the dough was rolled out with a rolling pin until a 4 mm thick sheet was obtained. After that, the sheet was stored again at 4°C for only 30 minutes. Finally, the sheet was cut in small slices with a cookie cutter and baked at 170°C for 10 min with a Haceb HG CASIA 60 NE GN.

2.4.4.2. Physicochemical characterization of dough and cookies

A texture analyzer (TA.HDplusC [41]) was used to analyze dough and cookies. Firstly, for the dough, a back extrusion test was used to determine firmness, consistency, cohesiveness, and work of cohesion. The test mode implemented was a compression with a test speed of 1mm/sec, a 50% strain target mode, and a trigger force of 10g.

For the cookies, a three-point bend test was used to measure hardness (g) and fracturability (mm) for each sample. The test was performed with a test mode of compression, a test speed of 1 mm/sec, a distance target mode and 3mm. These parameters were measured with a replicate considering the replicability of the experiment. All cookies were measured in duplicate.

Additionally, a color evaluation was performed for the doughs and cookies samples using a hand-held colorimeter (CR-20, Minolta Co., Osaka, Japan). For each sample, results were obtained as an average of six measurements in different parts of the sample.

2.4.4.3. Sensory analysis of cookies formulated

The protocol of the sensory analysis was approved by the Ethics Committee of the Education Faculty of Universidad de los Andes. Fifty untrained adult panelists were evaluated for the study. The experimental procedure was explained, and written consent indicating the voluntary participant and possible risks was obtained for each participant before starting the survey. Samples (control and E1 to E3) were randomly listed as 362, 556, 154, 951, respectively. Participants were classified by gender, age range, status, and two questions about how often they eat cookies and what characteristics they look for in a cookie. Before each sample taste, participants were free to choose the order of the cookies’ evaluation, and they had to rinse their mouths with water and unsalted crackers (Saltinas®, Colombia) to clean their palate. On the one hand, consumers tasted each sample and rated linking using a 7 – points hedonic scale (1 = “extremely dislike”, 4 = “it does not matter”, 7 = “extremely like”) about general taste, appearance, texture, color, and flavor. On the other hand, 5 – points Just About Right (JAR) questions (1 = too much light, 3 = Just About Right, 5 = too much intense) [42] were made about crispness and sweetness.

2.4.4.4. Data analysis of sensory testing

Sensory data analysis was performed through Minitab® and Excel® software. On the one hand, the hedonic scale questions were analyzed through the statistical General Linear Model (GML) as the model was adjusted to the data obtained by the surveys in each of the categories. Therefore, a Tukey test was made to compare the different pairwise replacement formulations in the perception of a potential consumer. On the other hand, the JAR analysis was held through a penalty analysis method (or mean drop). The test determines how much acceptability has been decreased by attributes that are not optimal [43].
show the calculation for the mean drop value.

\[ \text{Equation 5. Mean drop for too low} \]
\[ \text{Too low} = \frac{\text{GAM (JAR group) – GAM (Low group)}}{\text{NJ (Low group)}} \]

\[ \text{Equation 6. Mean drop for too high} \]
\[ \text{Too high} = \frac{\text{GAM (JAR group) – GAM (High group)}}{\text{NJ (High group)}} \]

Where,
\[ \text{GAM} \rightarrow \text{Global acceptability mean} \]
\[ \text{NJ} \rightarrow \text{Number of judges} \]

It is important to state that the effect of the attribute in the global acceptance of the product is important if the mean drop value is greater than one and the percentage of surveyors with a different score from JAR values higher than 20%.

2.4.4.5. Theoretical Proximal analysis

A theoretical proximal analysis of the best-scored cookie in the sensory analysis was made. This analysis considers the formulation and the caloric intake of every ingredient in the cookie. Also, depending on the calculations made with the TDF determination, the proximal analysis included the amount of TDF in one portion of the cookie. A nutrition fact label was made to arrange the data obtained in the product.

3. Results and discussion

3.1. Characterization of tomato peel

3.1.1. Total dietary fiber

Table 3 summarizes the approximate composition of the samples' total dietary fiber, protein, and ash content. As shown in Table 3, tomato peel dietary fiber has a low content of protein (0.75%) and ash (0.0019%), being the main compound of the carbohydrates represented by dietary fiber [44]. The TDF content of organic tomato peel was found to be higher than other vegetables and fruits such as cauliflower stem (35 g/100g) [45], kiwifruit pomace (2 – 30 g/100g) [46], guava peel and seeds (48.6 g/100g) [47], carrot peels (45.5 g/100g) [48]. Moreover, other studies estimated a soluble and insoluble dietary fiber content of 8.9 g/100g and 48.5 g/100g, respectively [49].

Considering the results shown in Table 3, there is a reasonable estimation of TDF. Nevertheless, other studies made a high estimation of TDF content in tomato peel (86.15 g/100g [44] and 85.7 g/100 g [50]). This could happen due to the blanching process performed in the samples used in this study since this heat treatment change the functional properties of the fiber, such as the breaking of the glycosidic linkages and, consequently, the dietary fiber polysaccharides depolymerization [51].

Table 3. Approximate composition of total dietary fiber, protein and ashes of tomato peel.

<table>
<thead>
<tr>
<th>Approximate compositionb</th>
<th>Tomato peel (DB)²</th>
<th>Protein (g/100g)</th>
<th>Ash (g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>49.46 (0.057)</td>
<td>0.75 (0.14)</td>
<td>0.0019 (0.008)</td>
</tr>
</tbody>
</table>

² All results are reported on a dry weight basis. Values in parenthesis are the standard deviations.

3.1.2. Color analysis

A color analysis (Table 4) was made to evaluate the change in CIELAB color parameters in the tomato before and after the blanching process made by TOVISA, considering the high temperatures (60°C) of the process.

Table 4. Average color parameters of tomato peel before and after hot-water blancher process.

<table>
<thead>
<tr>
<th>CIELAB coordinatesa</th>
<th>No treated sampleb</th>
<th>Treated samplea</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L^* )</td>
<td>22.6</td>
<td>12.4</td>
<td>( \Delta L^* ) 10.2</td>
</tr>
<tr>
<td>( a^* )</td>
<td>15.8</td>
<td>18.3</td>
<td>( \Delta a^* ) -2.5</td>
</tr>
<tr>
<td>( b^* )</td>
<td>22.3</td>
<td>14.8</td>
<td>( \Delta b^* ) 7.5</td>
</tr>
</tbody>
</table>

a Chromatic coordinate of the CIELAB system (\( L^* \) = brightness, \( a^* \) = green – red coordinates, \( b^* \) = yellow – blue coordinates). b Values reported are an average of 6 measurements per sample.

Table 4 shows the average of 6 measurements of the CIELAB coordinates (\( L^* \), \( a^* \), \( b^* \)) and the differences (\( \Delta L^* \), \( \Delta a^* \), \( \Delta b^* \)) before and after the blanching process made by TOVISA. Brightness coordinate is the parameter with the greatest change, increasing the brightness of the sample before heat treatment. Besides, the coordinate \( a^* \) had a negative change, resulting in a red color decrease and an increase in the green color. Finally, the coordinate \( b^* \) had a considerable positive difference, which means an increase in the yellow color and a decrease in blue color in the samples treated with the blanching process. Furthermore, considering the differences in \( L^* \), \( a^* \) and \( b^* \) parameters, it is possible to estimate the total difference of color (\( \Delta E^* = 15.2 \)). This difference between the treated sample and the untreated one is due to the degradation of carotenoids because of their thermolability, principally lycopene. This degradation made by the heat produced during the blanching process causes oxidation and isomerization cis-trans [52].

3.2. Extraction and encapsulation of carotenoids from tomato peel

3.2.1 Ultrasound-assisted extraction

Table 5 shows the average total carotenoid content using CE (control) and the UAE experimental runs in duplicate. As mentioned above, the percentage was estimated taking as reference the CE (100% of recovery of total carotenoid content).
Table 5. Total carotenoid content (TCC)\(^*\) using UAE and EC methods and statistical analysis using Tukey's test.

<table>
<thead>
<tr>
<th>Run</th>
<th>Extraction Method</th>
<th>TCC (mg g(^{-1}))</th>
<th>% recovery of total carotenoids content</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>EC</td>
<td>305.61(^{*\prime}) (33.19)</td>
<td>100.00</td>
</tr>
<tr>
<td>1</td>
<td>UAE</td>
<td>253.89(^{ab\prime}) (19.39)</td>
<td>83.08</td>
</tr>
<tr>
<td>2</td>
<td>UAE</td>
<td>125.07(^{c}) (10.66)</td>
<td>40.92</td>
</tr>
<tr>
<td>3</td>
<td>UAE</td>
<td>205.81(^{b}) (11.21)</td>
<td>67.34</td>
</tr>
<tr>
<td>4</td>
<td>UAE</td>
<td>190.22(^{bc}) (6.44)</td>
<td>62.24</td>
</tr>
</tbody>
</table>

\(^*\)mg b-carotene equivalent/100g. Means followed by the same letter within the same column share the same Tukey's test aggrupation. Therefore they are not significatively different. \((\alpha=0.05\%)\).

\(^{ab}\prime\)Share the same Dunnet's test group. Therefore they are not significatively different. \((\alpha=0.05\%)\)

Values in parenthesis are the standard deviations.

Firstly, as shown in Table 5, run 1, 3 and 4 have similar means and standard deviations. Secondly, run 2 has the lowest mean, considering the control. This run has the lowest solvent – biomass ratio and a solvent ratio of 20 EtOH:80 EA. This suggests a better solvent affinity with carotenoids when there is a high solvent-biomass ratio, and the proportion of ethyl acetate in the mixture of solvents is bigger than ethanol. Even though ethanol has a good penetration in the foods matrix [52], incorporating other solvents helps obtain the desired solute retention in the solvent, increase solubility, and improve resolution [36]. In this case, the addition of ethyl acetate decreases the polarity of the solvent mixture, giving more affinity to carotenoids.

Furthermore, Table 5 shows the statistical aggrupation of Tukey’s test. The means that do not have a letter in common are significantly different. To estimate confidence intervals, it was used 98.98% individual confidence level to obtain a 95% joint confidence level using Tukey’s method. Bearing this in mind, it is possible to affirm that with a 5% significance level, the null hypothesis is rejected for those pair of samples with a p-value greater than 0.05. \((1 – 2, 2 – C, 3 – C)\) and \((4 – C)\). In other words, all the pairs of mean samples mentioned above are significantly different. Despite this, the corresponding means of pair of samples 1 – 3 and 2 – 4 are significantly equal. Those pairs have one element in common, and they have the same solvent ratio \((80\% \text{ EA}:20\% \text{ EtOH})\) for pair of samples 1 – 3 and \((20\% \text{ EA}:80\% \text{ EtOH})\) for pair of samples 2 – 4. In addition, pairs 1 – 4 and 3 – 4 are also significantly equal. There are no levels in common for the first one, and for the second one, those pairs use the same solvent – biomass ratio \((0.05\%)\). Considering all estimations performed in the Tukey test, there is no way to confirm that one level is more significant than the other by using this test. Thus, the main effects plot was used to examine differences between level means of factors (solvent – biomass and solvent ratio).

Considering this method, solvent ratio (EA – EtOH) is the factor with more influence on the response variable, consistent with Tukey test analysis. There is a greater concentration when the amount of ethyl acetate is higher than ethanol in the solvent mixture. Furthermore, solvent – biomass does not have a steep slope, which suggests that this factor does not severely affect the total carotenoid content obtained in the extraction.

Now, it is important to determine which sample is significantly equal or superior to the control (CE). For this, a Dunnett method that analyzes the differences between the mean of total carotenoid content of samples (1 to 4) and the conventional extraction using acetone was carried out. Essay 1 was the only sample grouped with the control. That means that there is no significant difference between the two means [37], even though acetone has a good penetration in the foods matrix and has a good solubility of carotenoids and xanthophylls [52]. The non-polarity or low polarity of carotenoids such as lycopene and \(\beta\) – carotene suggests that for a suitable extraction solvent, it should be used a non-polar or slightly polar like hexane (non-polar), diethyl ether (low polarity), or ethyl acetate (medium polarity) [52], [53]. Thus, the variables involved in an extraction process (solubility, affinity, food matrix penetration, polarity) are similar when acetone or a mixture (80 ethyl acetate: 20 ethanol) are used as a solvent.

As shown in Table 5, assay 1 \((80\% \text{ EA}:20\% \text{ EtOH} \text{ solvent ratio})\) was the sample with the highest recovery percentage. This mixture of solvent used had a higher ethyl acetate content than ethanol. With this, it can be inferred that this mixture has a greater affinity with carotenoids due to their polarity but a lower penetration into the food matrix. This is where the emerging ultrasound technology plays an important role since the mechanical effect of ultrasound provides greater penetration of solvent into the cellular material of tomato peel, resulting in the breakdown of cell walls to ease the carotenoid content release [5]. For this reason, applying green solvents like ethanol and ethyl acetate in emerging technologies as ultrasound could be an excellent alternative to extract carotenoids without the need to use a toxic or environmentally harmful solvent or invest a lot of time in conventional extraction processes.

3.2.2 Microencapsulation process

*Figure 2* shows the total carotenoid extract after solvent mixture (80 EA: 20 EtOH) evaporation and before being diluted on sunflower oil. On the other hand, *Figure 2B*
illustrates the result of spray drier microencapsulation.

Figure 2. Extraction and microencapsulation results. (A) Oleoresins obtained of UAE after solvent evaporation. (B) Microencapsulation of extract.

Table 6 shows the parameters obtained for the microencapsulation resultant powder. The emulsion density was measured, and a result of 1.091 (0.01) g/ml was obtained. This data is important to evaluate the feeding mass in the spray dryer procedure and calculate the dry procedure's efficiency.

Table 6. Microencapsulation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (%)</td>
<td>2.49 (0.1)</td>
</tr>
<tr>
<td>Dissolution rate (s)</td>
<td>188.68 (5.51)</td>
</tr>
<tr>
<td>Density (g/mL)</td>
<td>0.57 (0.50)</td>
</tr>
<tr>
<td>Drying yield (%)</td>
<td>67.3 (0.50)</td>
</tr>
<tr>
<td>Encapsulation efficiency (%)</td>
<td>58.1 (0.81)</td>
</tr>
</tbody>
</table>

As shown in Table 6, the moisture content of powder has a good estimation considering Szabo et al. and Turchiuli et al. studies [38], [54]. The low result assures a good spray-drying process, efficiently eliminating the moisture of the emulsion. Hence, it attributes to the powder's good stability during storage [55]. Also, it is important to determine the dissolution rate in powders due to reconstitution capacity that directly affects the quality of powders in foods [56]. The encapsulation efficiency is directly affected by the feed properties and spray drying conditions [39]. Table 6 shows 58.1% of encapsulation efficiency. Compared with Duran et al. study, it has similar efficiency values, allowing good carotenoid retention. However, the same ratio relation between airflow and feed flow was taken into account from Szabo et al. study [38]. The decrease of parameters mentioned above could produce an increase in encapsulation efficiency.

3.3 Cookies formulation with the inclusion of tomato peel

After all the formulations were performed, four different doughs were obtained, as shown in Figure 3. Also, once the dough was baked, the cookie results are shown in Figure 4. A color analysis of the dough and the cookies is shown in Table 7. Average color parameters of dough and cookies. In order to have a magnitude for the change of color in each case, an ΔE calculation was also made.

Figure 3. Cookie doughs for different formulations. (A) Control. (B) 15% flour and fats. (C) 30% flour (D) 30% fat

Figure 4. Baked cookies with different formulations. (A) Control. (B) 15% flour and fats. (C) 30% flour (D) 30% fat

Table 7. Average color parameters of dough and cookies.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Dough</th>
<th>Cookie</th>
<th>ΔE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>34.6</td>
<td>17.0</td>
<td>17.8</td>
</tr>
<tr>
<td>30% flour</td>
<td>35.1</td>
<td>15.0</td>
<td>15.1</td>
</tr>
<tr>
<td>15% flour – 15% fat</td>
<td>38.0</td>
<td>15.1</td>
<td>17.7</td>
</tr>
<tr>
<td>30% fat</td>
<td>37.4</td>
<td>14.8</td>
<td>18.8</td>
</tr>
</tbody>
</table>

Regarding the results shown in the change of color, parameters are important to consider the different formulations and the principal chemical reactions occurring there. For fiber added cookies, it must be taken into account that the fiber was obtained from tomato peel which gives the doughs and cookies a characteristic red (orange in this case because of previous blanching treatment) hue. However, as carotenoids found in tomato peel are thermolabile as they were baked, an important degradation occurs, which carries out a difference in color [7]. However, the most important change is due to Maillard reactions.
and water loss during the baking process. These reactions happen during heating between reducing carbohydrates and amino structures in proteins [57]. Wheat flour is an important source of proteins in which gluten represents a relevant part. As the dough is kneaded and mixed, gluten matrices can be formed. Thus, a higher gluten content tends to favor Maillard Reactions to happen, hence, a change in color parameters. Consequently, it can be seen that 30% of flour replacement cookies had less color change. Another important factor to consider is baking time. A study made by Zilic et al. [57] shows that for high carbohydrate content food matrices, baking time had a significant effect on color parameters L*, a* and b*.

3.3.1. Texture analysis of dough and baked cookies

It is important to understand the textural properties of the doughs because with this, it is possible to predict their behavior during manipulation, for example, in kneading, rolling, and cutting [58]. Table 8 illustrates the back extrusion test for doughs. As shown in Table 8, the dough with less firmness is the control. On the contrary, the dough with a 30% replacement of fats and 15%-15% replacement of fats and flour, respectively, were the samples with a considerable increase in firmness. During the manipulation of those doughs, it was notable a firmer structure but a lower spreadability during the rolling process. Additionally, this increase of firmness is reasonable because during mixing, the lipids of the unsalted butter act as a lubricant, covering the surface of the flour, preventing the formation of gluten network during the kneading process [59]. Thus, the final product of samples with the replacement of fats has a firm and hard texture dough.

![Table 8. Dough texture analysis](image)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Firmness (g)</th>
<th>Consistency (g.s)</th>
<th>Cohesiveness (g)</th>
<th>Work of Cohesion (g.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>825.51b (7.81)</td>
<td>3155.69g (43.26)</td>
<td>-212.59b (9.79)</td>
<td>-34.55b (3.81)</td>
</tr>
<tr>
<td>30 % flour</td>
<td>1077.79g (9.25)</td>
<td>4870.20b (18.11)</td>
<td>-221.62b (0.13)</td>
<td>-13.29b (1.03)</td>
</tr>
<tr>
<td>15% flour – 15% fat</td>
<td>1239.52b (33.18)</td>
<td>3863.90g (72.84)</td>
<td>-15.76a (11.26)</td>
<td>-0.10a (0.01)</td>
</tr>
<tr>
<td>30% fat</td>
<td>2823.0a (69.96)</td>
<td>13745.78g (75.29)</td>
<td>-22.11a (1.11)</td>
<td>-0.20a (0.02)</td>
</tr>
</tbody>
</table>

Means followed by the same letter within the same column share the same Tukey’s test aggregation, therefore they are not significatively different. (α=0.05%). Values in parenthesis are the standard deviations.

Additionally, consistency values increase when there was a high replacement of flour or fats like in samples 15% Flour – 15% Fat and 30% fat. Still, it is more significant when there is a replacement in fats formulation. Cohesiveness can be described as the strength of the internal bonds making up the body of the dough [60]. Considering the results shown, control and sample with a 30% replacement of flour have higher cohesiveness values. Hence, it is possible to establish that the replacement of flour does not considerably affect the strength between the dough particles. It means the value is not significatively different from the control one. In other words, avoid the formation of the gluten network produced by the proteins in flour, increasing the dough’s cohesiveness while decreasing the firmness. This improves the manipulation during the kneading and rolling process. Table 9 shows the texture analysis results in terms of hardness and fracturability.

![Table 9. Baked cookies texture analysis](image)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hardness [g]</th>
<th>Fracturability [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5923.44a (55.40)</td>
<td>39.765b (1.91)</td>
</tr>
<tr>
<td>30% flour</td>
<td>2891.58a (148.19)</td>
<td>36.09a (2.09)</td>
</tr>
<tr>
<td>15% flour - 15% fat</td>
<td>3440.48b (117.21)</td>
<td>36.865a (0.42)</td>
</tr>
<tr>
<td>30% fat</td>
<td>5926.12a (57.79)</td>
<td>37.84a (0.33)</td>
</tr>
</tbody>
</table>

Means followed by the same letter within the same column share the same Tukey’s test aggregation, therefore they are not significatively different. (α=0.05%). Values in parenthesis are the standard deviations.

It is important to define the hardness of a food matrix as the required force to compress a food with teeth, tongue or palate [61]. Therefore, it can be expressed as a force to compress a food matrix in the mouth. Considering the results shown, sample 30% fat and control have the higher hardness values, and they are not significantly different. The ones with flour replacement were the ones that had a lower value of hardness. These behaviors can be explained as a cookie with 30% flour replacement and 15%-15% flour and fat replacement, in which wheat flour was replaced with dietary fiber. Replacement of flour can decrease gluten content and moisture, which will affect the formation of gluten matrices. It was reported that the hardness of cookies depends on the structure of the composite matrix of protein aggregates, lipids, and sugars, which are embedded in some ungelatinized starch granules [62]. Hence, this contributed to the decrease in hardness. Other studies replacing wheat flour with gluten-free cereals such as rice or amaranth, also report reducing this hardness texture parameter [62]–[64]. For the fracturability, all the results obtained were similar. It is crucial to define fracturability as the tendency of a material to fracture, crumble, crack, shatter or fail upon applying a relatively small amount of force or impact [65]. The results shown in Table 9 are relevant to state that in the four cases, fracturability had similar behavior. Therefore, it can be concluded that the formulation and replacement of fats and flour in the cookie do not affect the fracturability in a significant way as all the samples share the same Tukey’s test aggregation.

3.3.2 Sensory analysis

Results of the sensory analysis were divided in terms of gender, age, and frequency of cookie consumption. For the first one,
there were more men (54%) surveyed than women (46%). The age range with the most participation in the sensory analysis was 18 – 25 years old with 88%, while the other ranges of ages (26 – 35, 36 – 45 and > 45) had each 4% of participation. Finally, more people consume cookies weekly (54%), followed by daily consumption (20%) and people who only have monthly and sporadic consumptions, with a participation of 16% and 10%, respectively.

Table 10 shows the results of the sensory analysis attributes measured for the hedonic survey. First, in terms of global acceptability, it shows Tukey’s test’s results applied to the data set. 30% fat replacement sample was the only one in which the mean was not significantly different from the control cookie.

Table 10. Hedonic scale mean value for all attributes.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Global acceptability</th>
<th>Appearance</th>
<th>Texture</th>
<th>Color</th>
<th>Flavor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.7a (1.2)</td>
<td>4.7a (1.8)</td>
<td>6.0a (1.2)</td>
<td>3.9a (1.8)</td>
<td>5.8a (1.3)</td>
</tr>
<tr>
<td>30% Flour</td>
<td>3.6b (1.4)</td>
<td>4.8a (1.5)</td>
<td>4.3b (1.8)</td>
<td>4.2a (1.6)</td>
<td>2.9a (1.4)</td>
</tr>
<tr>
<td>15% Flour - 15% Fat</td>
<td>5.1b (1.6)</td>
<td>5.4ab (1.0)</td>
<td>4.6b (1.9)</td>
<td>5.4b (1.1)</td>
<td>5.0b (1.7)</td>
</tr>
<tr>
<td>30% Fat</td>
<td>5.2ab (1.3)</td>
<td>5.8b (1.4)</td>
<td>4.9b (1.7)</td>
<td>5.4b (1.4)</td>
<td>5.4ab (1.5)</td>
</tr>
</tbody>
</table>

Means followed by the same letter within the same column share the same Tukey’s test aggregation, therefore they are not significantly different. (α=0.05%). Values in parenthesis are the standard deviations.

Considering this, a cookie with 30% fat replacement was the only one as globally accepted as the control cookie. It can be explained the attribute of flavor in which shows that 30% fat replacement cookie and control cookie have no significant difference in their means. This implies that with this formulation, the flavor is accepted as the control one. Bearing in mind that 78% of consumers do not care about ingredients, but the flavor of the cookie, the importance of this attribute can be understood and therefore considered the most important one in the global acceptability of the cookie. However, other parameters such as color, appearance, and texture cookie with 30% fat replacement and control differ, and their means are significantly different. Another important result is the mean average of score of the texture in the three replacement cookies.

In this attribute, it was significantly lower than the one of control. However, considering cookies with 30% fat replacement, this mean difference was not a principal effect on the attribute of global acceptability. Another important result relies on the attribute of color and appearance. As a result of adding chemical colorant to the control cookie to achieve a similar color to the one in the tomato fiber, a rejection of the surveyed people was noticed. As it can be seen in color and appearance in 30% of fat replacement and 15% - 15% fat and flour replacement have a higher average mean than the control one, which means that this colorant addition was perceptible and unliked in the surveyed people.

Comparing Table 9 and Table 10 results. It can be evidenced a relationship between texture evaluated in the hedonic survey and cookie parameters such as hardness and fracturability. The sample with 30% fat replacement is the sample with better texture before the control, in the texture analysis (see Table 9), it can be evidenced that this sample and the control have the highest values of hardness. On the contrary, the sample with 30% flour replacement was the cookie with low texture values in the hedonic survey. This is consistent with hardness parameters. As shown in Table 9, this sample was the cookie with lower values of hardness or, in other words, the softest cookie.

For the JAR scale analysis, results showed how attributes such as crispness and sweetness infer the global acceptability of the product. In the case of the control cookie (Figure 5A) and the 30% fat replacement cookie (Figure 5B), the sweetness was well optimized as the JAR percentage was high. However, in the case of crispness, both cookies had a low JAR percentage and a high crispness percentage which can be translated as a need to revise and reduce crispness in those cookies. A mean drop penalization analysis was made (Table 11) to link up JAR scales and global acceptability results of the hedonic scale survey. For control cookies, none of the attributes affect the global perception of the product as only too low crispness, and too low sweetness had a mean drop greater than 1 (1.3 and 1.7 respectively). Still, the percentage of judges that infer that decision was low (12% and 10%, respectively). For 30% fat replacement cookie, there was an effect of the crispness attribute in which 24% of the judges considered it was too low and scored a mean drop of 1.2. Therefore, this attribute influenced the global acceptability but was not as strong to significantly differ compared with control. The other attributes and groups did not affect the global acceptability of the cookie.
Figure 1. JAR analysis for different cookies formulation

(A) Control. (B) 30% fat replacement. (C) 30% flour replacement. (D) 15% fat and 15% flour replacement.

Table 11. Mean drop analysis for JAR scale test

<table>
<thead>
<tr>
<th>Cookie</th>
<th>Attribute</th>
<th>Group</th>
<th>% judges</th>
<th>Mean Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Crispness</td>
<td>Very low</td>
<td>12</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>44</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Sweetness</td>
<td>Very low</td>
<td>10</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>32</td>
<td>-0.6</td>
</tr>
<tr>
<td>30% flour</td>
<td>Crispness</td>
<td>Very low</td>
<td>28</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>42</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>Sweetness</td>
<td>Very low</td>
<td>58</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>22</td>
<td>0.0</td>
</tr>
<tr>
<td>15% flour 15% fat</td>
<td>Crispness</td>
<td>Very low</td>
<td>82</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>6</td>
<td>-0.8</td>
</tr>
<tr>
<td></td>
<td>Sweetness</td>
<td>Very low</td>
<td>16</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>34</td>
<td>0.9</td>
</tr>
<tr>
<td>30% fat</td>
<td>Crispness</td>
<td>Very low</td>
<td>24</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>46</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Sweetness</td>
<td>Very low</td>
<td>6</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very High</td>
<td>36</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

For cookies with 15%-15% fat and flour replacement and 30% flour replacement, the same analysis was made to evaluate the reason for not having high global acceptability compared with the control cookie. Firstly, it is important to notice in Figure 5C and Figure 5D that the only well-optimized attribute was the sweetness on 15%-15% fat and flour replacement cookies. The results obtained for the 30% flour replacement cookie show that a higher percentage of judges considered that the cookie was very crispy and not very sweet. For the 15%-15% fat and flour replacement cookie, a significant number of judges considered that the crispness was very low. However, applying the mean drop analysis 15%-15% fat and flour replacement cookie attributes did not affect the global acceptability in any case. For 30% flour replacement cookie, the very low crispness and very low sweetness did influence global acceptability as their mean drops were 1.4 (with 28% of the surveyors) and 1.4 (with 58% of the surveyors), respectively.

Considering all the results, a final question was held for consumers to state the intention of purchasing any of the cookies. This question allows one to choose one or more cookies and even an option of neither of them. Control cookie and 30% fat replacement cookie were the more likely to be purchased by potential consumers, with 58% and 56% respectively of the consumers that will buy them. While 15% - 15% fat and flour replacement cookie is intended to be bought by 28% of the consumers and 30% flour replacement cookie is designed to be bought by 4% of surveyors. This confirms the global acceptability of both (30% fat and control) cookies to be likely. In terms of the study, it is important that 30% fat replacement
cookie had high acceptability. It opens a relevant framework to introduce a possible market analysis to take this cookie into the market and introduce it as a new functional product. The replacement of fats and the addition of fiber can be categorized as a replacement in the formulation of functional cookies and can be a step in the pursuit of the Colombian government to apply terms of sustainability and circular economy in all the food processing industry.

4 Theoretical proximal analysis

The formulation cookies with a 30 % fat replacement were established as a potential product. The nutritional fact of this product is shown in Figure 6. It was considered a bag of cookies as serving size with an approximate weight of 50 g (12 cookies per bag). The daily reference values were contemplated in the nutritional labeling module of the Colombia Health Ministry [66]. Additionally, minerals and vitamins of all the ingredients described in section 2.9 were considered. Table 2 was used as a reference for the percentages of all macro and micronutrients. As shown in Figure 6, the total amount of calories per serving was calculated considering the factors of conversion of proteins (4 kcal/g), Total carbohydrates (4 kcal/g) and fats (9 kcal/g) [66].

<table>
<thead>
<tr>
<th>Nutrition Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 servings per container</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Serving size</th>
<th>Calories 190</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fat 7.43 g</td>
<td>% Daily Value 11%</td>
</tr>
<tr>
<td>Saturated Fat 5.03 g</td>
<td>25%</td>
</tr>
<tr>
<td>Trans Fat 0</td>
<td>0%</td>
</tr>
<tr>
<td>Cholesterol 17.43 mg</td>
<td>6%</td>
</tr>
<tr>
<td>Sodium 161.3 mg</td>
<td>7%</td>
</tr>
<tr>
<td>Total Carbohydrate 28.38 g</td>
<td>9%</td>
</tr>
<tr>
<td>Dietary Fiber 2.52 g</td>
<td>10%</td>
</tr>
<tr>
<td>Total Sugars 11.5g</td>
<td>6%</td>
</tr>
<tr>
<td>Includes 11.5 g Added Sugars</td>
<td>0%</td>
</tr>
<tr>
<td>Protein 2.65 g</td>
<td>5%</td>
</tr>
</tbody>
</table>

Vitamin B1 0.23 mg 15%
Vitamin B2 0.1 mg 6%
Calcium 16.4 mg 2%
Iron 1.4 mg 8%
Folic acid 0.23 mg 11%

The % Daily Value tells you how much is included in a serving of foods contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Figure 6. Bag of cookies nutritional chart.

For labeling and nutritional requirements, it was considering the resolution 810 of 2021 of the Ministry of Health and Social Protection of Colombia [67]. Considering the requirements for nutritional claims, it is possible to establish on the label of the product the claim “excellent source of fiber,” considering as requirement that there must be at least 6 g of fiber in 100 g of food. In addition, the requirement for claims in minerals and vitamins is at least 30% in the DV for 100 g of food. Considering this, it is possible to claim an “excellent source of vitamin B1 or thiamin” [67]. Although, other nutritional claims describe the absence of a compound. In Figure 6, the complete lack of trans fat can be evidenced. Considering this, it is possible to establish the claim “free of trans fat.” Finally, if it contains a maximum of 0.02 g per 100 g (in solids), it is possible to use the descriptor “low in cholesterol.”

Considering the current Colombian market, “Compañía de Galletas Noel S.A.” is consolidated as the main producer of cookies in Colombia, with a 55.9% share in the national biscuit market [68]. Noel’s product that is most closely related to the product of 30% replacement of fats in terms of serving size, appearance, and bag size is the MiniChips® brand. Comparing both nutritional facts. There is a difference in total fats, 7.43 g per 50 g in the cookie with 30% replacement of fats and 10 g per 50 g of MiniChips®. Bearing this in mind, it is possible to observe the difference in total fat associated with the replacement with the fiber of the tomato peel. Consequently, there is a significant difference in the fiber content. For MiniChips®, a content of 1.4 g of crude fiber per 50 g is evidenced, while for cookies in this study, there is a 2.52 g per 50 g of dietary fiber. Thus, there is a substantial increase in the daily reference value for the dietary fiber due to the incorporation of the fiber present in tomato peel. Without this contribution, wheat flour was the only ingredient with a fraction of dietary fiber. (3% DV for a 50 g bag of chips). Therefore, incorporating the fiber from tomato peel is an excellent opportunity to launch products with higher dietary fiber content and global acceptability.

5 Conclusions

Tomato peel is an unused industrial residue with high potential due to its functional compounds such as lycopene, β-carotene and TDF. The usage of these compounds after the residue is produced to enhance the circular economy and sustainability concepts in the global and local food industry. On the one hand, the extraction of carotenoids can be held with green processes such as UAE and solvents whose effects on the environment are not as harmful as those used in CE. In this case, the optimal extraction was made with a mixture of 80 AE:20 EtOH and a 0.025 (w/v) solvent-biomass ratio. The encapsulation of these carotenoid content concluded with an efficiency of 58.1%, which is considered acceptable. On the other hand, tomato peel is a good source of TDF, which is known to have many functional effects, as discussed before. A concentration of 49.46g TDF/100g biomass DB was found. This fiber can be used in different aspects, such as functional food formulations. In the case of this study, TDF was considered a potential replacement for the fats in the formulation of butter cookies. The addition of this fiber contributes to reducing blood sugar levels and the prevention of cardiovascular disease if the daily intake is enough, as mentioned before. Therefore, through the valorization of a residue a proposal in functional food enhances public health issues. Also, this development considers the urge of the local government of Colombia to create a culture of sustainability and circular economy in the country, looking forward to strengthening the use and harvesting of resources obtained from residues. One of the goals made by the Colombian government in the achievement of the 12 SDO (sustainable development objectives) for the United Nations is to revalue at least 12% of the organic residues applying alliances with industries and enforcing investigation. Thus, this study...
demonstrates that some unused residues have great potential and show a significant step into the government’s goals considering responsible production and consumption.

6 Further work

In this study, two of the principal functional compounds of the tomato peel were evaluated in terms of their possibility of usage in the food industry as additives or replacements in formulations. However, due to limitations, there was no evaluation of both compounds together in the development of functional foods. For future work, it can be an excellent opportunity to evaluate the integration of encapsulated carotenoids in the formulation of a cookie that replaces fat for tomato fiber. With that in mind, the cookie's functionality will be higher as it can provide a more functional effect if the intake is constant. It also can be an opportunity to know the potential consumer perception of the product once the capsules are added to the formulation. Since the wall material of encapsulation can prevent the degradation of carotenoid molecules (which are highly thermolabile), it can be studied up to what point this protective layer fulfills its function.

References

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