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The Effect of Storage Duration on Fat Deterioration and Sensory Quality of Beef Rendang at Dapoer Rendang Riry, Payakumbuh City

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Abstract. *Rendang is a high-fat food product susceptible to quality deterioration during storage, particularly due to lipid oxidation and potential microbiological contamination from inadequate packaging. This study investigated the effect of storage duration on the quality of beef rendang stored at room temperature, as indicated by fat deterioration, sensory changes, and microbiological quality. Beef rendang was stored for three months in vacuum-sealed aluminum foil packaging at room temperature. Monthly analyses included fat content, free fatty acid (FFA) levels, thiobarbituric acid (TBA) value, total plate count (TPC), initial spoilage assessment using the Eber test, and sensory evaluation of color, aroma, texture, taste, and overall appearance. Protein, moisture, and ash contents were determined at the beginning and end of storage to evaluate compliance with SNI 7764:2012. Protein was analyzed using the Kjeldahl method, while moisture and ash were determined gravimetrically following AOAC (2007) procedures. The results showed a gradual decline in product quality during storage. Fat content decreased from 27.00±0.16% to 20.95±0.43%, while FFA levels increased from 3.31±0.17% to 5.52±0.34%. The TBA value increased from 0.01±0.002 to 0.07±0.002 mg Ma/kg. Sensory attributes exhibited a decreasing trend over the storage period. No microbial growth, including Salmonella and Escherichia coli, was detected, and the Eber test indicated no ammonia formation. Protein, moisture, and ash contents remained within SNI limits. Overall, quality deterioration was mainly associated with lipid degradation, while the product remained safe and suitable for consumption throughout storage.*

Keywords: *beef rendang, fat deterioration, sensory quality, storage duration, vacuum packaging.*

Type of the Paper: Regular Article.

1. Introduction

Rendang is a traditional dish originating from The Minangkabau ethnic group of West Sumatra and is widely recognized as a special food served during various cultural and ceremonial occasions. Its savory, spicy, and richly spiced flavor profile has contributed to rendang's popularity not only in Indonesia but also internationally. In 2021, rendang was ranked among the "50 Best Foods in the World" by CNN, although its position declined to 11th place by 2024 [1]. One of the most preferred variants is beef rendang, which undergoes a prolonged cooking process resulting in a dark brown color and a tender texture, primarily due to caramelization reactions and the complex combination of spices used [2].

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In West Sumatra, rendang is prepared using a variety protein sources, and its designation typically reflects the main ingredient incorporated into the dish. For instance, rendang tuna indicates that tuna is used as the principal protein, while rendang lokan signifies the use of lokan clam (Geloina erosa). Similarly, rendang telur identifies eggs as the primary protein component. When the term rendang is used without further qualification, it customarily denotes a product made from beef or buffalo meat [3]. Beef possesses high nutritional value, particularly protein (18.8 g/100 g), fat (14.0 g), and water content (66.0 g), and also contains cholesterol and fatty acids that play essential roles in body metabolism [4]. In West Sumatra, many micro, small, and medium enterprises (MSMEs) are engaged in the production of beef rendang as part of efforts to preserve local culture and support regional economic development. One such enterprise is *Dapoer Rendang Riry*, established in 2002 in Payakumbuh City. The enterprise offers various rendang variants, with beef rendang as its flagship product. The rendang produced by this enterprise is vacuum-packed and stored at room temperature; however, it does not undergo a sterilization process, making it potentially susceptible to quality deterioration during storage due to fat oxidation and microbiological contamination.

High-fat food products such as rendang are particularly vulnerable to chemical and microbiological deterioration during storage. Lipid oxidation can lead to a decline in flavor and aroma quality and may result in the formation of toxic compounds, whereas microbiological contamination may occur if packaging conditions are not adequately hygienic [5]. Lipid oxidation is recognized as a primary cause of deterioration in meat and meat products, affecting unsaturated fatty acids and leading to changes in aroma, color, flavor, and overall sensory attributes [6,7]. The end-products of this process can reduce nutritional value and generate harmful compounds [7,8].

Oxidative processes in meat products during storage can degrade color pigments, lipids, and proteins, contributing to the deterioration of flavor, texture, color, and nutritional value. Lipid oxidation is particularly critical for products stored under aerobic conditions, leading to off-flavors and off-odors [9]. Previous studies have demonstrated that storage duration influences the chemical and sensory quality of sago flour-based egg rendang [10], while other research reported that the shelf life of vacuum-packed egg rendang in aluminum foil was approximately 99 days based on TBA values and sensory evaluation of rancidity [11]. Studies on shredded meat products, which is similar in terms of low moisture content and processing methods, have shown that storage time and temperature significantly impact lipid oxidation and protein co-oxidation, thereby, affecting physicochemical properties and lipid stability [12,13]. However, comparable studies focusing on beef rendang, particularly in Payakumbuh City, remain limited. Therefore, this study aimed to investigate the effect of storage duration at room temperature on the chemical,

microbiological, and sensory quality of beef rendang produced by *Dapoer Rendang Riry* in Payakumbuh City.

2. Materials and Methods

2.1 Materials and Equipment

The primary ingredients used in this study were beef, red chili, bird's eye chili, shallots, garlic, ginger, galangal, bay leaves, turmeric leaves, and kaffir lime leaves. All ingredients were obtained from *Ibuh Market*, Payakumbuh. The analyses were conducted at the Uji Mutu dan Analisa Laboratory, State Agricultural Polytechnic of Payakumbuh. The chemicals utilized included benzene (CAS No. 71-43-2) , ethanol (CAS No. 64-17-5), NaOH (CAS No. 1310-73-2), phenolphthalein (CAS No. 77-09-8) indicator, distilled water, 4 N HCl (CAS No. 7647-01-0), antifoam, TBA reagent (CAS No. 504-17-6; 0.02 M thiobarbituric acid solution in 90% glacial acetic acid, CAS No. 64-19-7), sensory evaluation forms, mineral water, eosin methylene blue agar (EMBA, Oxoid) medium, salmonella shigella agar (SSA, Merck) medium, buffered peptone water (BPW), and Eber reagent.

The equipment used in this study comprised a 100 cm cauldron, aluminum basin, knife, coconut milk extractor, coconut grater machine, rendang ladle (sanduak marandang), Soxhlet extractor, aluminum cup, thimble, analytical balance (KERN ABJ 220-4NM), oven (Labtech LDO-150 N), desiccator, electric heater (hotplate), volumetric flask (Pyrex), graduated cylinder (Pyrex), cotton for thimble cover, Erlenmeyer flask (Iwaki), dropper pipette, water bath, graduated cylinder (Pyrex), volumetric pipette (Pyrex), burette (Pyrex), funnel, blender, distillation flask, distillator, thermometer, volumetric pipette, erlenmeyer flask with stopper (Iwaki), spectrophotometer (UV Mini 1240 Shimadzu), sensory evaluation plates, autoclave, and volumetric pipettes.

2.2 Research Method: Preparation and Packaging of Beef Rendang

This study employed a completely randomized design (CRD) with four treatments and four replications. The treatments corresponded to different storage durations at room temperature: P1 (0 months), P2 (1 month), P3 (2 months), and P4 (3 months). These durations were selected to assess progressive quality changes under constant room temperature. The 0–3 month intervals were selected to simulate commercial distribution and marketing conditions and to assess lipid degradation trends, microbiological stability, and the maximum storage period compliant with quality and food safety standards. Each treatment was replicated four times, resulting in total of 16 experimental units.

Beef rendang was prepared according to the standard production practices of Dapoer Rendang Riri [3]. Preparation began by pressing grated coconut to obtain fresh coconut milk.

Ground spices (ginger, galangal, garlic, red chili, and bird's eye chili) and complementary spices (kaffir lime leaves, bay leaves, turmeric leaves, and sliced shallots) were weighed, washed, and drained. Lean beef cuts were selected, washed, drained, and cut into uniform pieces (approximately 4×4×4 cm). Cooking commenced by simmering coconut milk and spices in a 100 cm cauldron over a wood-fired stove for 1–2 hours. After the coconut oil separated, the beef was added and cooked for an additional 1–2 hours until a tender texture and brownish color were achieved. Following cooking, the rendang was packaged in 250 g portions using vacuum-sealed aluminum foil and then steamed for 10–15 minutes to ensure product stability. The packaged product was then stored at room temperature (±29–32 ºC) for 0, 1, 2, and 3 months.

2.3 Analysis Procedures

Observations and sample analyses were conducted throughout the three-month storage period at room temperature. The analytical procedures evaluated lipid deterioration parameters: fat content [14], free fatty acid content [15], thiobarbituric acid (TBA) value [16], as well as microbiological analysis comprising total plate count (TPC) [17] and the Eber test [18]. Sensory quality assessment and chemical composition analysis including protein, moisture, and ash content of beef rendang, were also performed.

2.4 Data Analysis

The data were analyzed using analysis of variance (ANOVA) at a significance level of $\alpha = 0.05$, corresponding to a 95% confidence level. The ANOVA results were interpreted to determine the presence of statistically significant effects. When significant differences were identified, further analysis was conducted using Duncan's multiple range test (DMRT). The DMRT was applied to variables including fat content, free fatty acid levels, TBA values, and sensory quality parameters throughout the three-month storage period. All statistical analyses were performed using IBM SPSS Statistic 2025.

3. Results and Discussion

3.1 Chemical Characteristics of Fat

The fat content of beef rendang is derived from both the intrinsic fat in beef as well as from the coconut milk and spices used during its preparation. The mean values of the chemical characteristics of beef rendang fat over the three-month storage period are presented in Table 1. As shown in Table 1, the fat content of beef rendang decreased progressively over the three-month storage period. Fat content decreased progressively from 27.00% at 0 month (P1) to 20.95% after three months of storage (P4). This decline suggests the occurrence of lipid degradation during storage. Despite this reduction, the fat content of beef rendang throughout the storage period remained within the limits specified by the Indonesian National Standard (SNI 7764:2012), which sets a maximum fat content of 27%. Prolonged storage resulted in a reduction in fat content, which

may be attributed to lipid oxidation and hydrolytic degradation processes [19]. Extended storage duration leads to greater accumulation of free fatty acids, reflecting the progressive decline in lipid quality [20,21].

Table 1. Average fat content, free fatty acids, and TBA value of beef rendang during three months of storage.

Storage Duration	Fat Content (%)	Free Fatty Acids (%)	TBA Value (mg MA/kg)
P1 (0 month)	27.00±0.16^{a}	3.31± 0.17^{a}	0.01±0.002^{a}
P2 (1 month)	23.65±0.47^{b}	3.58±0.21^{a}	0.05±0.002^{b}
P3 (2 month)	21.92±0.54^{c}	4.93±0.27^{b}	0.06±0.003^{c}
P4 (3 month)	20.95±0.43^{d}	5.52±0.34^{c}	0.07±0.002^{d}

Note**:** Data are presented as mean values ± standard deviation of each treatment. Different superscript letters indicate significant differences according to Duncan's multiple range test (DMRT) at α = 0.05.

In contrast, the FFA content increased significantly over time, from 3.31% in P1 to 5.52% in P4. Nurfiqih et al. [22] stated that the higher the moisture content of a food material, the faster hydrolysis occurs, resulting in greater FFA formation. According to Chamel [23], hydrolytic reactions break triglycerides into glycerol and free fatty acids, thereby contributing to an increase in FFA levels that accompanies the decrease in fat content. In addition, lipid auto-oxidation leads to the formation of secondary oxidation products, such as malonaldehyde, which can be quantified through TBA measurements. Table 1 indicates an increase in FFAs with storage duration, demonstrating that hydrolytic degradation is occurring in rendang samples. An increase in FFAs can contribute to unpleasant, sharp flavors and odors [24]. While low water content mitigates some degradation pathways, others—particularly oxidative processes—can still proceed, especially if activity falls into the very low or higher ranges that are less protective against oxidation [25].

Vacuum-packaged beef rendang was subjected to steaming. The steaming process was carried out after vacuum packaging. During steaming, fat reacts with oxygen to form peroxides, which subsequently decompose into FFAs. Julinar et al. [26] noted that vacuum packaging can minimize oxygen exposure and reduce auto-oxidation, but high-temperature treatments can still trigger thermal degradation of fats. Steaming can cause partial melting of fat within the meat tissue, which may then evaporate or break down into other compounds such as aldehydes, ketones, and FFAs through auto-oxidation reactions. The absence of oxygen helps to extend both the microbiological and oxidative shelf life of meat products [27]. Studies have shown that vacuum sealing can significantly reduce the increase in malondialdehyde (a marker of lipid oxidation) over extended storage periods compared to aerobic conditions [28].

Malondialdehyde (MDA) is a major secondary product of lipid oxidation and serves as an important indicator for assessing fat deterioration and quality changes in beef rendang during the three-month storage period. Lipid oxidation, as a primary mechanism of meat deterioration, results in the degradation of unsaturated fatty acids into various oxidative compounds, including MDA. Studies show that MDA and other products of fat oxidation can have detrimental effects on the

quality of meat [29]. A consistent observation in meat products is the increase in both TBA values and free fatty acid content with extended storage. This trend signifies ongoing lipid degradation and the progression of rancidity [30,31].

TBA reacts with malonaldehyde (MDA), a compound commonly used as an indicator of lipid oxidation and rancidity in fatty food products. As shown in Table 1, the TBA value, indicating the formation of secondary lipid oxidation products such as malondialdehyde (MDA), increased significantly during storage. It rose from 0.01 mg MDA/kg at the beginning to 0.07 mg MDA/kg after three months. Although the values remained relatively low, this upward trend confirms the progressive development of oxidative rancidity. Despite this increase, all TBA values remained within the acceptable limits specified by the Indonesian National Standard (SNI 7764:2012), which establishes a maximum allowable value of 0.3 mg MDA/kg.

3.2 Microbial Counts of Salmonella *spp. and* Escherichia coli

Salmonella is recognized as one of the leading causes of foodborne diseases worldwide and can result in severe intoxication symptoms, potentially leading to death [32,33]. *Escherichia coli* is widely used as an indicator organism to assess the overall microbiological quality of food products and production environments [34,35]. The results of the TPC analysis for *Salmonella* and *Escherichia coli* in beef rendang during three months of storage are presented in Table 2.

Table 2. Microbial counts of *Salmonella* and *Escherichia coli* in beef rendang during three months of storage.

Storage Duration	*Salmonella*	*Escherichia coli*
P1 (0 month)	Negative	Negative
P2 (1 month)	Negative	Negative
P3 (2 month)	Negative	Negative
P4 (3 month)	Negative	Negative

As shown in Table 2, no Salmonella or Escherichia coli were detected in beef rendang throughout the three-month storage period. According to Fadhina [36] prolonged cooking at high temperatures can suppress microbial growth, thereby providing a natural preservative effect. In the United States, the U.S. Food and Drug Administration (FDA) and the USDA Food Safety and Inspection Service (USDA-FSIS) apply a strict zero-tolerance policy for *Salmonella* in ready-to-eat (RTE) foods [37,38]. Furthermore, *Escherichia coli* O157:H7 is designated as an adulterant; therefore, its presence automatically renders a product unsafe and unacceptable for human consumption [38].

The extended cooking time and high temperatures involved in rendang preparation are highly effective in eliminating most pathogenic bacteria. Studies confirm that specific temperatures and durations are effective for the thermal inactivation of *Salmonella* and *E. coli* in meat products [39,40]. Many spices possess bioactive compounds that have been scientifically proven to inhibit the growth of various pathogenic microorganisms, including *Salmonella* and

Escherichia coli. Spices commonly used in rendang, such as ginger, garlic, shallots, and chili, contain bioactive compounds with proven antimicrobial activities against foodborne pathogens like *Salmonella* and *Escherichia coli* [41,42].

3.3 Initial Spoilage

The Eber test is a conventional qualitative chemical method used to identify spoilage processes in meat [43]. The results of the initial spoilage test using the Eber method on beef rendang during the three-month storage period are presented in Table 3.

Table 3. Results of the Eber test on beef rendang during the three-month storage period.

Storage Duration	Eber Test Result
P1 (0 month)	Negative
P2 (1 month)	Negative
P3 (2 month)	Negative
P4 (3 month)	Negative

The microbiological analysis results indicated that beef rendang at all storage durations (P1, P2, P3, and P4) tested negative for *Salmonella* and *Escherichia coli*. The absence of Salmonella and Escherichia coli (Table 2) suggests that the processing and sanitation practices applied during rendang production, including the use of spices, were effective in inhibiting the growth of these pathogenic microorganisms [44]. The absence of *Salmonella* in all samples is consistent with national food safety standards, which require negative results for this bacterium [45]. This further confirms that the rendang product possesses high hygienic quality and is safe for consumption [46,47]. These findings are in line with previous studies reporting that certain samples showed no presence of *Salmonella* spp., thereby meeting the requirements of the Indonesian National Standard, which specifies a negative result per 25 mL [48].

3.4 Sensory Quality

Sensory quality is one of the important aspects in determining the overall quality of beef rendang. The sensory evaluation carried out in this study was a hedonic test, which included assessments of color, aroma, texture, taste, and overall appearance. The panelists consisted of 30 untrained individuals [43]. The beef rendang samples were presented to the panelists, who were asked to rate their preference using a 5-point hedonic scale. The 5-point hedonic scale used was: strongly like (5), like (4), neither like nor dislike (3), dislike (2), and strongly dislike (1) [49]. The average sensory scores of beef rendang during three months of storage are presented in Table 4.

3.4.1. Color

As shown in Table 4, analysis of variance indicated that the color of beef rendang during three-months storage period did not differ significantly ($p > 0.05$) among treatments P1, P2, and P3, but P1 was significantly different ($p < 0.05$) from P4 (3 months). Color represents the first

sensory attribute perceived by consumers when evaluating a food product, and therefore serves as a critical indicator of food quality.

Table 4. Average sensory scores of beef rendang during three months of storage.

Storage Duration	Observed Parameters				
	Color	Aroma	Texture	Taste	Overall appearance
P1 (0 month)	3.83±0.75^{a} (like)	4.20±0.71^{a} (like)	3.77±0.75^{a} (like)	4.47±0.57^{a} (like)	4.03±0.72^{a} (like)
P2 (1 month)	3.63±0.67^{a} (like)	3.67±0.55^{b} (like)	3.50±0.68^{ab} (like)	4.10±0.61^{a} (like)	4.00±0.53^{a} (like)
P3 (2 month)	3.53±0.68^{ab} (like)	3.43±0.82^{bc} (neither like nor dislike)	3.37±0.61^{b} (neither like nor dislike)	3.63±0.89^{b} (like)	3.60±0.81^{b} (like)
P4 (3 month)	3.23±0.63^{b} (neither like nor dislike)	3.13±0.94^{c} (neither like nor dislike)	3.30±0.75^{b} (neither like nor dislike)	3.50±0.78^{b} (like)	3.53±0.73^{b} (like)

Note: Data are presented as mean values ± standard deviation of each treatment. Different superscript letters indicate significant differences according to Duncan's multiple range test (DMRT) at $\alpha = 0.05$.

By the third month of storage, the color of beef rendang became less preferred, as the meat exhibited a dark brownish-black appearance. This slight discoloration observed over the three-month storage period is presumed to be influenced by interaction involving carbonyl compounds formed as a result of lipid auto-oxidation. Nurhayati et al. [50] stated that during storage, the interaction of carbonyl compounds from lipid auto-oxidation can form dark pigments that cause discoloration in rendang. The color score decreased from 3.83 ± 0.75 to 3.23 ± 0.63 at the end of the storage period. Changes in the color of rendang are generally associated with ongoing oxidation processes and browning reactions, which lead to a darker appearance and may be perceived as less fresh by panelists. Color changes in rendang during storage can be explained by several oxidative mechanisms, such as lipid oxidation, which leads to color deterioration. Specifically, color changes occur because secondary products of lipid oxidation form pro-oxidants that can react with oxymyoglobin, resulting in the formation of metmyoglobin, which imparts a brownish or dull color to the meat [51].

3.4.2. Aroma

Aroma is a parameter that is very sensitive to chemical changes during storage. As shown in Table 4, the analysis of variance revealed that the aroma of beef rendang in P1 was significantly different ($p < 0.05$) from P3 and P4. Treatment P4 was significantly different ($p < 0.05$) from P1, P2 and P3. During the three months of storage, a decline in aroma acceptance by panelists was observed (Table 4). The aroma of rendang changed from a typical pleasant aroma (liked) to a less preferred rancid odor, which was likely caused by lipid auto-oxidation. The aroma parameter exhibited the most significant decline, decreasing from 4.20 ± 0.71 (liked) at month 0 to 3.13 ± 0.94 (neutral) at month 3. This reduction is most likely attributed to the degradation of volatile compounds and the occurrence of lipid oxidation during storage. Although rendang spices such as

garlic, ginger, and galangal possess antioxidant properties that contribute to oxidative stability [51], prolonged storage still triggers aroma changes due to interactions between plant-based lipids from coconut milk and animal fats from beef [52]. According to Shahidi and Hossain [53], lipid auto-oxidation begins with the formation of peroxide compounds, which then degrade into secondary compounds such as aldehydes, ketones, alcohols, and free fatty acids. These compounds reduce sensory quality by producing rancid odors.

The increase in TBA values signifies the formation of secondary oxidation products, such as aldehydes and ketones, which are responsible for the undesirable off-flavors and off-odors often described as "rancid," "stale," or "cardboard-like" [6,49]. These compounds negatively impact the complex and rich aroma profile characteristic of fresh rendang [54]. The rise in FFA values indicates the breakdown of triglycerides into free fatty acids, which can contribute to soapy or sour off-flavors [24], further diminishing the overall palatability of the rendang. The increase in TBA values commonly observed during the storage of meat products is inversely related to aroma stability scores, whereby higher levels of malondialdehyde correspond to lower panelist preference for the product's aroma [55,56].

3.4.3. Texture

Meanwhile, the texture parameter decreased from 3.77 ± 0.75 (liked) to 3.30 ± 0.75 (neutral). This decline in texture quality can be associated with changes in moisture content and protein denaturation during storage [57]. Beef, which has a high protein content (approximately 59.67%), tends to undergo structural changes that affect tenderness and mouthfeel when stored for extended periods [5,52]. According to Estiasih et al. [58], lipid auto-oxidation reduces the water-holding capacity of muscle tissue. When this capacity decreases, moisture is easily lost, resulting in tougher and drier meat.

The texture scores show a decreasing trend, also indicating a gradual loss of the desired tenderness and succulence characteristic of freshly prepared rendang. Changes in texture can result from protein denaturation and aggregation, moisture loss, or interactions between meat components and fat degradation products during extended storage [59,60].

3.4.4. Taste

Taste is the second most important factor in food acceptability after its appearance. The analysis of variance showed that the taste of beef rendang in P1 was not significantly different ($p > 0.05$) from P2 but was significantly different ($p < 0.05$) from P3 and P4 during the three-month storage period. Hedonically, the taste of beef rendang was still generally liked across all treatments. This change in taste was likely related to lipid auto-oxidation, which produces undesirable odor- and flavor-causing compounds. These oxidation-derived compounds, such as aldehydes and ketones, contribute significantly to the development of rancid or undesirable off-flavors [51,56].

As the TBA value increases, the intensity of these off-flavors becomes more pronounced, which directly reduces panelists' preference for the taste parameter [56].

3.4.5. Overall Appearance

Although a decline in scores was observed across all parameters, the results at P4 indicate that the rendang still maintained an acceptable level of consumer acceptance. This is supported by the fact that the traditional processing of rendang, involving prolonged heating, not only functions as a preservation method through the reduction of water activity but also contributes to the development of robust sensory characteristics [5].

4. Conclusions

Based on the study results, a decline in fat quality of beef rendang was observed during three months of storage period, as indicated by a decrease in fat content and a rise in TBA values reflecting lipid deterioration. Sensory evaluation also showed a gradual decline in color, aroma, texture, taste, and overall appearance; however, the product remained in the "liked" category and was acceptable to panelists. Furthermore, microbiological analysis during storage revealed negative results for *Salmonella* and *Escherichia coli*, and Eber spoilage test was also negative, indicating the absence of pathogenic microbial growth and ammonia compound formation, thereby confirming that beef rendang remained safe and suitable for consumption.

Abbreviations

TPC	*Total Plate Count*
ALB	Asam Lemak Bebas (*Free Fatty Acid / FFA*)
TBA	*Thiobarbituric Acid*
SNI	Standar Nasional Indonesia
ANOVA	*Analysis of Variance*
DMRT	*Duncan's Multiple Range Test*

Data Availability Statement

Data will be made available on request.

CRediT Authorship Contribution Statement

Yanda Bhinnelka: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing – original draft. **Susi Desminarti**: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, resources, software, supervision, validation, visualization, writing – review and editing. **Agustina Agustina**: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, resources, software, supervision, validation, visualization, writing – review and editing.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest or competing interest.

Declaration of Use of AI in the Writing Process

The authors declare that artificial intelligence (AI) tools were used to assist in the writing process of this manuscript. Specifically, AI-based tools, including Jenni AI and ChatGPT Plus, were utilized to support language refinement, grammar correction, and improvement of clarity and readability. The AI tools were not used to generate scientific ideas, conduct data analysis, interpret results, or draw conclusions. All scientific content, including study design, data collection, analysis, and interpretation, was entirely developed and verified by the authors. The authors take full responsibility for the content of this manuscript and confirm that all information presented is original, and accurate. The use of AI tools did not compromise the integrity, validity, or scientific contribution of the work.

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