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Validation of Analytical Method for Determining Formaldehyde Levels in Imported Apples Sold in Pontianak City using UV–Vis Spectrophotometry

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Abstract: The Indonesian government has implemented various efforts to protect food from biological, chemical, and physical contaminants that may endanger public health. Formaldehyde, an aqueous solution containing 37% formaldehyde, is commonly used as an antiseptic, disinfectant, and preservative for biological specimens. However, its misuse in food products, such as imported apples, remains a concern in Indonesia. This study aims to detect and measure formaldehyde levels in imported apples sold in Pontianak City by comparing peeled and unpeeled samples. Qualitative analysis was conducted using Schiff reagent color tests, while quantitative analysis employed UV-Vis spectrophotometry. The results showed the presence of formaldehyde in unpeeled imported apples, with concentrations ranging from 5.23–22.65 mg/kg (1.57–6.80 mg/serving). Meanwhile, peeled imported apples exhibited lower formaldehyde levels, ranging from 2.55–6.75 mg/kg (0.76–2.02 mg/serving) across six districts in Pontianak City. Statistical testing with the Independent Sample T-Test showed a significant distinction between peeled and unpeeled imported apples. Therefore, peeling imported apples prior to consumption may reduce potential exposure to formaldehyde. Consumers are advised to wash apples thoroughly under running water and purchase products from reliable sources to minimize the risk of contamination. Furthermore, strengthened regulatory monitoring and stricter enforcement against the illegal use of formaldehyde in food products are necessary to ensure consumer safety and protect public health.

Keywords: formaldehyde, peeled and unpeeled imported apples, schiffs reagent, UV-Vis spectrophotometry

1. INTRODUCTION

The Indonesian government has implemented various measures to ensure food safety, as stipulated in the Republic of Indonesia's Government Regulation Number 86 of 2019, which aims to prevent contamination from biological, chemical, and other harmful substances [1]. A 2017 study by the Indonesian Food and Drug Authority (BPOM) reported numerous food poisoning cases, primarily caused by the improper use of additives such as preservatives, colorants, and flavor enhancers [2].

Formaldehyde is a prohibited additive primarily used for preserving biological specimens and corpses. However, it is frequently misused by traders to extend the shelf life of food products such as fruits, tofu, wet noodles, and meatballs [3,4]. The ban on formaldehyde use is stipulated in Minister of Health Regulation of the Republic of Indonesia Number 033 of 2012, which regulates food additives. This regulation explicitly prohibits the addition of formaldehyde to any food products, underscoring the government's firm commitment to protecting public health from the dangers associated with this chemical substance [5].

According to the International Program on Chemical Safety (IPCS), the safe intake limit for formaldehyde is 0.1–0.2 mg/day in liquid form and 1.5–14 mg/day in food for adults. The U.S. National Institute for Occupational Safety and Health (NIOSH, classifies exposure to formaldehyde at 20 ppm as highly hazardous [6]. Excessive intake can cause organ and systemic damage, with

symptoms such as nausea, vomiting, respiratory distress, skin irritation, and diarrhea. Long-term exposure may result in gastrointestinal bleeding, liver and kidney dysfunction, and an increased risk of cancer [7]. Moreover, consuming formaldehyde at doses of 30 mL can potentially cause death in humans [8].

A study conducted by BPOM RI in 2013 revealed that 13.82% of 24,906 food samples contained hazardous substances, including formaldehyde [9]. Research by Manoppo et al. (2014) in Manado City identified formaldehyde in nine samples of imported apples, grapes, and pears, with concentrations ranging from 0.080 to 0.195 μg/mL in unwashed samples and 0.060 to 0.136 μg/mL in washed samples [10]. Similarly, Mudaffar (2021) reported the presence of formaldehyde in imported apple and grape samples in Palopo City, with concentrations of 6.31 ppm and 10.56 ppm, respectively [11].

As reported by the Central Bureau of Statistics (BPS) in 2022, Indonesia imported 749.6 million kilograms of fruit [12]. Before reaching the market, these imports must go through licensing procedures with relevant government institutions, such as the Directorate General of Customs and Excise and the Agricultural Quarantine Agency. The fruits then undergo a quarantine process for several weeks, including isolation, observation, treatment, detention, rejection, destruction, and final release before being distributed to traders [13]. The extended distribution period, from the country of origin to quarantine procedures, can lead to a decline in fruit quality. Moreover, the limited availability of cold storage facilities in markets has led some traders to use formaldehyde as a preservative to prolong shelf life and reduce potential losses [3]. This research plays a crucial role in the field of pharmacy, particularly in supporting BPOM's function of evaluating the quality of imported fruits to ensure they are free from formaldehyde contamination, thereby protecting public health from potentially harmful food products. formaldehyde detection is conducted through a qualitative analysis using the Schiff reagent color test, which reacts with formaldehyde in the sample. This reaction results in the formation of a complex compound that produces a reddish-purple color, indicating the presence of formaldehyde [10].

Formaldehyde quantification is conducted using UV–Vis Spectrophotometry, which measures light absorption at specific wavelengths in the visible and ultraviolet spectrum. This method is used because formaldehyde absorbs light in the visible range. To guarantee the accuracy and dependability of the results, the analytical method should be validated by evaluating its specificity, linearity, range, accuracy, precision, LOD, and LOQ, ensuring adherence to quality standards. The detection process involves a derivatization reaction to form chromophore groups, where formaldehyde reacts with Schiff reagent to produce a colored complex that absorbs light within the 400-800 nm range [10-15]. Research on formaldehyde content in imported apple samples sold in Pontianak City has not been conducted previously. Therefore, based on the aforementioned explanation, the researchers are interested in conducting this study, which aims to detect and measure formaldehyde concentrations in peeled and unpeeled imported apples sold in Pontianak City.

2. MATERIALS AND METHODS

2.1. Materials

The samples analyzed in this study consisted of 8 imported apple specimens commercially distributed in Pontianak City, Indonesia. The specimens were obtained from local fruit retailers and supermarkets across six sub-districts: East, Central, North, West, South, and Southeast Pontianak to ensure a representative distribution of products available to consumers. A systematic coding was applied based on the collection region and sample treatment. The suffix "TK" (Tidak Dikupas) denotes unpeeled samples, while "DK" (Dikupas) indicates peeled samples. For most regions, the unpeeled and peeled treatments were derived from the same apple specimen to evaluate the presence of formaldehyde on both the skin and the flesh. However, in East and Southeast Pontianak, two distinct specimens were collected from different vendors to account for potential variability in chemical applications within the same area, resulting in separate codes.

The chemical reagents used included formaldehyde 37% (formalin) standard (Merck), Schiff reagent (Merck), HCl 37% pa (E.Merck), filter paper (Whatman), and distilled water. Analytical measurements were conducted using a UV-Vis spectrophotometer (1800 Double Beam Shimadzu) and supported by standard laboratory equipment, including an analytical balance (Ohaus), beakers (Iwaki), measuring cylinders (Pyrex), volumetric flasks (Pyrex), dropper pipettes (Mico), micropipettes (Socorex Acura), mortar, graduated pipettes (Iwaki), plastic containers (Tupperware), vials, napkins, and pH paper.

2.2. Sample Preparation

8 Imported apple samples, both peeled and unpeeled, were weighed (15 grams each) and crushed using a mortar. The entire 15 grams of the crushed sample was transferred into a 25 mL volumetric flask and diluted to volume with distilled water. The mixture was filtered through filter paper, and the resulting filtrate was used for the quantitative determination of formaldehyde by UV–Vis Spectrophotometry [3].

2.3. Qualitative Test

10 mL filtrate of the prepared imported apple samples was taken and acidified with HCl until the pH was less than 3. An equal volume of colorless Schiff reagent was then added. The color change was observed if the sample solution exhibited a color similar to the positive control (red to purple), it indicated the presence of formaldehyde in the imported apple samples. However, if the sample solution exhibited a color similar to the negative control (clear), it indicated that the imported apple samples did not contain formaldehyde [3].

2.4. Standar Solution Preparation

A total of 2.70 mL of 37% formaldehyde standard solution (formalin) was taken and transferred into a 1000 mL volumetric flask. It was then diluted with distilled water up to the marked line to obtain a formaldehyde solution with a concentration of 0.1% (1000 ppm) [3].

2.5. Operating Time

A total of 0.1 mL of 0.1% (1000 ppm) formaldehyde standard solution was pipetted and transferred into a 10 mL volumetric flask. Then, 3 mL of Schiff reagent was added, and the solution was diluted with distilled water up to the marked line, resulting in a concentration of 10 ppm. Incubation was carried out at 0, 5, 10, 15, 20, 25, 30, 35, 40, and 45 minutes [16]. The absorbance of the solution was measured at a theoretical maximum wavelength of 554 nm using 3 mL of Schiff reagent diluted with distilled water in a 10 mL volumetric flask as a blank.

2.6. Determination of Maximum Wavelength

A 10 ppm formaldehyde standard solution was prepared and transferred into a 10 mL volumetric flask, followed by the addition of 3 mL of Schiff reagent and dilution with distilled water up to the marked line. The solution was then incubated based on the operating time results. The absorbance was measured at wavelengths ranging from 300–700 nm using 3 mL of Schiff reagent diluted with distilled water in a 10 mL volumetric flask as a blank [17].

2.7 Method Validation

2.7.1. Specificity Test

The selectivity test was conducted by comparing curves (Absorbance vs. Wavelength) from three solutions 10 ppm formaldehyde standard solution prepared from 0.1% (1000 ppm) formaldehyde, sample solution with the addition of 0.1% (1000 ppm) formaldehyde standard solution and sample solution without the addition of formaldehyde. All three solutions were scanned at wavelengths ranging from 300–700 nm to determine the maximum wavelength [18].

2.7.2. Linearity

0.1% (1000 ppm) formaldehyde standard solution was diluted into five concentration series. Each series was prepared by adding 3 mL of Schiff reagent into a 10 mL volumetric flask, resulting in concentrations of 3, 4, 5, 6, and 7 ppm. The solutions were then diluted with distilled water up to the marked line and incubated according to the operating time results. Absorbance measurements

were performed using UV-Vis spectrophotometry at the maximum wavelength obtained, with 3 mL of Schiff reagent diluted with distilled water in a 10 mL volumetric flask as a blank [10].

2.7.3. LOD and LOQ

The limit of detection (LOD) is defined as the lowest concentration of an analyte that can be detected, corresponding to a signal approximately three times the standard deviation of the blank, whereas the limit of quantification (LOQ) is the lowest concentration that can be quantified with acceptable accuracy and precision, and in this study both parameters were determined using standard solutions in the concentration range of 3–7 ppm within the linear calibration range for calculation based on the standard equations [19].

$$Sy/x = \frac{\sqrt{\sum(Y-Yi)^2}}{n-2}$$

$$\sigma = S_{Y/X}\sqrt{\frac{\sum X_i^2}{n\sum(Xi-X)2}}$$

$$LOD = (3.3 \times \sigma) / S$$

$$LOQ = (10 \times \sigma) / S$$

2.7.4. Accuracy and Precision

Peeled and unpeeled imported apple samples were selected to represent commercially available products in the local market. Prior to analysis, the samples were subjected to preliminary screening to ensure the absence of detectable formaldehyde. A total of 15 g of each sample was weighed, crushed using a mortar, and diluted with distilled water in a 25 mL volumetric flask up to the mark. The mixture was then filtered using filter paper to obtain a clear filtrate for further analysis. Then, 2 mL of the filtrate was taken and added with 3 mL of Schiff reagent. The mixture was diluted in a 10 mL volumetric flask. The procedure was carried out on apple samples spiked with formaldehyde at three concentration levels, namely 2.2 ppm, 2.8 ppm, and 3.4 ppm, as well as on samples without the addition of formaldehyde as a control. Each test was repeated three times (triplicate). The solution was incubated according to the operating time results and then measured for absorbance using UV-Vis spectrophotometry at the maximum wavelength obtained, using 3 mL of Schiff reagent diluted with distilled water in a 10 mL volumetric flask as a blank [3]. The percentage of recovery (%recovery), standar deviation (SD) and %RSD was calculated using the following formula :

$$\%\text{Recovery} = \frac{measured\ concentration}{actual\ concentration} \text{ x } 100\%$$

$$\text{SD} = \frac{\sqrt{\sum(Xi-\bar{X})^2}}{n-1}$$

$$\text{RSD} = \frac{SD}{X} x\ 100\%$$

2.8. Quantitative Sample Test

A total of 1 mL of the prepared sample filtrate was taken and mixed with 3 mL of Schiff reagent, then diluted with distilled water to a final volume of 10 mL in a volumetric flask. The procedure was repeated three times (triplicate). The solution was incubated according to the operating time and then measured for absorbance using UV-Vis spectrophotometry at the maximum wavelength obtained. A blank solution consisting of 3 mL of Schiff reagent diluted with distilled water to a final volume of 10 mL in a volumetric flask was used as the blank [3].

3. RESULTS AND DISCUSSION

3.1. Qualitative Test

The colorimetric test in this study was performed by adding Schiff reagent to the imported apple samples and observing any color change to indicate the presence of formaldehyde. A positive control using a standard formaldehyde solution and a negative control (blank sample without formaldehyde) were included to validate the interpretation of the color change. Schiff reagent is specific for aldehyde groups and reacts with free aldehydes, including formaldehyde, to form a magenta or purple-colored complex. The reaction between formaldehyde (HCHO) and Schiff reagent involves the interaction of formaldehyde with decolorized fuchsin-sulfonic acid, resulting in the restoration of the chromophoric structure and the formation of a purple-colored

Schiff base complex. Therefore, the appearance of a purple coloration indicates the presence of formaldehyde in the sample. The intensity of the color is qualitatively associated with the concentration of formaldehyde present. The reaction mechanism between formaldehyde and decolorized leucofuchsin, forming a magenta complex, is shown in Figure 1.

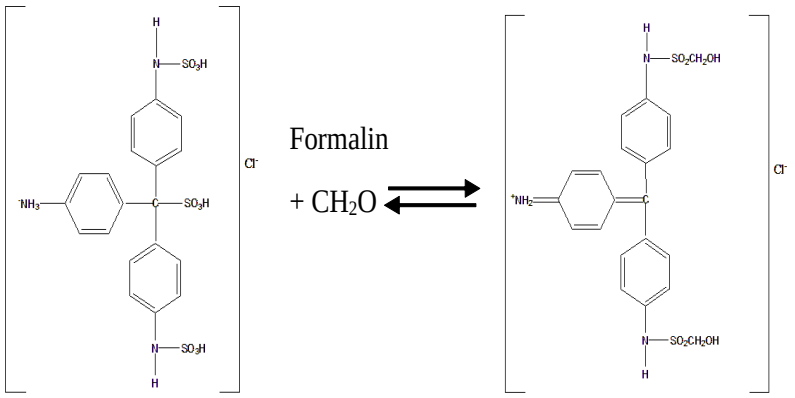

Figure 1. Reaction of formaldehyde with Schiff's reagent to form a magenta-colored complex.

Based on the test results of 8 imported apple samples, each treated with peeling and non-peeling, 6 out of the 8 samples tested were identified as positive for formaldehyde. The results of the qualitative color test for the imported apple samples are shown in Table 1.

Table 1. Results of Color Test for Imported Apple Samples with Schiff Reagent

Region	Region Code	Color	Result
East Pontianak	PTTK 1	Purple	(+)
	PTDK 1	Purple	(+)
	PTTK 2	Yellow	(-)
	PTDK 2	Yellow	(-)
Central Pontianak	PKTK	Purple	(+)
	PKDK	Yellowish Purple	(+)
North Pontianak	PUTK	Purple	(+)
	PUDK	Yellowish Purple	(+)
West Pontianak	PBTK	Purple	(+)
	PBDK	Yellowish Purple	(+)
South Pontianak	PSTK	Reddish Purple	(+)
	PSDK	Purple	(+)
Southeast Pontianak	PTGTK 1	Purple	(+)
	PTGDK 1	Yellowish Purple	(+)
	PTGTK 2	Yellow	(-)
	PTGDK 2	Yellow	(-)

Information : PT: East Pontianak; PK: Central Pontianak; PU: North Pontianak; PB: West Pontianak; PS: South Pontianak; PTG: Southeast Pontianak. TK: Unpeeled; DK: Peeled. Numbers 1 and 2 indicate different specimens from different vendors.

3.2. Determination of Maximum Wavelength

Determining the wavelength of maximum absorbance is essential for accurate spectrophotometric analysis. This study identified the optimal wavelength for the formaldehyde-Schiff reagent complex to be 554 nm. Selecting this peak wavelength ensures higher sensitivity and reliability in quantifying formaldehyde concentrations across all tested samples.

3.3. Specificity

Specificity testing is a parameter used to assess the ability of an analytical method to detect the desired analyte without interference from other components in the sample. This test measures the method's ability to

differentiate the target analyte from other substances that may be present in the sample and have similar properties, ensuring that the measurement results are solely derived from the analyte being measured. In this study, specificity testing was performed by measuring the curves of a 0.1% (1000 ppm) formaldehyde standard solution at a concentration of 10 ppm, the curve of the sample with the addition of the 0.1% (1000 ppm) formaldehyde standard solution, and the curve of the sample alone. The results of the specificity test for the 10 ppm concentration showed that at the 554 nm wavelength, which is the maximum absorption wavelength for formaldehyde, there were no significant absorption peaks from other components. This was evident from the peaks observed for both the sample with the added standard and the sample of imported apples. These results indicate that the UV-Vis spectrophotometry method used has good specificity in detecting formaldehyde in the samples.

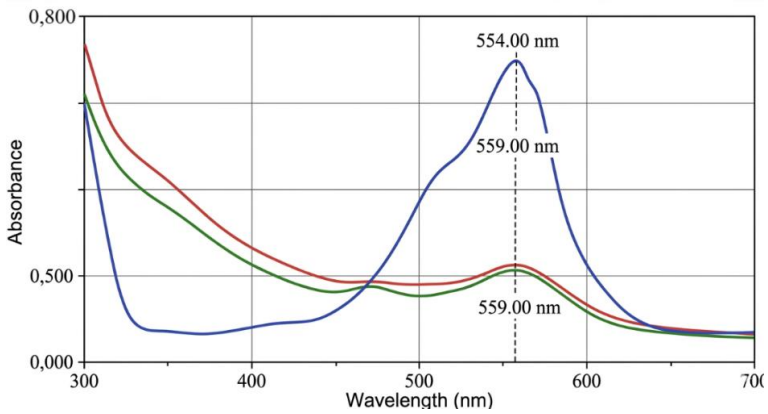

Figure 2. Specificity test results using UV-Vis spectrophotometry : (blue line) 10 ppm formaldehyde standard, (red line) sample added to formaldehyde standard, and (green line) sample

3.4. Operating Time

The determination of operating time was carried out using UV-Vis spectrophotometry in the quantitative analysis by evaluating the relationship between measurement time and the absorbance value of the solution at the maximum wavelength (λmax). The λmax was previously determined to ensure optimal sensitivity for formaldehyde detection. This study aimed to identify the optimal time required to achieve stable and consistent absorbance readings. The results showed that the reaction between formaldehyde and Schiff reagent reached maximum color intensity at 30 minutes, indicating that the reaction had reached equilibrium. This was evidenced by the increase in absorbance values up to the 30th minute. Based on the operating time test results shown in Figure 1, it can be observed that from 0 to 25 minutes, the reaction was still progressing, as indicated by the continuous increase in absorbance. However, a decrease in absorbance was observed after 30 minutes (at 35 minutes). This decrease may be attributed primarily to the instability of the Schiff base complex, leading to gradual color fading, possibly accompanied by minor reagent degradation. Therefore, measurements should be conducted at 30 minutes to obtain optimal and reliable results.

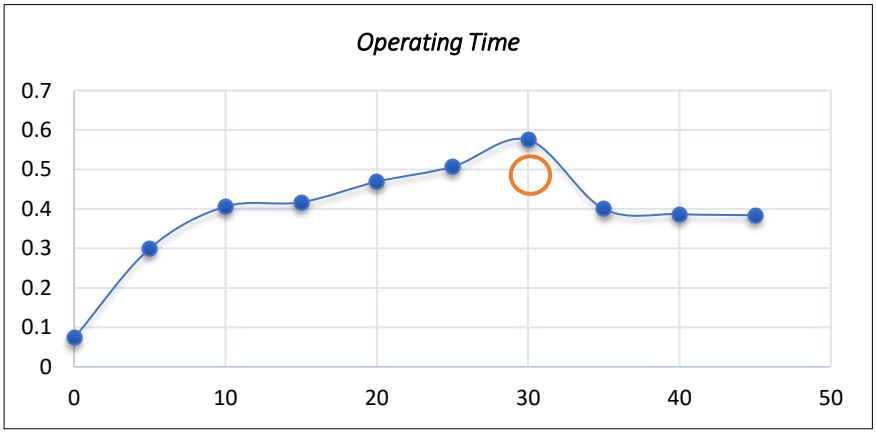

Figure 3. Operating Time Curve

3.4. Method Validation

3.4.1. Linearity

Linearity was evaluated to determine the ability of the analytical method to provide a proportional response to analyte concentration within a defined range. The method showed linear behavior over the concentration range of 3–7 ppm using five concentration levels with triplicate measurements at each level. The absorbance values obtained ranged from 0.348 to 0.744. This range is still within the acceptable limits of the Lambert–Beer law (0.2–0.8), indicating that the relationship between concentration and analytical response remained linear under the applied conditions. Linear regression analysis produced the equation y = 0.0986x + 0.0582 with a coefficient of determination (R^2) of 0.999. This result indicates that the analytical response was strongly influenced by the variation in analyte concentration. The correlation coefficient (r) of 0.999 also confirms a strong linear relationship between concentration and response. These results meet the commonly accepted linearity criteria based on method validation guidelines including SNI, ICH, and AOAC. Therefore, the analytical method can be considered to have adequate linear performance within the evaluated concentration range and is suitable for quantitative determination.

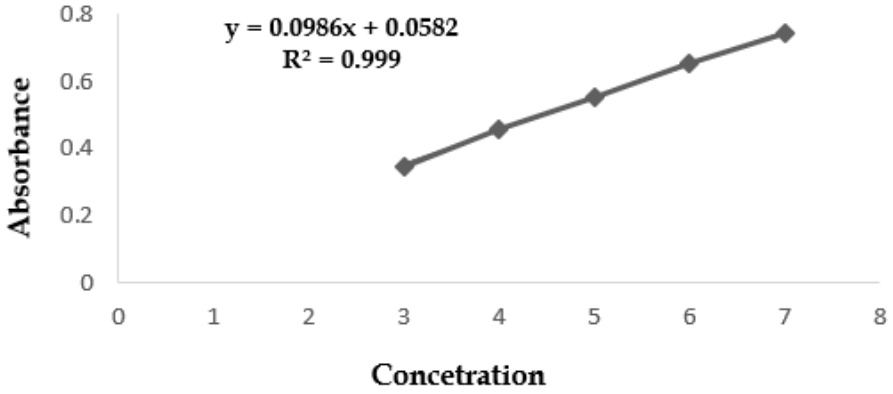

Figure 4. Calibration Curve of Formaldehyde

3.4.2. LOD and LOQ

The Limit of Detection (LOD) signifies the smallest amount of analyte that can be distinctly identified from instrumental noise or a blank sample, whereas the Limit of Quantitation (LOQ) corresponds to the lowest concentration measurable with consistent accuracy and precision. LOQ also reflects the sensitivity level of the analytical method used. LOD and LOQ are determined through a calibration curve created using a standard formaldehyde solution with a linear regression equation, y = bx + a. The LOD value for formaldehyde obtained from the calculations in this study is 0.314 ppm.

3.4.3. Accuracy

Accuracy was evaluated using a standard addition (spiking) approach at three concentration levels, each analyzed in triplicate. The percentage recovery values ranged from 92.364% to 99.331%. The mean recovery values obtained at the evaluated concentration levels were 95.733 ± 0.266%, 93.813 ± 1.255%, and 98.337 ± 1.242%, respectively. These results indicate good agreement between the measured and added analyte concentrations across the studied range.The obtained recovery values comply with commonly accepted accuracy criteria described in method validation guidelines, including those established by SNI and AOAC 2016. Acceptable recovery ranges are generally reported to be within 80–115%, depending on analyte concentration. The relatively narrow variation in recovery values observed in this study suggests that the analytical method provides reliable quantification with satisfactory trueness and precision. Overall, the %recovery results demonstrate that the analytical method exhibits acceptable accuracy within the evaluated concentration range [20,21]. The %recovery values in this study can be seen in Table 2.

Table 2. Accuracy Test Result

Concentration	Rep	True Concentration (ppm)	%Recovery	Average %Recovery	Range
2.2	1	2.110	95.887		
2.2	2	2.099	95.426	95.805	
2.2	3	2.099	95.426		
2.8	1	2.647	94.537		92.364-99.331
2.8	2	2.586	92.364	93.813	
2.8	3	2.647	94.537		
3.4	1	3.296	96.945		
3.4	2	3.357	98.735	98.337	
3.4	3	3.377	99.331		

3.4.4. Precision

The measurements performed on the same sample provide consistent or repeatable values over time. Precision is determined by the relative standard deviation (RSD) value. The %RSD values obtained in this study ranged from 0.2784% to 1.3374%. The precision test results indicate that the %RSD values obtained meet the acceptance criteria set by SNI and AOAC standards. According to SNI standards, the %RSD should be < 5.3%. Furthermore, according to AOAC, for a concentration of 1 ppm, a good %RSD value is < 11%. Therefore, it can be concluded that this precision test shows precise measurements that are close to the true value. The %RSD values in this study can be seen in Table 3.

Table 3. Precision Test Result

Concentration	Rep	True Concentration (ppm)	Average (ppm)	SD	%RSD
2.2	1	2.110			
2.2	2	2.099	2.103	0.0058	0.2784
2.2	3	2.099			
2.8	1	2.647			
2.8	2	2.586	2.627	0.0351	1.3374
2.8	3	2.647			
3.4	1	3.296			
3.4	2	3.357	3.343	0.0422	1.2628
3.4	3	3.377			

3.5. Quantitative Sample Test

Imported apple samples that were identified as positive for formaldehyde in the qualitative screening using Schiff reagent were subsequently subjected to quantitative determination by UV-Vis spectrophotometry. The samples were grouped based on treatment, namely unpeeled and peeled apples collected from six districts in Pontianak City. The quantitative results showed that formaldehyde concentrations in unpeeled apple samples ranged from 5.231 ± 0.145 to 22.65 ± 0.717 mg/kg. The highest concentration was detected in samples obtained from South Pontianak, while the lowest level among unpeeled samples was observed in Southeast Pontianak. In comparison, peeled apple samples exhibited generally lower formaldehyde concentrations, ranging from 2.549 ± 0.060 to 6.748 ± 0.245 mg/kg. This trend indicates that the removal of the apple peel may contribute to a reduction in formaldehyde levels across different sampling locations. The estimated formaldehyde intake per serving, calculated based on an assumed average apple weight of 300 g, ranged from 1.569 to 6.795 mg for unpeeled samples and from 0.764 to 2.024 mg for peeled samples. These findings suggest that consumption of unpeeled apples may result in higher potential exposure to formaldehyde compared to peeled apples. To evaluate the statistical significance of the observed differences between treatments, an independent samples t-test was performed. The analysis revealed a statistically significant difference in formaldehyde concentrations between unpeeled and peeled apple samples ($p < 0.05$), indicating that the peeling

process significantly influenced the measured formaldehyde levels. Although peeling reduced formaldehyde concentrations, detectable levels were still present in several samples, highlighting potential implications for food safety and consumer exposure. The results of formaldehyde content determination in imported apple samples can be seen in Table 4.

Table 4. Formaldehyde Levels in Imported Apple Samples

Samples	Treatment	Average (mg/kg)±SD	Mg/Serving (Assumed 300 g)
East Pontianak	Not Peeled	11.53 ± 1.474^{a}	3.459
	Peeled	5.402 ± 0.755^{b}	1.620
Central Pontianak	Not Peeled	10.73 ± 0.118^{a}	3.219
	Peeled	3.357 ± 0.158^{b}	1.007
North Pontianak	Not Peeled	7.284 ± 0.085^{a}	2.185
	Peeled	2.549 ± 0.060^{b}	0.764
West Pontianak	Not Peeled	9.605 ± 0.019^{a}	2.881
	Peeled	2.672 ± 0.035^{b}	0.801
South Pontianak	Not Peeled	22.65 ± 0.717^{a}	6.795
	Peeled	6.748 ± 0.245^{b}	2.024
Southeast Pontianak	Not Peeled	5.231 ± 0.145^{a}	1.569
	Peeled	2.830 ± 0.076^{b}	0.849

Information : (^{a} , ^{b}) within the same sample location indicate a significant difference between treatments (Independent Sample T-Test, $p < 0.05$).

4. CONCLUSION

Qualitative test results in this study indicated that six out of eight imported apple samples sold in Pontianak were positively identified as containing formaldehyde, as evidenced by a color change to red or purple in the qualitative color test. The formaldehyde content in these apples was determined using UV-Vis spectrophotometry. In unpeeled samples, formaldehyde concentrations ranged from 2.377 ppm (5.231 mg/kg and 1.569 mg/serving) to 6.796 ppm (22.65 mg/kg and 6.795 mg/serving). Meanwhile, in peeled samples, the concentrations ranged from 1.528 ppm (2.549 mg/kg and 0.764 mg/serving) to 3.067 ppm (6.748 mg/kg and 2.024 mg/serving). The Independent Sample T-Test statistical analysis showed a significant difference ($p < 0.05$) between peeled and unpeeled apples, confirming that the peeling process significantly reduces formaldehyde content in imported apples.

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Conflict of Interest: The authors declare no conflict of interest

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