



Research Article

Effects of thermal and temporal conditions on the quality attributes of palm sugar milk coffee

Syahril Makosim¹, Abu Amar^{2*}, Shinta Leonita², Rizal Ainur Ichsan²

¹Engineer Professional Program, Institut Teknologi Indonesia, Tangerang Selatan 15417, Indonesia

²Department of Agricultural Industrial Technology, Institut Teknologi Indonesia, Tangerang Selatan 15417, Indonesia

Abstract Palm sugar milk coffee (PSMC), a ready-to-drink (RTD) beverage with a distinct palm sugar flavor, exhibited a significant decrease in acidity after 8 weeks of storage, despite a 52-week shelf life at room temperature. A study investigated the impact of storage temperature (30°C and 20°C) and storage time (0 to 12 weeks) on PSMC's acidity, total microbes, and sensory attributes using a two-factor Randomized Block Design with two repetitions. The analysis revealed that storage time significantly influenced the pH value of PSMC, confirming the observed decrease in acidity. However, storage temperature did not significantly affect the pH, total microbial count, or sensory characteristics ($p>0.05$). The sensory evaluation indicated that the product remained acceptable for up to 12 weeks of storage, maintaining a pH range of 6.52 to 6.58. In conclusion, while storage time significantly impacts PSMC's acidity, storage temperature does not, and the product retains acceptable sensory quality for 12 weeks.

Keywords milk coffee, palm sugar, temperature, storage time



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*Corresponding author

Abu Amar
Tel: +62-21-7560345
E-mail: abu.amar@iti.ac.id

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1. Introduction

Coffee is one of the most popular beverages in the world. Coffee is a drink with a distinctive flavor and is also driven by traditional, historical, social, and economic aspects, which makes it a major attraction for people across the globe (Maulidan and Alam, 2018). Coffee is a plantation product that has significant economic value among other crops and plays an important role as a source of foreign exchange for the country. Coffee is also one of Indonesia's leading export commodities in the agricultural sector, with the income of one and a half million coffee farmers in Indonesia. According to Rahardjo (2017), world coffee consumption breaks down as follows 70% for Arabica, 26% for Robusta, and 4% for varieties. Coffee beans processed through fermentation with ethanoic acid can yield a type of coffee wine that may assist in reducing obesity (Park et al., 2023). Research into the impact of roasting methods (light, medium, and dark) applied to coffee from Brasilia (Monte Alegre) and coffee from Ethiopia (Sidamo) indicates a reduction in chlorogenic acid concentration without affecting total phenol content (Suh et al., 2014). Coffee contains many physiologically active compounds, such as chlorogenic acid (CGAs) and caffeine (Jeon et al., 2019). Chlorogenic acid has numerous health benefits for producing pharmacological effects that are nutritious (Farhaty and Muchtaridi, 2016). The benefits of chlorogenic acids are a multifaceted health booster in coffee for human health as an antioxidant, antiviral, hepatoprotective, and plays a role in antispasmodic activity (Farah and Donangelo, 2006). Furthermore, Farah and Donangelo (2006) showed that the abundance of phenol compounds, especially chlorogenic acid,

besides having good properties for body health, also makes a distinctive contribution to the formation of coffee aroma. Therefore, processed coffee beverages boast various forms of processed coffee: namely, roasted coffee bean, ordinary ground coffee, instant coffee, and even now, types of ready-to-drink coffee products. Typically, only high-quality coffee beans are chosen for beverages, meaning those of lower quality are not being fully utilized. However, research has shown that transforming these lesser-quality beans into a novel product called coffee milk jam achieves a high sensory score of 4 out of 5 (Nabila and Tsaniah, 2024). The research into the production process of milk coffee beverages with the addition of various ingredients, such as milk, sugar, and chocolate, has been extensively conducted and demonstrates an impact on panelist acceptance. The addition of cocoa bean extract to milk coffee beverages can extend the product's shelf life (Kim et al., 2019). Furthermore, to create healthier drinks, the use of palm sap could be promoted as a beverage sweetener due to its low glycaemic index (Sarkar et al., 2023).

The marketing landscape for ready-to-drink (RTD) coffee products in Indonesia, particularly processed coffee encompassing both ground and instant varieties, is fiercely competitive. This intense competition drives major producers to innovate and introduce new coffee products under fresh brands continuously. The top brand award conducted a brand satisfaction survey for coffee beverages in 2020. The brand satisfaction survey can be seen in Table 1.

The recent surge in popularity of RTD coffee products has fueled a race among Indonesian companies to introduce new offerings. One such innovation is palm sugar milk coffee (PSMC). Beyond its common application in coffee and milk beverages, palm sugar is also utilized in fermented drinks

(Maspeke et al., 2024). However, a recent issue has emerged concerning PSMC. Customers in Surabaya and Jakarta have reported a noticeable souring of the beverage's taste within eight weeks of purchase. While no similar complaints have been received from other major Indonesian cities like Bandung, Yogyakarta, Semarang, Palembang, Medan, Makassar, and Denpasar, this specific concern warrants investigation by the manufacturer.

According to Yoon et al. (2017), the shelf life of beverage milk products supplemented with coffee extract reached 14.3 weeks at 4°C storages. It is known that the PSMC drink product has a shelf life of one year. Therefore, in this study, it will be verified whether it is true that during eight weeks of storage at room temperature, the taste of palm sugar milk coffee has already changed to a very sour taste.

2. Materials and methods

2.1. Materials

The ingredients used in the production process of PSMC include instant coffee obtained from (PT Aneka Coffee Industry, Sidoarjo, East Java, Indonesia), liquid palm sugar (PT Anugerah Alam, Medan, North Sumatera, Indonesia), skim milk powder was purchased from (Synlait industries, Dunsandel, Canterbury, New Zealand), KIN fresh milk (PT ABC Kogen Dairy, West Java Indonesia), plant creamer (Santos Premium Creamer, PT Santos Jaya Abadi Sidoarjo, East Java Indonesia), palm sugar flavored INS1520 & INS260 (Givaudan, Petaling Jaya Malaysia), sodium bicarbonate E500 was obtained from (Novabay, Singapore), vegetable stabilizer E407 was obtained from (CP Kelco, Wulian, China).

2.2. Sensory evaluation

The color, aroma, taste, and acidity of the PSMC were tested organoleptically using the triangle test method. The samples presented were samples stored at temperatures of 30°C and 20°C. This triangular differentiation test is carried out by presenting 2 samples of the same and 1 different sample, which have been coded at random. The panelists are asked to compare the differences between the three samples (Setyaningsih et al., 2010). The triangular differentiation test was conducted on 30 trained panelists who work as employees of PT AKD. The sensory evaluation research, which uses a triangular differentiation test for the palm sugar milk coffee

Table 1. Top brand award survey results¹⁾ in the year of 2021

No	Brand	Top brand index (%)
1	Good Day	36
2	Luwak White Coffee	18.5
3	Granita	13.7
4	Nescafe	9.5
5	Kopiko 78C	7.6

¹⁾Data from https://www.topbrand-award.com/komparasi_brand/bandingkan?id_award=1&id_kategori=2&id_subkategori=434&tahun_awal=2021&tahun_akhir=2025&brand1=Good%20Day&brand2=Granita&brand3=KOPIKO%2078C&brand4=Luwak%20White%20Koffie&brand5=NESCAFE

product, has been granted ethical clearance by the appropriate institutional ethics committee. This clearance was issued by the Jakarta II Health Polytechnic, operating under the authority of the Indonesian Ministry of Health, and carries the reference number LB.02.01/1/KE/L/461/2022.

2.3. Processing and storage conditions

This research started from the process of transferring fresh milk to a mixing tank, a mixing tank with a capacity of 20 tons, then heating the fresh milk to a temperature of 50°C. Next, the vegetable stabilizer and water were put into the mixing tank, and the first stirring was carried out for 10 min until the vegetable stabilizer dissolved completely. Next, the second heating process is to a temperature of 60°C with raw materials such as coffee solution, skim milk powder, non-dairy creamer, palm sugar, acidity regulator, and flavor. The second stirring was carried out for 15 min until all the ingredients were completely dissolved. Furthermore, the palm sugar milk coffee drink is transferred to the homogenization process using a homogenizer machine. The sterilization process was carried out with an ultra-high temperature (UHT) machine at a temperature of 142°C for 2 sec. Packaged PSMC beverage products are then stored for 12 weeks at different storage temperatures, namely temperature of 30±1°C, and a temperature of 20±1°C.

2.4. Measurement of quality characteristics

The equipment used in this study is a series of machines for the production of palm sugar milk coffee, milk, and palm sugar, and equipment for analysis purposes. Production equipment consists of a digital balance, filling machines, sterile bottle machines, sterile bottle caps, carton box packaging machines, automatic palm sugar coffee drinks consisting of Ultra High Temperature (UHT) machines, high shear mixer machines, homogenizer machines, mixing tanks, a slurry coffee tank, and a cooling pipe. The analytical equipment includes a digital pH meter, a Bunsen burner, pipette tips, micro pipettes, plastic cups, 100 mL beakers, Schott Duran bottles, test tubes, petri dishes, and incubators. All research and product analysis are carried out at PT AKD. The analytical materials used include plate count agar (PCA) media and buffered peptone water (BPW) media.

Analysis of pH value in PSMC products was carried out using a digital pH meter with 20 mL of each sample. A

digital pH meter is equipment used in the laboratory to measure the acidity of a solution, whether the solution is acidic, basic, or neutral. The electrode used is a glass electrode. The way a digital pH meter works is that the pH electrode is inserted into the sample solution, which then the electrode will detect the sample solution and convert the signal from the pH electrode into an electrical signal. The electrical signal will be amplified by an amplifier circuit in the form of an analog voltage, which will be converted into digital data so that the results will be displayed on the LCD.

Total plate count (TPC) describes the number of microbes contained in a product by counting the number of bacterial colonies grown on agar media. This test uses the cup count method. The calculation of the total plate count begins with a sample that has been diluted in BPW media. The dilution was carried out at 10¹ by taking 1 mL of the sample and then putting it in a petri dish, then adding PCA media and incubating at 35°C for 3 days. Growing colonies are counted by a colony counter.

2.5. Statistical analysis

The experimental design model used in this study was a two-factor Randomized Block Design (A and B). Factor A is storage temperature, consisting of two weeks: a1 = temperature of 30°C, a2 = temperature of 20°C, and Factor B is storage time from 0 weeks to 12 weeks, or 13 levels. Observations made include analysis of pH value, TPC, and organoleptic analysis (triangle test), with two replications. The significance of differences between experimental groups was determined by Duncan's multiple range test at $p < 0.05$.

3. Results and discussion

The PSMC production process follows the existing process flow at PT AKD with the aim that the results are in accordance with those in the field. The UHT process and the combination with aseptic filling produce a product that lasts for 1 year at room temperature with a quality that is still acceptable to panelists. The raw materials used in this study are also in accordance with those commonly used at PT AKD.

3.1. pH value

The effect of storage temperature on the pH of PSMC

drinks can be seen in Table 1. Based on Table 2, it can be seen that storage of PSMC drinks at a temperature of 30°C or 20°C showed no significant difference. However, the effect of storage time on the pH value of PSMC significantly decreased ($p < 0.05$). There was a decrease in the pH value, although very slowly. Our findings concur with previous research by Ranvir et al. (2020). Their work demonstrated that UHT milk stored at 30 degrees Celsius exhibited a gradual decline in pH, even though the storage temperature itself remained constant. The contents of results and discussion must be consistent with the writing order of the research method section, 30°C. The decrease in pH at 30°C was much faster than that at 20°C. This difference can be understood as that the UHT process kills pathogenic and non-pathogenic bacteria, but it was estimated that the thermostable microbial enzymes may still not be completely denatured. Further investigation is needed into the specific thermostable microbial enzymes responsible for the gradual pH decrease, even in UHT-treated products, to develop more targeted inactivation strategies. There was a possibility that the temperature of 30°C was still able to carry out its activities, even though it was very slow. This was because the PSMC drink is produced from the heating process using the UHT sterilization method with aseptic processing. A UHT process uses a high temperature of 142°C with a very short time, which is 2 seconds.

The UHT process effectively kills microbes and produces products with guaranteed nutritional value during the storage process. The higher the temperature used can kill pathogenic microorganisms, inhibit invertase enzymes, and even kill all microorganisms in food ingredients. The higher the temperature, the smaller the decrease in pH. However, during 12 weeks of storage at 30°C and 20°C, the pH value of the product seemed to decrease. The decrease in pH was caused by the raw materials used in the PSMC drink. In fact, the pH was always above 6.5 in all types of treatment products. This means that the entire production process was still in aseptic

condition. Even the pH of several beverage products using cow's milk is 6.64, and plant-based milks (almond milk, oat milk, and soya milk) have a pH range of between 5.7 and 7.4 (Gupta et al., 2025).

This was supported by Table 3 regarding the total number of microbes in the product; no microorganism growth was found. This indicated that no microorganisms were detected in the product. Therefore, the decrease in pH was caused by enzymes found in fresh milk as raw materials. This enzyme could still degrade lactose when stored at a temperature of 30°C. If the storage temperature is not controlled, it will accelerate the degradation of lactose to produce organic acids, which results in a decrease in pH (Suardana and Swacita, 2009). The acidity of instant coffee is determined, among other things, by the type of coffee beans as the basic ingredient. Robusta coffee has a pH of 5.8, and Arabica 5.2. An increase in the amount of instant ground coffee causes a decrease in the pH of the product. The raw materials used will affect the acidity level of the PSMC drink (Lingle, 2011). In addition to raw materials, the decrease in acidity level can be caused by leakage of packaging during storage, which allows oxygen to enter through the gaps. The oxygen that enters the product will cause microorganisms to grow inside the packaging, so it could cause the acidity level in the product to decrease. Investigating the Impact of Sub-Optimal Acidity Regulating Food Additive Dosages and Heating Process Inconsistencies on Product Quality, as Indicated by Customer Feedback and Field pH Data. Good Handling Practices (GHP), which is not carried out properly, will cause the product to be prone to leakage and damage to the packaging. In other research reported, pasteurized milk has a shelf life of one month at low temperatures. There were still thermoduric microbial enzymes that were believed to hydrolyze lactose slowly (Kristanti, 2017). A more detailed analysis is needed of the degradation pathways of lactose and other components in the PSMC formulation that contribute to

Table 2. Change in average pH value* of palm sugar milk coffee (PSMC) product during 12 weeks of storage period

Storage temperature (°C)	Storage period (weeks)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
20	6.58 ^{1gh2)}	6.58 ^{gh}	6.58 ^{gh}	6.58 ^{gh}	6.57 ^{fg}	6.57 ^{fg}	6.57 ^{fg}	6.56 ^{cf}	6.56 ^{cf}	6.55 ^{de}	6.54 ^{cd}	6.54 ^{cd}	6.53 ^{bc}
30	6.58 ^{gh}	6.57 ^{fg}	6.57 ^{fg}	6.56 ^{cf}	6.57 ^{fg}	6.57 ^{fg}	6.57 ^{fg}	6.56 ^{cf}	6.55 ^{de}	6.54 ^{cd}	6.52 ^{ab}	6.52 ^{ab}	6.51 ^a

¹⁾Mean value (n=2).

²⁾Means with different superscript letters (^{a-h}) in the rows are significantly different ($p < 0.05$) by Duncan's multiple range test $h > g > f > e > d > c > b > a$.

Table 3. Total microbial counts of the palm sugar milk coffee (PSMC) product during 12 weeks of storage period

Storage temperature (°C)	Storage period (weeks)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
20	ND ¹⁾	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

¹⁾ND, not detected.

the slight pH reduction over extended storage, even in the absence of microbial growth.

3.2. Total microbial counts

PSMC drink was a product having high water content, which would generally be more susceptible to overgrown microorganisms that can contaminate the product, so it was heated using the UHT method. In accordance with the BPOM Standard (2009) HK.00.06.1.1.52.4011, the maximum limit of total microbes TPC is 1×10^2 colonies/g. Based on the results of the microbiological test (Table 3), it can be seen that no total microbes TPC grew during storage at both temperatures of 30°C and 20°C. This showed that the storage temperatures of 20°C and 30°C, could each maintain product sterility, so that they could inhibit microbial growth. Most microorganisms require an optimum temperature for growth. However, heating with the UHT method at a temperature of 142°C for 2 sec was not able to inactivate the microbial enzymes found in fresh milk ingredients, when the storage temperature is above room temperature, or errors in post-distribution handling that do not follow the GHP rules result in the acidity level of the product decreasing. PSMC beverage products are packaged in polyethylene terephthalate (PET) containers that have been chemically sterilized. This packaging material is capable of inhibiting the ingress of air, including CO₂ and water vapor, making it suitable for soft drink packaging. This property prevents the growth of microbes from entering and makes the product last longer (Nisticò, 2020).

3.3. Organoleptic triangle test

Based on the results of organoleptic tests (Fig. 1), it was found that PSMC drinks which were stored at temperatures of 20°C for 12 weeks, had organoleptic characteristics (color, aroma, taste and acidity) which were not significantly different from organoleptic characteristics (color, aroma, taste and acidity) PSMC drink stored at temperature of 30°C for the

same storage time. If the calculated sensory difference score (t-value) exceeds the critical value of 17 at a 5% significance level ($p < 0.05$), then a statistically significant difference exists between the products. Conversely, if the calculated sensory difference score does not exceed these critical values, then no statistically significant difference is observed between the products. This indicates that, from a sensory perspective, the products stored under different temperature and duration conditions could not be significantly distinguished based on their sensory attributes-color, aroma, flavor, and sourness. Human sensory organs are unable to distinguish the taste, aroma and color changes in coffee as well as the level of acidity. This is different from the pH value in Table 2, which shows statistical differences. This is indicated by the pH value, which decreases slightly during storage but cannot be felt by humans as panelists.

Qualitatively, there was a sensory change in acidity, which was initially slightly sour to moderately sour after 11 weeks of storage in the product stored at a temperature of 30°C. This was because the largest composition in the product was fresh milk, palm sugar, and instant coffee powder. The addition of fresh milk and palm sugar was intended to add flavor, as well as improve the texture and color of the product. The addition of palm gives a distinctive sweet taste of palm sugar. A study by Sudiarto et al. (2023) indicates that the use of sugar, such as palm sugar with ginger can function as a health drink. According to Lingle (2011), the coffee roasting process produces a browning reaction that gives rise to three types of aromas, namely nutty, caramelly, and chocolaty. The addition of palm sugar further accentuates the caramel aroma. Drinking palm sugar milk coffee is healthier because palm sugar has better nutrition and has a lower glycemic index than regular white sugar. Drinking palm sugar coffee turns out to be able to provide better enthusiasm than coffee with honey for futsal players (Febriani et al., 2021). Palm sugar has a unique caramel-like flavor with a hint of

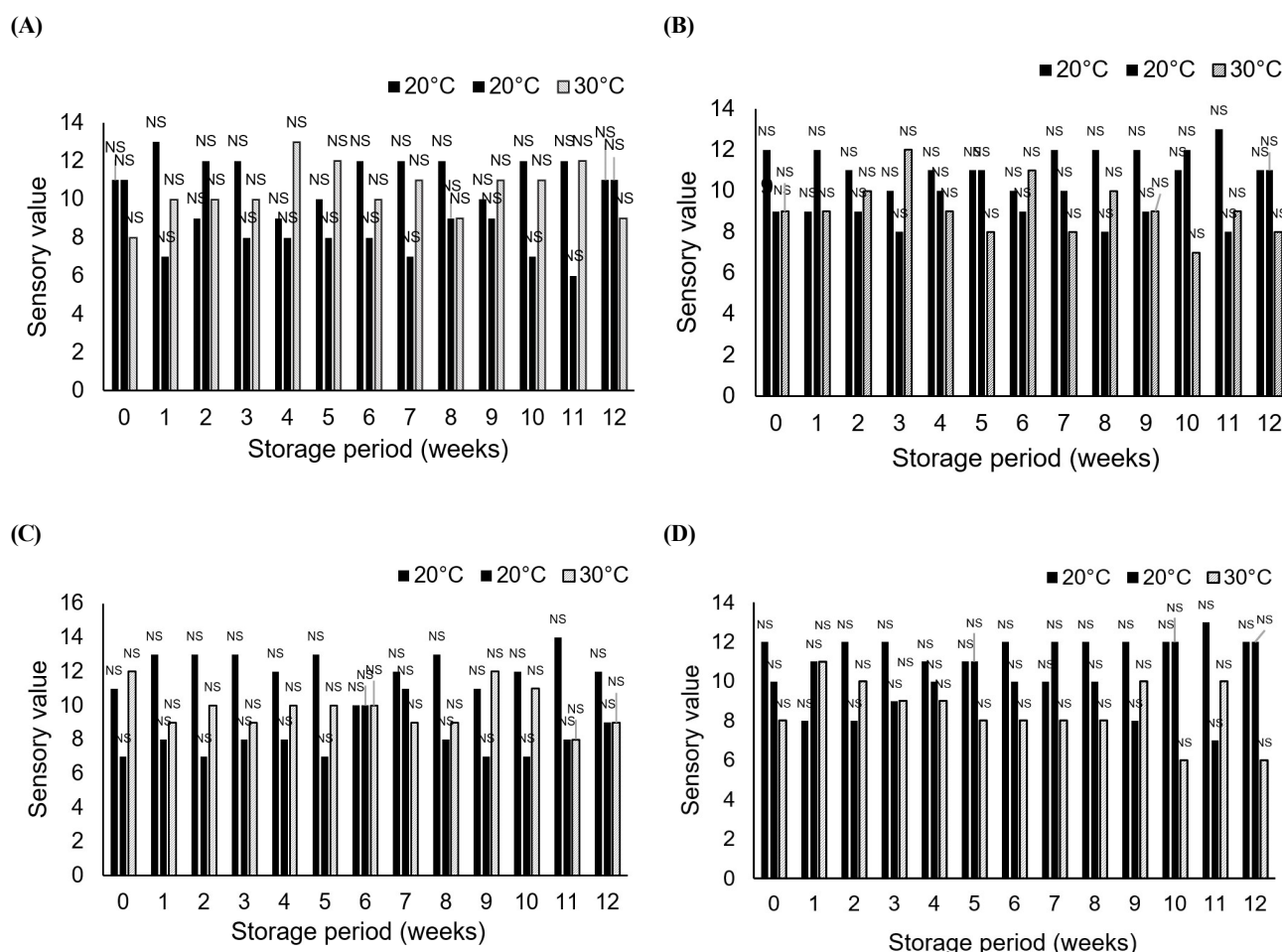


Fig. 1. Effect of storage temperature on the organoleptic characteristics by triangle test of palm sugar milk coffee (PSMC) drinks during storage. (A), color; (B), taste; (C), flavor; (D), sourness. If the calculated sensory difference score (t-value) exceeds the critical value of 17 at a 5% significance level ($p < 0.05$), then a statistically significant difference exists between the products. NS, no significant differences within the same storage period ($p > 0.05$).

molasses. This can add complexity and depth to coffee that some people find more appealing than the simple sweetness of regular sugar. This is even more delicious if added with milk. For milk-based confectionery products, panelists believe that the product must have a milky taste (Salsabilah et al., 2024). Therefore, the PSMC flavor should also have a noticeable milky taste to make it more enjoyable. As highlighted by Fitri et al. (2025), both sugar and fat milk diminish the antioxidant activity in espresso-based coffee beverages. The addition of milk to coffee is still controversial. The fat in milk reacts with the phenols in coffee, thereby reducing its functionality (Rashidinejad et al., 2022). Furthermore, Asiyah et al. (2024) indicated that milk coffee enriched with rose flower powder is able to maintain its antioxidant activity.

The possibility of future development will also use coconut sugar, which has a specific and distinctive aroma. Other advantages are that it is more soluble, has a longer shelf life (Fadhillah et al., 2020). Instant coffee powder had the characteristics of being easily soluble in water, without leaving coffee grounds, and giving an acidic impression. The three foodstuffs have varying pH; so, during storage, there was a decrease in the pH of the product. Another component affected the shelf life was the use of the right emulsifier which will extend the shelf life of RTD beverage (Ahn et al., 2017).

As is known, the quality of food products would change and decreased during the storage process. The declining quality of food products could be an indication that the product was nearing the end of its shelf life.

3.4. Determination of optimal conditions

Based on the results of this study, it was found that storing PSMC drinks in PET bottles at 20°C for 12 weeks did not significantly affect their acidity level, total microbial count, or organoleptic characteristics, compared to storage at 30°C. PSMC drinks, which stored at 30°C after 12 weeks of storage, had an acidity level that was not different from the acidity level of the product before storage. This was not in accordance with the results of a complaint from one customer from the cities of Jakarta and Surabaya who reported that there had been a decrease in the acidity of the PSMC drink after 2 months of storage. Storage of PSMC drinks was carried out at temperatures of 30°C and 20°C as a simulation of storage conditions. Beyond storage temperature, other contributing factors to the observed decrease in the acidity of PSMC beverages included a suboptimal dosage of acidity-regulating food additives, which consequently failed to maintain acidity during storage, and an inadequate heating process. It was assumed that the heating temperature was not reached and the sterilization process was not proper, which resulted in an unqualified product. Another reason the packaging process was not tight was that water vapor, oxygen, and light from the environment were going into the packaging and were absorbed by the PSMC drink. As a result, the oxidation process would occur. The change of pH value of the PSMC drink could occur during the handling process, and during distribution was not good. PSMC drinks were packaged in packaging material having low permeability to oxygen to maintain the quality of PSMC drinks. They were not easily rancid and were not contaminated with microbes. PET bottles were easy to open and close, minimizing product contamination. PET was widely used as a food packaging material because of its excellent mechanical properties, such as being clear, resistant to UV rays, and good oxygen barrier (Ros-Chumillas et al., 2007).

4. Conclusions

Storage of palm sugar milk coffee (PSMC) drinks can be done effectively at both 30°C and 20°C, maintaining product quality, including sensory attributes, for up to 12 weeks. While storage time significantly impacts the pH value of PSMC, it remains within an acceptable range of 6.52-6.58 even after 12 weeks. Importantly, storage temperature does not significantly affect the pH, total microbial count, or

sensory characteristics (color, aroma, taste, and acidity) of the product. This indicates that PSMC remains safe and appealing to consumers under these storage conditions, despite the observed decrease in acidity over time.

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Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Makosim S, Amar A. Methodology: Leonita S, Ichsan RA. Formal analysis: Leonita S, Ichsan RA. Validation: Leonita S. Writing - original draft: Makosim S, Amar A. Writing - review & editing: Makosim S, Amar A.

Ethics approval

This research was approved by Komisi Etik Penelitian, Poltekkes Kemenkes Jakarta II. Ethical Approval No: LB.02.01/1/KE/L/461/2022.

ORCID

Syahril Makosim (First author)
<https://orcid.org/0009-0003-9458-195X>
 Abu Amar (Corresponding author)
<https://orcid.org/0009-0002-1992-8207>
 Shinta Leonita
<https://orcid.org/0009-0000-4571-3280>
 Rizal Ainur Ichsan
<https://orcid.org/0009-0009-4664-231X>

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