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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 ($p < 0.05$). 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

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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 требуемым 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 °C 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 ($p < 0,05$). Введение кукурузного крахмала в рецептуру позволило снизить количество воды и кислотность, а также повысило 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 промышленного условиях требуются дополнительные исследования.

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

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Introduction

Tomato (*Solanum lycopersicum* L.) is one of the world's most economically important and widely cultivated crops [1, 2]. It is considered a multi-function ingredient and is frequently utilized to improve the flavor, color, and texture of various food products [3]. Tomatoes have been reported to have advantageous nutritional and health benefits due to their components such as vitamin C, carotenoids (mainly lycopene, lutein, and β-carotene), as well as phenolic compounds [4–6]. Previous studies have associated the consumption of tomatoes with improving immune responses and reducing the risk of cardiovascular diseases and certain cancers [7–10]. Therefore, tomatoes and tomato-derived products are considered a good source of nutrients.

According to the Food and Agricultural Organization, approximately 200 million tons of tomatoes are produced annually worldwide [11]. Of the total production, around 75% is used for direct consumption, while the rest is utilized as an ingredient in processed tomato-based products [11, 12]. It is expected that 30% of fresh tomatoes will be wasted along the production chain.

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 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). The L, a, b, and ΔE between the test samples and the control sauce were calculated using the following Eq. (1):

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \qquad (1)$$

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 1. Corn starch concentrations in tomato sauce

Таблица 1. Концентрация кукурузного крахмала в томатном соусе

Formula	Corn starch, %
1	0
2	1
3	4
4	7

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):

$$TA = \frac{V \times N \times B \times FP}{W} \tag{2}$$

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):

$$\text{Moisture content} = \frac{W_1}{W} \times 100 \tag{3}$$

where W is the sample's weight before drying, g; W_1 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 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^{-2} and cultured into Potato Dextrose Agar (Merck, Germany). The colony growth was recorded on each plate after 5 days of incubation at 25°C.

Sensory analysis. The sensory analysis of the tomato sauces was conducted using a hedonic rating test [35]. The analysis was performed in a sensory laboratory with separate spaces for the panelists. The tomato sauce parameters (color, aroma, taste, texture, and overall acceptance) were assessed using a 9-scale hedonic rating test (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like or dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely).

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 ΔE 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]. 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 (ΔE) 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

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

Таблица 2. Показатели цвета томатного соуса L^*, a^*, b^* и ΔE: образцы с разной концентрацией кукурузного крахмала

Formula	L^*	a^*	b^*	ΔE
1	34.52 ± 0.52^a	14.27 ± 0.54^a	8.08 ± 0.72^a	0^a
2	35.42 ± 0.26^b	15.59 ± 0.58^b	9.80 ± 0.32^b	2.48 ± 0.68^b
3	36.55 ± 0.85^c	14.61 ± 0.46^a	9.51 ± 1.04^b	2.81 ± 0.82^b
4	37.61 ± 0.25^d	16.00 ± 0.50^b	11.51 ± 0.48^c	5.00 ± 0.58^c

Values are expressed as mean ± SD. The numbers followed by different letters in the column are statistically different ($p < 0.05$).

Значения выражаются как среднее ± стандартное отклонение. Цифры, за которыми следуют разные буквы в столбце, статистически различаются ($p < 0,05$).

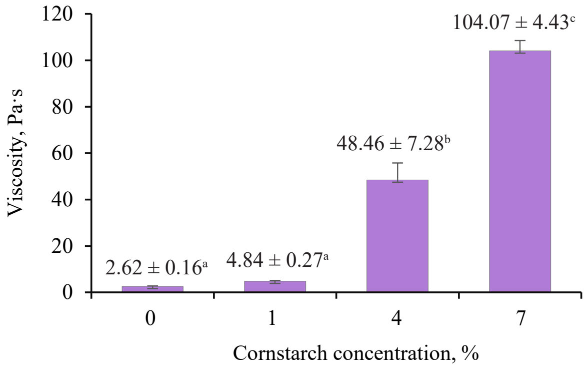

Figure 1. Effect of corn starch on the viscosity of tomato sauces

Рисунок 1. Влияние кукурузного крахмала на вязкость томатного соуса

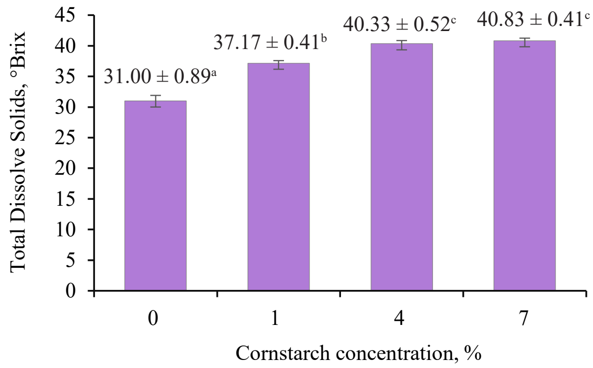

Figure 2. Effect of corn starch on total dissolved solids of tomato sauces

Рисунок 2. Влияние кукурузного крахмала на общий сухой остаток в томатном соусе

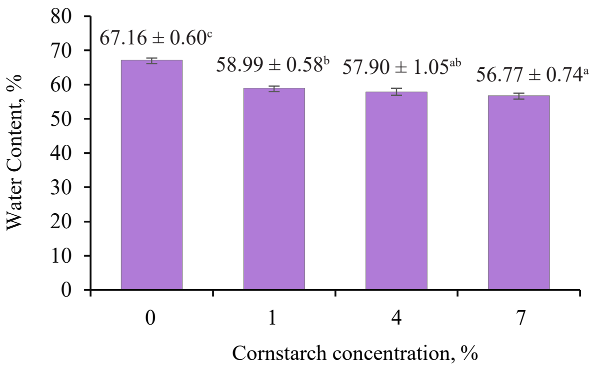

Figure 3. Effect of corn starch on moisture content of tomato sauces

Рисунок 3. Влияние кукурузного крахмала на содержание влаги в томатном соусе

obvious color differences, while 4% of corn starch produced obvious color changes.

Effect of corn starch on viscosity and total dissolved solids of tomato sauce. The viscosity of the tomato sauces manufactured with different corn starch concentrations is shown in Fig. 1. According to the results, the addition of corn starch increased the viscosity of the tomato sauce significantly ($p \leq 0.05$). In particular, adding 7% of corn starch resulted in the highest viscosity of the tomato sauce (104.07 Pa·s), compared to the control. During the heat treatment process in the production of tomato sauce, corn starch undergoes gelatinization and swelling, increasing the sauce's viscosity [23]. Due to water absorption during gelatinization, the prevention of syneresis and stable texture in tomato sauce could be achieved [39].

The increased viscosity of the tomato sauce may also be affected by the content of total dissolved solids (Fig. 2). Our results showed that the addition of corn starch increased total dissolved solids significantly ($p < 0.05$). In particular, adding up to 4% of corn starch increased the total solids content to 31.00–40.33°Brix. However, higher concentrations 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

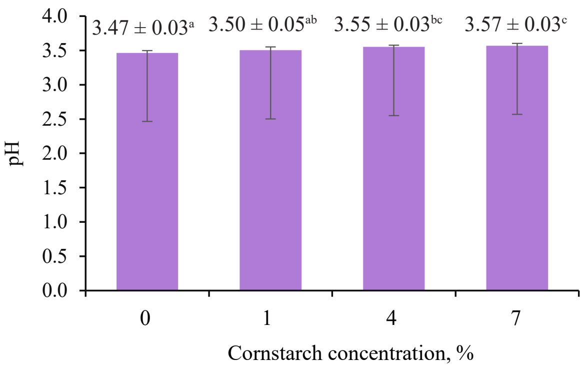

Figure 4. Effect of corn starch on pH values of tomato sauce

Рисунок 4. Влияние кукурузного крахмала на значения pH томатного соуса

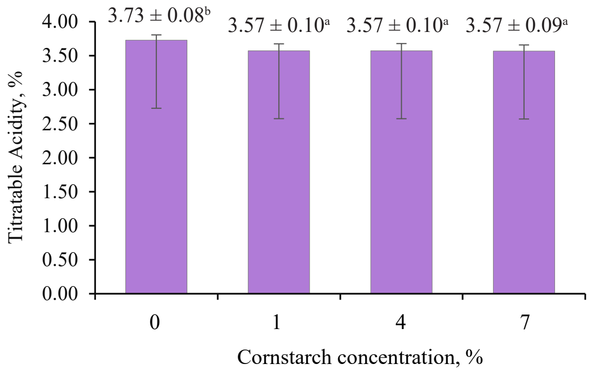

Figure 5. Effect of corn starch on titratable acidity of tomato sauce

Рисунок 5. Влияние кукурузного крахмала на титруемую кислотность томатного соуса

Table 3. Microbial analysis of tomato sauce

Таблица 3. Микробный анализ томатного соуса

Formula	Total microbes, CFU/g	Mold and yeast, CFU/g
1	$< 2.5\times10^2$ (0)	$< 1.0\times10^2$ (0)
2	$< 2.5\times10^2$ (0)	$< 1.0\times10^2$ (0)
3	$< 2.5\times10^2$ (0)	$< 1.0\times10^2$ (0)
4	$< 2.5\times10^2$ (0)	$< 1.0\times10^2$ (0)

Table 4. Tomato sauce acceptance by hedonic rating

Таблица 4. Потребительская привлекательность томатного соуса по гедонистической шкале

Formula	Color	Aroma	Flavor	Texture	Overall
1	5.95 ± 1.62^{ab}	4.65 ± 2.02^{a}	5.08 ± 1.83^{a}	5.70 ± 1.47^{bc}	5.10 ± 1.55^{a}
2	6.90 ± 1.28^{c}	6.18 ± 1.60^{b}	6.43 ± 1.55^{b}	6.45 ± 1.48^{c}	6.50 ± 1.50^{b}
3	6.60 ± 1.26^{bc}	5.78 ± 1.46^{b}	5.90 ± 1.61^{ab}	5.33 ± 1.86^{b}	5.70 ± 1.49^{ab}
4	5.70 ± 1.77^{a}	5.60 ± 1.60^{ab}	5.50 ± 1.84^{ab}	4.18 ± 2.23^{a}	5.03 ± 1.86^{a}

Values are expressed as mean ± SD. The numbers followed by different letters in the column are statistically different ($p < 0.05$).

Значения выражаются как среднее ± стандартное отклонение. Цифры, за которыми следуют разные буквы в столбце, статистически различаются ($p < 0,05$).

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 2×10^2 CFU/g for total microorganisms and 5×10^1 CFU/g for molds and yeasts (SNI 01-3546-2004). The results confirmed that the tomato sauces were produced in accordance with good manufacturing practices for producing processed foods. In particular, 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 ($< 2.5\times10^2$ 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.

Contribution

S. Heriyanto conceptualized the research, collected and analyzed the data, and wrote the manuscript. A. Romulo designed the study, supervised the research, as well as wrote, edited, and submitted the manuscript.

Conflict of interests

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

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

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References

1. Kumar M, Tomar M, Bhuyan DJ, Punia S, Grasso S, Sá AGA, *et al.* Tomato (*Solanum lycopersicum* L.) seed: A review on bioactives and biomedical activities. Biomedicine and Pharmacotherapy. 2021;142. https://doi.org/10.1016/j.biopha.2021.112018

2. Liu W, Liu K, Chen D, Zhang Z, Li B, El-Mogy MM, *et al. Solanum lycopersicum*, a model plant for the studies in developmental biology, stress biology and food science. Foods. 2022;11(16). https://doi.org/10.3390/foods11162402

3. Bot F, Calligaris S, Cortella G, Nocera F, Peressini D, Anese M. Effect of high pressure homogenization and high power ultrasound on some physical properties of tomato juices with different concentration levels. Journal of Food Engineering. 2017;213:10–17. https://doi.org/10.1016/j.jfoodeng.2017.04.027

4. Dai T, McClements DJ, Niu X, Guo X, Sun J, He X, *et al.* Whole tomato juice produced by a novel industrial-scale microfluidizer: Effect on physical properties and *in vitro* lycopene bioaccessibility. Food Research International. 2022; 159. https://doi.org/10.1016/j.foodres.2022.111608

5. Khan UM, Sevindik M, Zarrabi A, Nami M, Ozdemir B, Kaplan DN, *et al.* Lycopene: Food sources, biological activities, and human health benefits. Oxidative Medicine and Cellular Longevity. 2021;2021. https://doi.org/10.1155/2021/2713511

6. Li N, Wu X, Zhuang W, Xia L, Chen Y, Wu C, *et al.* Tomato and lycopene and multiple health outcomes: Umbrella review. Food Chemistry. 2021;343. https://doi.org/10.1016/j.foodchem.2020.128396

7. Zhang W, Yu Y, Xie F, Gu X, Wu J, Wang Z. High pressure homogenization versus ultrasound treatment of tomato juice: Effects on stability and *in vitro* bioaccessibility of carotenoids. LWT. 2019;116. https://doi.org/10.1016/j.lwt.2019.108597

8. Mannino F, Pallio G, Altavilla D, Squadrito F, Vermiglio G, Bitto A, *et al.* Atherosclerosis plaque reduction by lycopene is mediated by increased energy expenditure through AMPK and PPARα in ApoE KO mice fed with a high fat diet. Biomolecules. 2022;12(7). https://doi.org/10.3390/biom12070973

9. Cámara M, Fernández-Ruiz V, Sánchez-Mata M-C, Cámara RM, Domínguez L, Sesso HD. Scientific evidence of the beneficial effects of tomato products on cardiovascular disease and platelet aggregation. Frontier in Nutrition. 2022;9. https://doi.org/10.3389/fnut.2022.849841

10. Puah B-P, Jalil J, Attiq A, Kamisah Y. New insights into molecular mechanism behind anti-cancer activities of lycopene. Molecules. 2021;26(13). https://doi.org/10.3390/molecules26133888

11. Méndez-Carmona JY, Ascacio-Valdes JA, Alvarez-Perez OB, Hernández-Almanza AY, Ramírez-Guzman N, Sepúlveda L, *et al.* Tomato waste as a bioresource for lycopene extraction using emerging technologies. Food Bioscience. 2022;49. https://doi.org/10.1016/j.fbio.2022.101966

12. Trombino S, Cassano R, Procopio D, Di Gioia ML, Barone E. Valorization of tomato waste as a source of carotenoids. Molecules. 2021;26(16). https://doi.org/10.3390/molecules26165062

13. Sibomana MS, Workneh TS, Audain K. A review of postharvest handling and losses in the fresh tomato supply chain: A focus on Sub-Saharan Africa. Food Security. 2016;8:389–404. https://doi.org/10.1007/s12571-016-0562-1

14. Santiago-Ramos R, Silva CLM, Ramos IN. Modelling and optimization of the processing of a healthy snack bar made of grape and tomato pomaces. Foods. 2022;11(17). https://doi.org/10.3390/foods11172676

15. Solaberrieta I, Mellinas AC, Espagnol J, Hamzaoui M, Jiménez A, Garrigós MC. Valorization of tomato seed by-products as a source of fatty acids and bioactive compounds by using advanced extraction techniques. Foods. 2022;11(16). https://doi.org/10.3390/foods11162408

16. Oboulbiga EB, Parkouda C, Savadogo B, Guissou AWDB, Traore K, Traore AS, *et al.* Changes in physicochemical properties and bioactive compounds of tomato pulp submitted to different processing techniques. African Journal of Food Science. 2020;14(10):330–335. https://doi.org/10.5897/AJFS2020.1998

17. Silva YPA, Borba BC, Pereira VA, Reis MG, Caliari M, Brooks MS-L, *et al.* Characterization of tomato processing by-product for use as a potential functional food ingredient: Nutritional composition, antioxidant activity and bioactive compounds. International Journal of Food Sciences and Nutrition. 2019;70(2):150–160. https://doi.org/10.1080/09637486.2018.1489530

18. Crops and livestock products [Internet]. [cited 2023 Jan 10]. Available from: https://www.fao.org/faostat/en/#data/QCL

19. Laranjeira T, Costa A, Faria-Silva C, Ribeiro D, de Oliveira JMPF, Simões S, *et al.* Sustainable valorization of tomato by-products to obtain bioactive compounds: Their potential in inflammation and cancer management. Molecules. 2022;27(5). https://doi.org/10.3390%2Fmolecules27051701

20. Torbica A, Belović M, Mastilović J, Kevrešan Ž, Pestorić M, Škrobot D, *et al.* Nutritional, rheological, and sensory evaluation of tomato ketchup with increased content of natural fibres made from fresh tomato pomace. Food and Bioproducts Processing. 2016;98:299–309. https://doi.org/10.1016/j.fbp.2016.02.007

21. Belović M, Torbica A, Pajić-Lijaković I, Tomić J, Lončarević I, Petrović J. Tomato pomace powder as a raw material for ketchup production. Food Bioscience. 2018;26:193–199. https://doi.org/10.1016/j.fbio.2018.10.013

22. Al-Muhtaseb AH, Al-Harahsheh M, Hararah M, Magee TRA. Drying characteristics and quality change of unutilized-protein rich-tomato pomace with and without osmotic pre-treatment. Industrial Crops and Products. 2010;31(1):171–177. https://doi.org/10.1016/j.indcrop.2009.10.002

23. Herlina H, Lindriati T, Prahasbynar P. The use of crude extract water soluble polysaccharide from durian (*Durio zibethinus* Muur.) seeds in tomato sauce processing. agriTECH. 2016;36(3):286–293. (In Indonesian). https://doi.org/10.22146/agritech.16597

24. Himashree P, Sengar AS, Sunil CK. Food thickening agents: Sources, chemistry, properties and applications – A review. International Journal of Gastronomy and Food Science. 2022;27. https://doi.org/10.1016/j.ijgfs.2022.100468

25. Ali TM, Hasnain A. Physicochemical, morphological, thermal, pasting, and textural properties of starch acetates. Food Reviews International. 2016;32(2):161–180. https://doi.org/10.1080/87559129.2015.1057842

26. Siti N, Misra S, Baruah D, Badwaik LS, Deka SC. Physicochemical properties of taro and maize starch and their effect on texture, colour and sensory quality of tomato ketchup. Starch – Stärke. 2014;66(3–4):294–302. https://doi.org/10.1002/star.201300120

27. Dzhivoderova-Zarcheva M, Nikovska K, Dimova K. Rheological and structural properties of tomato ketchup as affected by the addition of native and modified starches. Bulgarian Journal of Agricultural Science. 2021;27(1):220–226.

28. Pathare PB, Opara UL, Al-Said FA-J. Colour measurement and analysis in fresh and processed foods: A review. Food and Bioprocess Technology. 2013;6:36–60. https://doi.org/10.1007/s11947-012-0867-9

29. Vigneshwaran G, More PR, Arya SS. Non-thermal hydrodynamic cavitation processing of tomato juice for physicochemical, bioactive, and enzyme stability: Effect of process conditions, kinetics, and shelf-life extension. Current Research in Food Science. 2022;5:313–324. https://doi.org/10.1016/j.crfs.2022.01.025

30. Sridhar K, Makroo HA, Srivastava B. Effect of cold- and hot-break heat treatments on the physicochemical characteristics of currant tomato (*Solanum pimpinellifolium*) pulp and paste. Foods. 2022;11(12). https://doi.org/10.3390/foods11121730

31. Tigist M, Workneh TS, Woldetsadik K. Effects of variety on the quality of tomato stored under ambient conditions. Journal of Food Science and Technology. 2013;50(3):477–486. https://doi.org/10.1007/s13197-011-0378-0

32. Rosalinda RAN, Suryati, Masrulita, Sylvia N, Meriatna. Utilization of star fruit (*Averhoa blimbi* L.) as a preservative in making chili sauce. Chemical Engineering Journal Storage. 2021;1(2):24–34. (In Indonesian). https://doi.org/10.29103/cejs.v1i2.5054

33. Tournas V, Stack ME, Mislivec PB, Koch HA, Bandler R. Yeasts, molds, and mycotoxins [Internet]. [cited 2023 Jan 15]. Available from: https://www.fda.gov/food/laboratory-methods-food/bam-chapter-18-yeasts-molds-and-mycotoxins

34. Maturin L, Peeler JT. Aerobic plate count [Internet]. [cited 2023 Jan 15]. Available from: https://www.fda.gov/food/laboratory-methods-food/bam-chapter-3-aerobic-plate-count

35. Meilgaard MC, Civille GV, Carr BT. Sensory evaluation techniques, 5th Ed. Boca Raton: CRC Press; 2006. 630 p. https://doi.org/10.1201/b19493

36. Asasia PAA, Yuwono SS. Effect of corn starch and citric acid concentration level on physico-chemical and organoleptic properties of rose jam. Jurnal Pangan dan Agroindustri. 2018;6(1):64–74. (In Indonesian). https://doi.org/10.21776/ub.jpa.2018.006.01.8

37. Yahia EM, Brecht JK. Tomatoes. In: Rees D, Farrell G, Orchard J, editors. Crop post-harvest: Science and technology: Perishables. Blackwell Publishing; 2012. pp. 5–23. https://doi.org/10.1002/9781444354652.ch2

38. Hussain N, Weng CH, Munawar N. Effects of different concentrations of pineapple core extract and maceration process on free-range chicken meat quality. Italian Journal of Food Science. 2022;34(1):124–131. https://doi.org/10.15586/ijfs.v34i1.2086

39. de Castro DS, dos Santos Moreira I, de Sousa FC, da Silva WP, Gomes JP, de Melo Queiroz AJ, *et al.* Physical, chemical and rheological properties of pitomba (*Talisia esculenta*) seed starch and its application as a thickener and stabilizer in ketchup. Australian Journal of Crop Science. 2021;15(6):842–849. https://doi.org/10.21475/ajcs.21.15.06.p2981

40. Sharoba AM, Senge B, El-Mansy HA, Bahlol HE, Blochwitz R. Chemical, sensory and rheological properties of some commercial German and Egyptian tomato ketchups. European Food Research and Technology. 2005;220:142–151. https://doi.org/10.1007/s00217-004-0981-7

41. Pahruzi A, Ninsix R. Study of the addition of cornstarch as a thickening agent on the characteristics of moli banana sauce. Jurnal Teknologi Pertanian. 2016;5(1):8–14. (In Indonesian). https://doi.org/10.32520/jtp.v5i1.85

42. Khayrul Alam M, Ahmed M, Sorifa Akter M, Islam N, Eun J-B. Effect of carboxymethylcellulose and starch as thickening agents on the quality of tomato ketchup. Pakistan Journal of Nutrition. 2009;8(8):1144–1149. https://doi.org/10.3923/pjn.2009.1144.1149

43. Pour FH, Makkawi YT. A review of post-consumption food waste management and its potentials for biofuel production. Energy Reports. 2021;7:7759–7784. https://doi.org/10.1016/j.egyr.2021.10.119

44. Raits E, Pinte L, Kirse-Ozolina A, Muizniece-Brasava S. Effect of hot-fill processing at reduced temperatures on tomato sauce microbiological stability in plastic packaging. 20th International Scientific Conference Engineering for Rural Development; 2021; Jelgava. Jelgava: Latvia University of Life Sciences and Technologies; 2021. p. 1843–1849. https://doi.org/10.22616/ERDev.2021.20.TF405

45. Singh S, Singh AK, Rai A. Effect of different thickeners on quality assurance and consumer preferences in tomato ketchup. Indian Journal of Agricultural Sciences. 2014;84(8):1014–1017. https://doi.org/10.56093/ijas.v84i8.43141