Tomato Pomace Ketchup: Physicochemical, Microbiological, and Sensory Characteristics

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Abstract.
Tomato (Solanum lycopersicum L.) is one of the most important crops that is extensively used in the food processing industry. During tomato processing, abundant by-products such as skins, pulps, seeds, and waste are generated and cause environmental burdens. To solve this problem, tomato pomace was subsequently used as a material for making tomato sauce. However, it is essential that the production of tomato ketchup meets the required standards. Therefore, it is important to analyze the physicochemical and sensory characteristics of the product. We aimed to study the effect of corn starch addition on the physicochemical and sensory properties of tomato ketchup made from tomato waste and to assess the acceptability of tomato sauce formulated with different concentrations of corn starch.

Tomato ketchup was cooked at 90°C for 15 min and then hot-filled into a sterile glass bottle. It was then analyzed for physical properties (color, viscosity, and total dissolved solids), chemical properties (pH, titratable acidity, moisture content), microbiological quality (total bacteria, mold, and yeast), and sensory acceptance.

The results showed that corn starch influenced the color characteristics of the tomato sauce. Adding more than 4% of corn starch increased the viscosity and total solids content significantly (<i>p</i> < 0.05). Also, corn starch addition decreased the water content and acidity, as well as increased the pH of the tomato sauce. Microbiological analysis showed no growth of bacteria, mold, or yeast in any of the test samples. According to sensory analysis, the tomato sauce with 1% of corn starch had the highest acceptance, while higher concentrations of corn starch decreased the texture acceptance.

Our findings may indicate that, with proper formulation, tomato by-products can be used as raw materials to develop sustainable alternative value-added products that consumers accept organoleptically. Further investigations can be conducted in the pilot-scale studies to enhance the feasibility of tomato pomace ketchup as a commercial product.

Keywords. Solanum lycopersicum L., corn starch, ketchup, tomato waste, quality, safety

Кетчуп из томатного жмыха: физико-химические, микробиологические и органолептические показатели

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Аннотация.
Томаты (Solanum lycopersicum L.) являются важной сельскохозяйственной культурой. При переработке томатов образуются побочные продукты (кожица, мякоть, семена, отходы), которые выбрасываются производителями. Чтобы снизить потери, томатные выжимки используют для приготовления томатного кетчупа. Качество готового томатного кетчупа должно соответствовать требованиям стандартам, особенно физико-химическим и органолептическим характеристикам продукта. Цель работы – изучить влияние кукурузного крахмала на физико-химические, микробиологические и органолептические свойства томатного кетчупа, приготовленного из томатных отходов, и оценить потребительскую привлекательность готового продукта.

Кетчуп готовили из томатных выжимок. Для загущения соуса добавляли кукурузный крахмал в концентрациях 1, 4 и 7 %. Соус варили при температуре 90 °С в течение 15 мин и горячим разливали в стерильные стеклянные банки. Анализ физических (цвет, вязкость, общий сухой остаток), химических (pH, титруемая кислотность, содержание влаги), микробиологических (общее количество бактерий, плесени и дрожжей) и органолептических свойств проводили по общепринятым методикам.

Результаты исследования показали, что кукурузный крахмал влияет на цветовые характеристики томатного соуса. Добавление более 4 % кукурузного крахмала позволило повысить вязкость и общий сухой остаток (р < 0,05). Введение кукурузного крахмала в рецептуру позволило снизить количество воды и кислотность, а также повысить pH томатного соуса. Микробиологический анализ не выявил роста бактерий, плесени или дрожжей в тестируемых образцах. Томатный соус с 1 % кукурузного крахмала получил самую высокую оценку по органолептическим показателям. Более высокие концентрации кукурузного крахмала негативно влияли на консистенцию продукта.

Правильно подобранная рецептура позволяет использовать побочные продукты переработки томатов в качестве сырья для производства экологичных продуктов с добавленной стоимостью и хорошими органолептическими характеристиками. Однако для повышения эффективности производства кетчупа из томатных выжимок в промышленных условиях требуются дополнительные исследования.

Ключевые слова. Solanum lycopersicum L., кетчуп, томатные отходы, кукурузный крахмал, качество, безопасность

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Significant losses and waste are generated during harvest, fruit handling, and industrial processing [13]. In industrial processing, tomatoes are used to produce ready-to-eat products such as ketchup, paste, juice, and jams. It generates significant residues such as tomato peels and seeds [14, 15]. These tomato pomaces have been proven to contain abundant amounts of nutrients and phytochemicals [16, 17].

Indonesia produced around 1.1 million tomatoes in 2020, and the production level is expected to increase gradually in the next few years [18]. The gradual rise in the production and consumption of tomatoes also increases waste generation. Therefore, the recycling of tomato waste is currently the leading solution among the top environmental stakes. The valorization of the product through developing a sustainable product is greatly encouraged, and tomato sauce can be one of such products [19]. To the best of our knowledge, there has never been a product produced from tomato waste and sold in Indonesia.

Among tomato-based products, tomato sauce or tomato ketchup is one of the most widely consumed food products in the world, and its production requires simple unit operations [20]. Some previous studies have shown the success of using tomato pomace as raw material for making tomato sauce [20, 21]. Tomato pomace is prone to microbial deterioration due to its high water content (approximately 80–90%); therefore, the processing must be conducted as soon as possible [22]. Moreover, this high water content could lead to a significantly diluted sauce [23]. Therefore, it is crucial to add a thickening agent to improve the rheological and sensory properties of the product, such as corn starch [24]. Corn starch has been widely used in food industries as an affordable thickener and a preferable choice due to its high thickening capacity, swelling properties, and paste clarity [25]. The addition of corn starch has been reported to have pasting properties comparable with other starches, which can prevent the separation of tomato ketchup serum and aggregation of solid particles during storage [26, 27]. The tendency of people to consume natural products has boosted the use of native corn starch and given rise to research on the use of native corn starch in food applications. Tomato ketchup is generally produced from tomato paste. We, however, used tomato pomace as a sole base for tomato ketchup. The amount of corn starch added to the formulation is crucial for the body texture and other characteristics of the product. Thus, we aimed to study the effect of corn starch on the physicochemical properties of tomato sauce and to assess the acceptability of tomato sauce formulated with different concentrations of corn starch.

Study objects and methods

In this study, we used tomato waste (FoodCycle, Indonesia), native cornstarch (Maizenaku, Indonesia), and other ingredients for making tomato sauce. The chemicals used for the experiment included sodium hydroxide (NaOH), phenolphthalein, phosphate buffer saline, ethanol 96%, tartaric acid, potato dextrose agar, and plate count agar (Merck, Germany).

**Tomato sauce preparation.** Tomato waste fraction was first collected. For this, around 500 g of tomato pomace was blanched at 90°C for 3 min and crushed using a blender for 5 min until forming a slurry pulp. The pulp was mixed with other ingredients (fixed percentage concentration, not mentioned) to make tomato sauce, except for corn starch used at different concentrations (Table 1). After the texture was thickened, the acidity of the tomato sauce was adjusted using the acidifying agent. The sauce was heated until the final total soluble solid was obtained. The ketchup was hot-filled into a sterile glass bottle and then heated at 90°C for 15 min. 

No other tomato products (such as paste) were added to the tomato ketchup.

**Color analysis.** The color of the tomato sauce was evaluated using a Chromameter NH310 (Shenzhen, China) [28]. In this experiment, three color matrices were measured: pixel value of lightness \( L \), pixel value of \( a \) (greenness to redness), and pixel value of \( b \) (blueness to yellowness). \( L, a, b, \) and \( \Delta E \) between the test samples and the control sauce were calculated using the following Eq. (1):

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

**Viscosity analysis.** The viscosity analysis of the samples was carried out using a Brookfield DV-1 viscometer (Ametek Brookfield, USA) at room temperature [29]. The spindle RV-07 was immersed into the sample and stirred at 10, 50, and 100 rpm for 3 min. The data shown in the display of the viscometer was then recorded.

**Total dissolve solids analysis.** The total dissolved solids of the tomato sauce were measured using a Brix refractometer [30]. The sample was homogenized and then centrifuged. The resulting clear liquid was then dropped onto the refractometer prism. The data shown in the refractometer was then recorded and expressed as °Brix.

**pH and titratable acidity measurement.** The acidity (pH) of the tomato sauce was measured using a pH meter following the procedures of the Association of Official Analytical Chemists [30]. pH meter was

<table>
<thead>
<tr>
<th>Formula</th>
<th>Corn starch, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>
calibrated with a standard buffer solution of pH 4.0, 7.0, and 10.0 before being used.

The titratable acidity, %, of the tomato sauce was determined using the acid-base titration method [31]. The sample was diluted, filtered, mixed with 0.1% phenolphthalein, and titrated with 0.1 N NaOH solution. The percentage of acidity was calculated as acetic acid using the following Eq. (2):

$$ TA = \frac{V \times N \times B \times FP}{W} \quad (2) $$

where $V$ is the volume of 0.1 N NaOH solution used for titration, mL; $N$ is the normality of NaOH solution (0.1 N); $B$ is the equivalent weight of acetic acid (60.052 g/mol); $FP$ is the dilution factor; $W$ is the sample’s weight, g.

**Moisture content analysis.** The moisture content, %, of the tomato sauce was determined by drying the sample in an oven at 105°C until a constant weight was achieved [32]. The water content was calculated using the following Eq. (3):

$$ \text{Moisture content} = \frac{W - W_i}{W_i} \times 100 \quad (3) $$

where $W$ is the sample’s weight before drying, g; $W_i$ is weight loss after drying, g.

**Total microbial analysis.** The total microbial analysis of the tomato sauce was carried out using the pour plate method [33]. The sample was diluted up to $10^{-3}$ and cultured into Plate Count Agar (Merck, Germany). The colony growth was observed on each plate after 48 h of incubation at 37°C.

**Enumeration of mold and yeast.** The enumeration of mold and yeast in the tomato sauce was carried out using the spread plate method [34]. The sample was diluted up to $10^{-5}$ and yellow colors is the natural content of carotenoid pigments. The amount of carotenoid pigments depends on the variety, fruit maturity level, and environmental conditions where the fruit ripens [37]. The value of total color differences ($\Delta E$) can be classified as very obvious ($\Delta E > 3$), obvious ($1.5 < \Delta E < 3$), and not noticeable ($\Delta E < 1.5$) [38]. According to Table 2, corn starch affected the samples’ color significantly. In particular, adding 7% of corn starch resulted in very lower the brightness level of the tomato source [36]. All the samples also had positive $a^*$ and $b^*$ values, which means the colors tended to be red and yellow. The main component responsible for the tomato’s red and yellow colors is the natural content of carotenoid pigments. The amount of carotenoid pigments depends on the variety, fruit maturity level, and environmental conditions where the fruit ripens [37]. The value of total color differences ($\Delta E$) can be classified as very obvious ($\Delta E > 3$), obvious ($1.5 < \Delta E < 3$), and not noticeable ($\Delta E < 1.5$) [38]. According to Table 2, corn starch affected the samples’ color significantly. In particular, adding 7% of corn starch resulted in very

**Statistical analysis.** The data were statistically analyzed using the IBM SPSS Statistics 25.0 software. The One-Way ANOVA and HSD Tukey’s at 95% confidence interval ($p < 0.05$) were used to analyze the differences in physicochemical and sensory properties of the tomato sauce.

**Results and discussion.**

The production of tomato sauce from tomato waste is one of the solutions to valorize tomato waste from industrial processing. The formulation of tomato sauce with corn starch was intended to obtain the best formula with high acceptability in terms of physicochemical and sensory characteristics.

**Effect of corn starch on the color of tomato sauce.** Color properties are the most essential physical characteristics in the acceptability of tomato sauce. The CIE $L^*$, $a^*$, $b^*$ color model was used to measure the color of the tomato sauces with different concentrations of corn starch (Table 2).

We found that the addition of corn starch changed the color of the tomato sauce. Particularly, adding up to 7% of corn starch changed the $L^*$, $a^*$, $b^*$, and $\Delta E$ values significantly ($p < 0.05$), compared to the control. Corn starch has a pure white color and produces a transparent gel. The higher the concentration of corn starch, the more transparent starch crystals and the higher the brightness level of the tomato source [36].

Table 2. Instrumental color parameters $L^*$, $a^*$, $b^*$, and $\Delta E$ of tomato sauce with different corn starch concentrations

<table>
<thead>
<tr>
<th>Formula</th>
<th>$L^*$</th>
<th>$a^*$</th>
<th>$b^*$</th>
<th>$\Delta E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34.52 ± 0.52</td>
<td>14.27 ± 0.54</td>
<td>6.80 ± 0.32</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>34.52 ± 0.26</td>
<td>15.59 ± 0.58</td>
<td>9.80 ± 0.32</td>
<td>2.48 ± 0.68</td>
</tr>
<tr>
<td>3</td>
<td>34.55 ± 0.85</td>
<td>14.61 ± 0.46</td>
<td>9.51 ± 1.04</td>
<td>2.81 ± 0.82</td>
</tr>
<tr>
<td>4</td>
<td>37.61 ± 0.25</td>
<td>16.00 ± 0.50</td>
<td>11.51 ± 0.48</td>
<td>5.00 ± 0.58</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD. The numbers followed by different letters in the column are statistically different ($p < 0.05$).
In particular, adding up to 4% of corn starch increased the total solids content to 31.00–40.33°Brix. However, higher concentrations of corn starch did not improve the total solids content in the tomato sauce. This is one of the critical quality parameters in tomato sauce production. The higher the content of total dissolved solids in the tomato sauce, the better its quality and consistency [40]. According to the Indonesian national standard for the production of tomato sauce, good quality tomato sauce must have at least 30°Brix (SNI 01-3546-2004). All the samples tested in our study met this requirement.

**Effect of corn starch on moisture content, pH, and acidity of tomato sauce.** Figure 3 shows the results of moisture content analysis. Significant differences were observed in all the tomato sauces with corn starch compared to the control. The lowest moisture content was detected in the tomato sauce formulated with 7% of corn starch (56.77%). Our data were in line with those in the previous research where higher concentrations of corn starch in tomato sauce lowered its water content [41]. On the other hand, our results were opposite to those in a study by K. Alam et al. who stated that adding a thickening agent could increase the water content [42]. The disparity between the data in the previous research and our results could probably be due to the type of thickening agent used and its water-binding ability.

As can be seen from Fig. 4, the addition of corn starch influenced the pH of the tomato sauces. In particular, their pH values ranged from 3.47 to 3.57. A slight increase in pH was observed in the tomato sauce formulated with more than 1% of corn starch. The pH values in our study met the pH requirements for tomato sauce (pH 3–4) (SNI 01-3546-2004). Our results were consistent with those in a previous study, where pH ranged between 3.40 and 3.84 [42]. The pH values were mainly influenced by the number of acids contained in the samples. The titratable acidity (Fig. 5) of the tomato sauces ranged from 3.57 to 3.73%. The addition of corn starch increased total dissolved solids significantly (p < 0.05).
of corn starch reduced the acidity of the tomato sauce \((p < 0.05)\). The titratable acidity values in our study were in line with the Indonesian national standard, which requires a minimum of 0.8% acidity in tomato sauce (SNI 01-3546-2004).

**Microbiology analysis of tomato sauces.** The results of the microbiological tests are shown in Table 3. As can be seen, none of the samples was found to be contaminated by microorganisms. Furthermore, the counts were lower than the maximum standard, which is \(2 \times 10^2\) CFU/g for total microorganisms and \(5 \times 10^5\) CFU/g for molds and yeasts (SNI 01-3546-2004). The results confirmed that the tomato sauces were produced promptly after the receipt of tomato waste, which prevented its decomposition and minimized the proliferation of microorganisms [43]. In addition, the low bacterial and mold yeast counts in our study could be related to the low pH of the tomato sauces and the heat treatment process during tomato sauce production [44].

**Sensory analysis of tomato sauces.** The results of the sensory analysis are shown in Table 4. The addition of corn starch showed the variation in sensory attributes acceptance. The panelists preferred the tomato sauce with 1% of corn starch in terms of color, aroma, flavor, texture, and overall acceptance. The statistical results showed a significant difference between the 1% corn starch sample and the control \((p < 0.05)\). Among the test samples, adding more than 1% of corn starch showed no differences in color, aroma, or flavor but...
tended to decrease the texture acceptance. This decrease is probably due to the capability of corn starch to weaken the distinctive aroma and flavor of tomato sauce [23]. A similar result was observed in the study by Singh et al., where the tomato sauce with a higher concentration of thickening agent tended to have a lower sensory score on aroma and flavor [45]. Besides, higher concentrations of corn starch reduced the acceptance of color in the tomato sauce. As for overall acceptance, adding more than 1% of corn starch did not cause a significant difference compared to the control (p > 0.05). These results showed the potency of tomato waste in Indonesia to be utilized into acceptable products through proper formulation.

Conclusion

To sum up, our study provided information on the effect of corn starch formulation on the physicochemical and sensory properties of the tomato ketchup made from tomato waste. According to our results, adding corn starch in certain concentrations can affect the physical characteristics of the tomato sauce. In particular, the addition of corn starch reduced the acidity and increased the pH of the tomato sauce. All the test samples were free from bacterial (< 2.5×10^2 CFU/g) or mold and yeast (1.0×10^2 CFU/g) contaminations. The sensory analysis showed that the tomato sauce formulated with 1% of corn starch had the highest acceptance by the panelists. Our results indicate that with proper formulation, tomato waste can be employed as raw material to develop an organoleptically acceptable and sustainable value-added product in Indonesia. To increase the feasibility of tomato pomace ketchup as a commercial product, additional research should be undertaken in the pilot-scale trials.

Conflict of interests

The authors declare no conflict of interests regarding the publication of this article.

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Conflict of interests

C. Heriyanto: концепция исследования, получение и анализ экспериментальных данных, написание текста статьи. А. Ромуло: план исследования, научное руководство, написание текста статьи и его редактирование.

Conflict of interests

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