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Determination of the Maximum Limits of Quality Parameters in Cooking Oil as a Contributor to Oxidative Damage in Instant Noodles

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ABSTRACT

Fried foods are widely favored due to their distinctive texture, aroma, and flavor developed during frying. However, lipid oxidation during frying and storage may reduce product quality and accelerate rancidity in instant noodles. This study aimed to determine the maximum acceptable peroxide value (PV) threshold of frying oil based on the sensory stability of instant noodles, evaluate oxidative deterioration during storage, and investigate the relationship between peroxide value and oil conductivity. The results showed that sensory degradation followed first order reaction kinetics. The slowest reaction rate constant was observed in the group with peroxide values (PV) ranging from 0.0 to 5.0 meq O_2/kg. No significant correlation was found between peroxide value (PV) and conductivity during the instant noodle heating process. This study demonstrated that frying oil with a peroxide value (PV) >5 meq O_2/kg significantly reduced the sensory stability of instant noodles during storage. These findings suggest that the quality limit for frying oil used in the instant noodle industry should be established based on the sensory stability of the final product (product-based oil quality threshold), rather than solely on the chemical characteristics of the oil prior to use.

1. INTRODUCTION

Mi instant noodles are one of the most popular ready-to-eat food products, with global market growth reaching 6.8% per year and estimated to be worth USD 74.85 billion in 2028 (Facts & Factors, 2022). Instant noodles produced through the frying process dominate the market because they have sensory characteristics preferred by consumers, such as golden color, crispy texture, aroma, and distinctive taste resulting from the frying process (Park *et al*., 2019). In addition to functioning as a cooking process, frying also plays a role in product preservation, so instant noodles generally have a shelf life of 6–12 months (Guo *et al*., 2022). Product quality stability during storage is strongly influenced by the oxidative stability of cooking oil because instant noodles contain approximately 15–20% oil and fat (Rani *et al*., 2018).

The reference value used in Indonesia for cooking oil quality is the Indonesian National Standard (SNI), namely SNI 7709:2019 (BSN, 2019) concerning palm cooking oil. Palm cooking oil has chemical quality parameters characterized by a maximum peroxide value of 10 meq O_2/kg. In determining standards, the instant noodle industry refers to stricter internal standards to ensure product quality. If instant noodle products do not comply with the predetermined peroxide value standard for cooking oil, the products are destroyed so that they are not distributed and consumed by humans but are instead used as animal feed. This causes considerable losses. The peroxide value parameter is an indicator of cooking oil quality during the frying process; this parameter serves as a reference for product rancidity during its shelf life. In addition to cooking oil, there is also a reference standard for the final fried product, namely the standard for instant noodles. The reference value used in Indonesia for instant noodles is stipulated in the Indonesian National Standard

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(SNI), namely SNI 3551:2018 (BSN, 2018). The SNI for instant noodles does not stipulate a peroxide value standard, but the odor and taste parameters of instant noodles are standards that must be achieved throughout their shelf life.

The continuous use of cooking oil at high temperatures (150–170 °C) causes lipid oxidation reactions that reduce oil quality. Oxidation reactions produce hydroperoxides, volatile carbonyl compounds, ketones, and other oxidation compounds that contribute to the emergence of rancid aroma, undesirable taste, and changes in the color of the oil to become darker (Negroni *et al*., 2001). An increase in peroxide value (PV) during repeated frying processes has been reported to increase from 1.62 meq O_2/kg to 12.78 meq O_2/kg after several frying cycles (Mariana *et al*., 2020). High peroxide values also have the potential to reduce the safety and acceptance of food products (Oh *et al*., 2023).

Various previous studies have evaluated the quality of cooking oil using chemical parameters such as peroxide value (PV), free fatty acid (FFA) content, anisidine value, and total polar compound content to describe the degree of oil degradation during the frying process (Abrante-Pascual *et al*., 2024). Changes in the chemical composition of oil during the heating process have the potential to affect its electrical characteristics, so conductivity measurements can be used to observe changes that occur in the oil during heating (Adelagun *et al*., 2023). These approaches focus on changes in the characteristics of oil as a raw material, so oil quality limits are generally determined based on chemical changes occurring in the oil itself. However, cooking oil that still meets standard requirements does not necessarily produce food products with optimum sensory stability during storage. During the frying process, some of the oil will be absorbed into the product and become the main source of further oxidation reactions that produce various volatile compounds that cause rancidity. Thus, the characteristics of oil before use do not fully represent the quality of the final product produced (Valle *et al*., 2024). Based on these conditions, there is still a research gap regarding the determination of cooking oil quality limits that are directly associated with the oxidative stability and sensory quality of fried food products. Most previous studies have used oil as the main object of evaluation, whereas studies on the relationship between cooking oil quality, the rate of oxidative deterioration of products, and product-based oil quality thresholds remain very limited.

This study aims to evaluate peroxide value and conductivity as indicators of oxidative deterioration of cooking oil and to determine their relationship with changes in the sensory quality of instant noodles during storage. In addition, this study develops a product-based oil quality threshold approach, namely the determination of cooking oil quality limits based on the sensory stability of the final product. This approach is expected to provide a more applicable basis for controlling cooking oil quality in the instant noodle industry through the integration of sensory analysis, accelerated storage, and oxidation kinetics.

2. MATERIALS AND METHODS

2.1. Materials

The materials used were palm cooking oil (Refined Bleached Deodorized Palm Olein), wheat flour, tapioca flour, cassava flour, an alkaline solution consisting of salt, sodium carbonate (soda ash), potassium carbonate, sodium tripolyphosphate, guar gum, soy lecithin, and food coloring (tartrazine CI 19140), reagents for peroxide value testing, including glacial acetic acid solution, chloroform (3:2, v/v) according to the AOCS method, potassium iodide, sodium thiosulfate solution ($Na_2S_2O_3$ 0.01 N), potassium dichromate, starch indicator (Amylum), distilled water, and RO water (reverse osmosis).

2.2. Methods

2.2.1. Oil Heating at Variations in Heating Time

The cooking oil raw material had predetermined and standardized quality parameters, with material acceptance values of peroxide value (PV) = 0.49 meq O_2/kg, free fatty acid (FFA) = 0.074%, cloud point (CP) = 10.0 °C, with a positive Tertiary Butylhydroquinone (TBHQ) value of 100 ppm. Five liters of prepared cooking oil were heated using a Modena FF 10550 ETSS Electric Deep Fryer at a temperature of 160 °C. A temperature of 160 °C was used to resemble the heating process of instant noodles in the instant noodle processing production process (Lekjing *et al*., 2026). Heating was carried out for 8 hours, and every hour, a 100 mL sample was taken to test the peroxide value, free fatty acids, and conductivity value, with three repetitions.

2.2.2. Determination of the Duration of the Instant Noodle Frying Process at a Certain Temperature

The experiment was conducted by frying wet noodles at a temperature of 160 °C for a time range of 0–180 seconds using a Modena FF 10550 ETSS Electric Deep Fryer. Every 30 seconds, 2 pcs of samples were taken to check the moisture content, followed by three repetitions. The wet noodles used were noodle pieces obtained from the noodle steaming process. The moisture content of the wet noodles in this study ranged from 28.69%–31.22%, with the target final moisture content after frying being below 3% and golden yellow in color (Lekjing *et al*., 2026).

2.2.3. Preparation of Instant Noodle Samples with Variations in Peroxide Value and Conductivity

Variations in peroxide value and conductivity were prepared by engineering the quality of cooking oil through controlling the oxidation level before it was used in the instant noodle frying process. This engineering aimed to produce noodle samples with three groups of variations in oil oxidation levels. The samples were divided into three variation groups based on the peroxide value (PV) of the oil used in the frying process, namely variation 1 (peroxide value 0.0–5.0 meq O_2/kg), representing fresh oil conditions to the initial stage of oxidation (low primary oxidation), variation 2 (peroxide value 5.1–10.0 meq O_2/kg), representing moderate oxidation conditions, in which hydroperoxide formation had occurred significantly, and variation 3 (peroxide value 10.1–15.0 meq O_2/kg), representing advanced oxidation conditions (high hydroperoxide accumulation), but still in the predominantly primary oxidation phase before decomposition into secondary products. The variation ranges were selected to represent the stages of oil degradation commonly occurring during repeated frying processes in the instant noodle industry (Oh *et al*., 2023).

2.2.4. Oxidative Deterioration Stability Test of Instant Noodles

Instant noodle samples produced from cooking oil with variations in peroxide value (PV) were stored in an oven at a temperature of 60 ± 2 °C for 8 days and evaluated at 5 observation points, namely days 0, 2, 4, 6, and 8. Sensory analysis was conducted using the Quantitative Descriptive Analysis (QDA) method by 10 trained panelists who were employees of PT. XYZ. Trained panelists were used to assess the intensity of sensory attributes consistently and structurally. The main attributes observed included rancid aroma, rancid taste, and aftertaste. This method is used to quantitatively measure the intensity of sensory attributes so that changes in product quality during storage can be observed objectively (Rodrigues *et al.*, 2024). The study was conducted using a numerical scale of 1–10, with a value of 1 indicating that the attribute was not detected and a value of 10 indicating that the attribute identity was very strong. The first-order reaction kinetic model was used to quantify the rate of change in sensory attributes through the rate constant (k). A higher rate constant (k) indicates a faster change in the intensity of the sensory attribute over the same period of time (Nguyen *et al.*, 2024).

2.2.5. Data Analysis

Data analysis in this study used Microsoft Excel and SPSS software. The analysis results consisted of correlation tests and first-order kinetic analysis.

3. RESULTS AND DISCUSSION

3.1. Correlation of Peroxide Value (PV), Free Fatty Acids (FFA), and Conductivity

The correlation of peroxide value (PV), free fatty acids (FFA), and conductivity is shown in Table 1. The results of the correlation analysis showed that the relationships between peroxide value (PV), free fatty acids (FFA), and conductivity were relatively weak. The Pearson correlation value between peroxide value (PV) and free fatty acids (FFA) was close to zero (r = -0.019), indicating no linear relationship between the two parameters. This indicates that peroxide value (PV) and free fatty acids (FFA) represent different degradation mechanisms, namely primary oxidation and hydrolysis (Grebenteuch *et al*., 2021). The correlation between peroxide value (PV) and conductivity (r = -0.313) and between free fatty acids (FFA) and conductivity (r = -0.395) also showed weak relationships. This indicates that conductivity is less sensitive in representing oxidative or hydrolytic changes in cooking oil over a certain heating period. These results indicate that oil degradation is a complex process that cannot be explained by a single parameter, so a multivariate approach is needed to understand the relationship between chemical parameters and product quality.

Table 1. Results of the correlation analysis of peroxide value (PV), free fatty acids (FFA), and conductivity

Variable	Pearson (r)	Spearman (p)
PV vs FFA	-0.019	-0.367
PV vs Conductivity	-0.313	-0.143
FFA vs Conductivity	-0.395	-0.365

The relationship between peroxide value (PV) and free fatty acids (FFA) during the heating process was analyzed to understand the relationship between oxidation and hydrolysis mechanisms in cooking oil. Based on the resulting correlation graph (Figure 1a), it can be seen that peroxide value (PV) and free fatty acids (FFA) showed different patterns of change during the heating period. The peroxide value (PV) increased sharply during the initial heating stage and reached its peak at approximately the 2nd hour, then gradually decreased. This pattern indicates a primary oxidation process, in which hydroperoxides are formed and subsequently decomposed into secondary oxidation compounds (Grebenteuch *et al*., 2021). In contrast, the free fatty acid (FFA) value showed a relatively consistent increase throughout the heating period, indicating that the triglyceride hydrolysis reaction proceeded gradually.

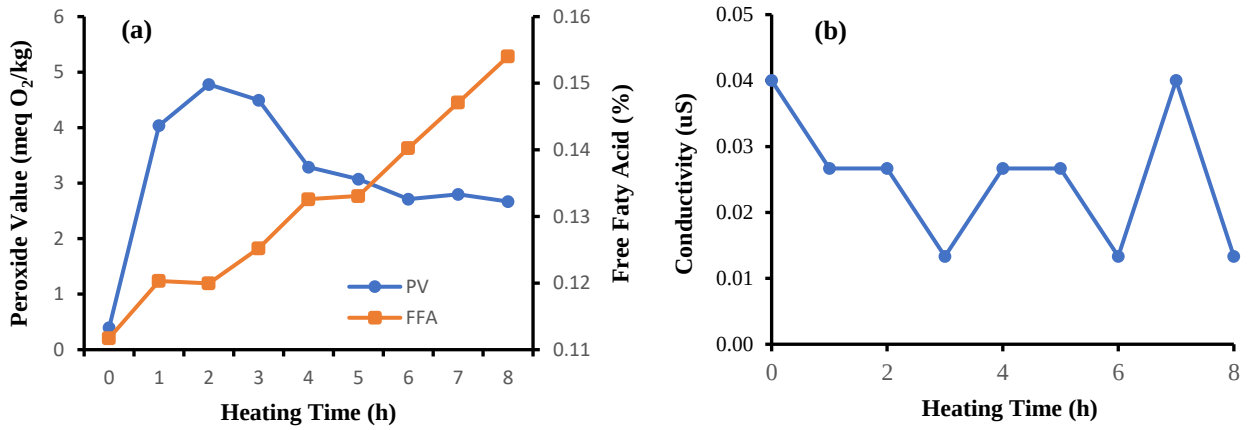


Figure 1. (a) Relationship between peroxide value and free fatty acids, and (b) relationship between conductivity and heating time

The conductivity values presented in Figure 1b indicate that changes in the electrical properties of oil are not only influenced by the formation of hydroperoxides or an increase in free fatty acids, but are also influenced by the accumulation of polar compounds resulting from oil degradation, water content, and various oxidation products formed during heating (Bazina *et al.,* 2025). As the level of oil degradation increases, the amount of polar compounds will increase, resulting in changes in electrical properties. However, the formation of polar compounds results from the interaction of various degradation mechanisms, including oxidation, hydrolysis, and polymerization, so changes in conductivity do not always show a linear relationship with a particular quality parameter, including peroxide value (Abrante-Pascual *et al*., 2024).

3.1.1. Optimum Frying Time for Instant Noodles

The results showed that the initial moisture content of the noodles before frying was 30.09%. After 30 seconds of frying, the moisture content decreased drastically to 4.62%, and at 60 seconds, it reached 1.86%, which met the target moisture content of < 3% and had a golden yellow color. The subsequent decrease occurred more slowly, namely 1.05% (90 seconds), 0.77% (120 seconds), 0.81% (150 seconds), and 0.67% (180 seconds), and resulted in a blackish noodle color. The decrease in moisture content showed a characteristic exponential pattern in the deep-fat-frying process, with a rapid decrease phase at the beginning of the process, followed by a slowing phase controlled by the internal diffusion of water from the starch-protein matrix of the noodles (Verma *et al*., 2026). The porous structure formed in instant noodles during frying plays a role in oil retention within the product, making the characteristics and stability of the frying oil crucial factors in the instant noodle frying process (Ooi *et al.,* 2024). Based on the results of frying time in relation to the target

moisture content reduction and the expected golden yellow color change, the optimum frying time was 60 seconds at a temperature of 160 °C.

3.1.2. Variations in Peroxide Value and Conductivity

The engineering of peroxide value (PV) was carried out using a controlled oxidation method by heating the oil at a temperature of 160 °C using a Modena FF 10550 ETSS Electric Deep Fryer. The oil was heated and used to fry wet noodles under the optimum temperature and time conditions (60 seconds) that had been previously determined. After every 30 noodle frying processes, oil samples were taken to check the peroxide value, free fatty acids, and conductivity value. In addition, the acid value, fat content, and moisture content of the instant noodles resulting from the frying process were also checked.

Each noodle sample was packaged in OPP (oriented polypropylene) packaging and tightly sealed according to the instant noodle packaging commonly used in the instant noodle industry. Instant noodle samples produced from cooking oil with variations in peroxide value were stored in an oven at a temperature of 60 ± 2 °C for 8 days and evaluated at 5 observation points, namely days 0, 2, 4, 6, and 8. The results of the analysis of changes in peroxide value (PV) and free fatty acids (FFA) every 20 instant noodle frying processes are shown in Figure 2.

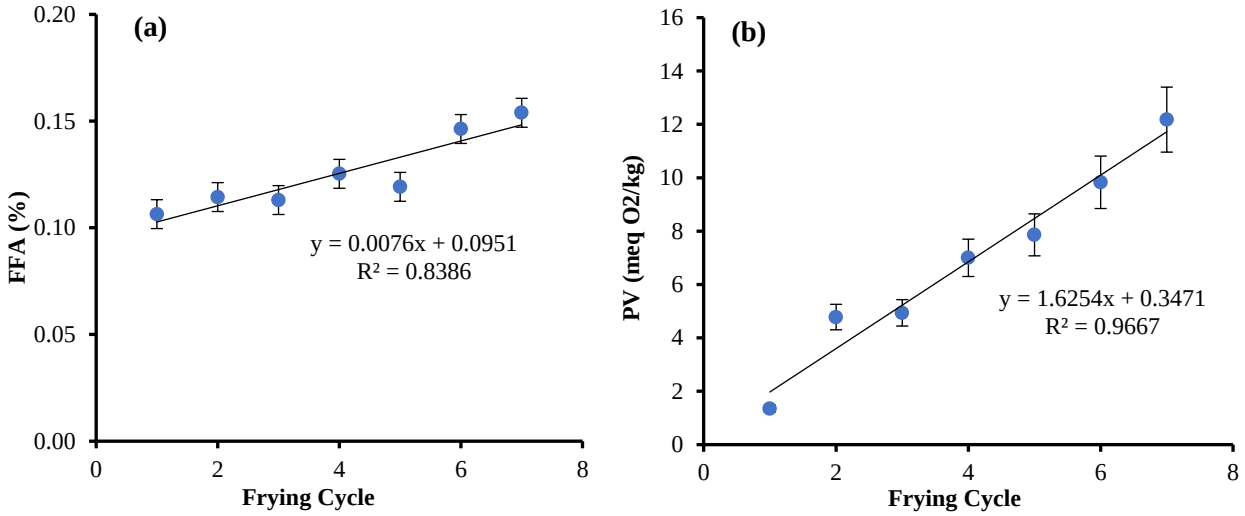


Figure 2. Effect of frying cycles on: (a) free fatty acids (FFA), and (b) peroxide value (PV) (1 sale = 20 frying cycles)

Compared with peroxide value (PV), the increase in free fatty acids (FFA) occurred more slowly, indicating that the oxidation process occurred more dominantly than hydrolysis during the instant noodle frying process. This condition was indicated by the slope value of peroxide value (PV), which was much higher than the slope of free fatty acids (FFA), namely 1.625 and 0.0076, respectively. The results of this study showed a tendency for the peroxide value (PV) and free fatty acids (FFA) to increase with increasing duration of oil use during the frying process. The increase in peroxide value (PV) and free fatty acids (FFA) during the frying process can be used as indicators of a decrease in cooking oil quality, which has the potential to affect the sensory stability and shelf life of instant noodles.

3.2. Oxidative Deterioration Stability Test of Instant Noodles

The oxidative deterioration stability test of instant noodles was conducted to evaluate changes in product sensory quality during accelerated storage at a temperature of 60±2 °C for 0, 2, 4, 6, and 8 days. The sensory attributes observed included rancid aroma, rancid taste, and rancid aftertaste in instant noodles fried using oil with different peroxide value (PV) variations, namely 0.0–5.0 meq O_2/kg, 5.1–10.0 meq O_2/kg, and 10.1–15.0 meq O_2/kg. The results of the Quantitative Descriptive Analysis (QDA) test showed that the incubation period at 60 °C caused an increase in the intensity of rancid aroma, rancid taste, and rancid aftertaste in all peroxide value (PV) treatment groups of instant noodles. The increase in these sensory attributes indicates that during storage, the lipid oxidation reaction was accelerated, producing volatile

compounds that caused rancidity in instant noodles. The QDA test results illustrate the relationship between cooking oil degradation and changes in the sensory quality of instant noodles. The relationship between the duration of accelerated storage and changes in the sensory quality of rancid aroma, rancid taste, and rancid aftertaste with variations in peroxide value (PV) is shown in Figure 3.

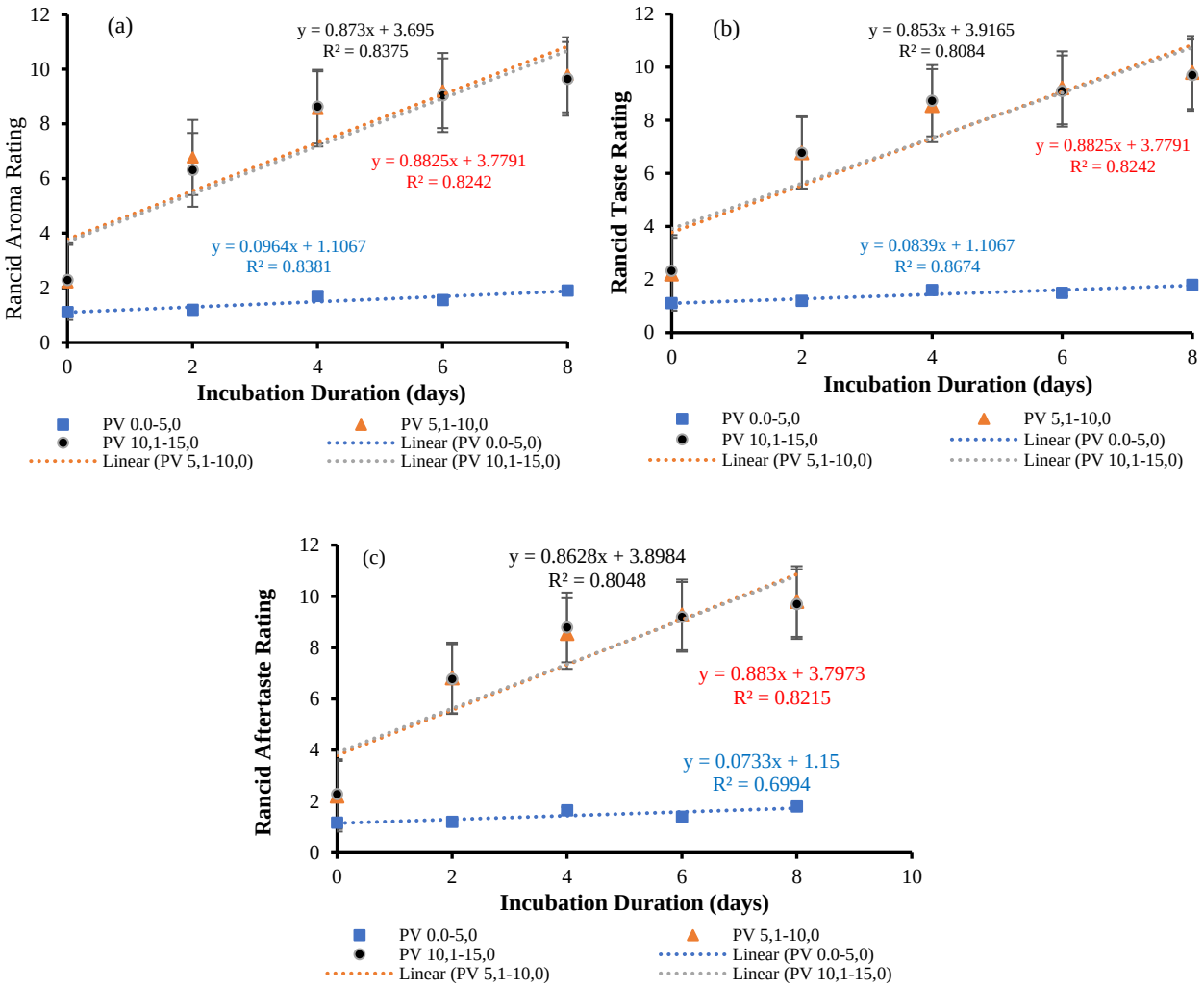


Figure 3. Effect of peroxide value and the duration of accelerated storage at 60 °C on thechanges in sensory quality of: (a) rancid aroma, (b) rancid taste, and (c) rancid aftertaste

The oil groups with moderate peroxide values (PV 5.1–10) and high peroxide values (10.1–15 meq O_2/kg) showed a much faster acceleration of rancidity formation compared with the low peroxide value group (PV 0.0–5.0 meq O_2/kg). This indicates that the initial oxidation level of cooking oil has a significant effect on the sensory stability of instant noodles during accelerated storage. Instant noodles fried using oil with a higher initial peroxide value (PV) showed a faster increase in rancidity intensity compared with instant noodles fried using oil with a low peroxide value (PV). The increase in rancidity in dry food products occurs due to the formation and decomposition of hydroperoxides into aldehydes, ketones, alcohols, and other volatile carbonyl compounds that have rancid flavor characteristics (Abrante-Pascual *et al.*, 2024). The oxidation of cooking oil during storage results in the accumulation of oxidative volatile compounds that directly affect the sensory quality of fatty food products. The organoleptic characteristics of instant noodles can change during storage, and an increase in storage temperature affects product stability (Shahabinejad *et al.*, 2024). Based on the pattern of changes in sensory attributes during storage, the rancidity reaction in instant noodles

showed a tendency to follow first-order kinetics. This was indicated by the rapid increase during the initial incubation stage, the rate of increase subsequently slowing down, the tendency to approach a plateau, and the autocatalytic characteristics of lipid oxidation only for moderate peroxide values (PV 5.1–10.0 meq O_2/kg) and high peroxide values (10.1–15 meq O_2/kg), as presented in Figure 3. In a first-order reaction, the reaction rate is influenced by the concentration of previously formed oxidative compounds. The general equation for first-order kinetics is ln Ct = Ln C_0 + kt, as shown in Table 2. This mechanism is consistent with the lipid autoxidation reaction, in which hydroperoxides formed during oxidation accelerate the formation of new free radicals, thereby accelerating oxidative degradation progressively (Liberty *et al*., 2025).

Table 2. First-order kinetic equations of peroxide value (PV) groups for sensory attributes (rancid aroma, rancid taste, and rancid aftertaste)

PV Group	Rancid Aroma		Rancid Taste		Rancid Aftertaste	
	First-Order Equation	Constant (k)	First-Order Equation	Constant (k)	First-Order Equation	Constant (k)
0.0-5.0	ln y = 0.0664t+0.1139	0.0664	ln y = 0.0594t+0.1126	0.0594	ln y = 0.0511t+0.1480	0.0511
5.1-10.0	ln y = 0.1648t+1.2109	0.1648	ln y = 0.1648t+1.2109	0.1648	ln y = 0.1648t+1.2136	0.1648
10.1-15.0	ln y = 0.1620t+1.2111	0.1618	ln y = 0.1573t+1.2526	0.1573	ln y = 0.1599t+1.2415	0.1599

The results showed that a small increase in peroxide value (PV) caused an exponential acceleration in the rate of sensory rancidity formation. This phenomenon indicates an oxidative acceleration effect, in which the accumulation of primary oxidation products accelerates the formation of secondary volatile compounds autocatalytically. An increase in temperature will accelerate the rate of lipid oxidation reactions according to the principles of reaction kinetics and the Arrhenius model. Oxidative reactions in fatty food products generally increase exponentially with increasing storage temperature due to increased free radical formation and decomposition of hydroperoxides into volatile compounds that cause rancidity (Calligaris *et al*., 2022). A peroxide value (PV) = 5 meq O_2/kg can be used as a critical oxidative limit to prevent accelerated sensory deterioration of instant noodles. Thus, it can be concluded that the product-based oil quality threshold approach shows that oil with a peroxide value (PV) above 5 meq O_2/kg begins to cause a significant decrease in the sensory stability of the product during storage. This value can be used as an oil quality limit based on the sensory stability of the final product.

4. CONCLUSIONS

This study shows that the initial quality of cooking oil, particularly peroxide value (PV), has a significant effect on the development of sensory rancidity during accelerated storage. An increase in the peroxide value (PV) of cooking oil was followed by an increase in rancid aroma, rancid taste, and rancid aftertaste of the product during incubation at 60 °C. The product-based oil quality threshold approach shows that oil with a peroxide value (PV) above 5 meq O_2/kg begins to cause a significant decrease in the sensory stability of the product during storage. This value can be used as an oil quality limit based on the sensory stability of the final product. Accelerated storage at 60 °C successfully accelerated the oxidative degradation of products fried with oil having a peroxide value (PV) above 5 meq O_2/kg and showed that an increase in the oxidation level of the oil accelerated the formation of volatile compounds that caused rancidity in instant noodles during storage. A peroxide value (PV) of oil below 5 meq O_2/kg can be used as the maximum oil quality limit based on the sensory stability of the final product.

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DECLARATION OF GENERATIVE AI UTILIZATION

Not applicable. The authors did not use any generative AI tools or services in the preparation of this manuscript. All content is entirely the intellectual work of the authors.

AUTHOR CONTRIBUTION

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
BF	✓	✓		✓	✓	✓		✓	✓	✓	✓			
DRA	✓	✓		✓						✓		✓		
DH	✓	✓		✓						✓		✓		

C: Conceptualization
M: Methodology
So: Software
Va: Validation
Fo: Formal Analysis
I: Investigation
D: Data Curation
R: Resources
O: Writing - Original Draft
E: Writing - Review & Editing
Vi: Visualization
Su: Supervision
Fu: Funding Acquisition
P: Project Administration

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