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The Effect of Heating Temperatures on the Formation of Vanillin from Curcumin

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ABSTRACT

Background: Food additives are components added to food to change or affect the shape, characteristics, or properties of food products. Vanillin is one of the flavors widely used in food, perfume, and cosmetic industries. Natural vanillin is obtained from *Vanilla planifolia* through vanilla bean extraction, but this production is limited so that alternative methods, such as chemical synthesis and biotechnological technique, are increasingly used. Curcumin from the rhizomes of turmeric plant (*Curcuma longa*) can be degraded into vanillin through a degradation process.
Aims & Methods: This study aims to explore the degradation process of curcumin into vanillin using ethanol solvents at temperatures of 50, 60, and 70°C. The parameters analyzed were color changes using colorimetry, curcumin content using spectrophotometry, and vanillin content using HPLC.
Results: The results show that increasing the treatment temperature caused a significant decrease in curcumin content and an increase in vanillin content. The heating temperature of curcumin affected the curcumin content, although it did not affect the color intensity and vanillin content formed. Vanillin was not formed by heating curcumin at the temperatures of 50, 60, and 70ºC. A temperature of 60°C resulted in the formation of significant vanillin content.

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1. Introduction

Food additives are components that are introduced into food with the aim to change or affect the shape, characteristics, or properties of the food product. In the food industry, there are various types of food additive used, such as flavors. They are food additive in the form of concentrated materials, with or without flavoring adjunct, and are generally added to food produce a certain taste or aroma. Flavors are not intended to produce a salty, sweet, or sour taste to food products (Indonesian Food and Drug

Authority, 2020). Flavors have a concentrated form, only need to be added in small amounts, and are not intended to be consumed directly. One type of flavors that is widely circulated is vanillin, both in liquid or powder form. It is often used as a food additive to strengthen the aroma and taste of various food products, such as bread, candy, ice cream, and others.

Vanillin is a compound used as a flavor and can be naturally obtained from a plant known as *Vanilla planifolia*. This compound belongs to the aromatic aldehyde group, with the chemical name 3-methoxy-4-hydroxybenzaldehyde, beside also belongs to the phenolic compound group. Physicochemically, vanillin is usually a solid with a white color, soluble in water, and has a distinctive vanilla taste and aroma (Banerjee & Chattopadhyay, 2019). Vanillin is considered one of the most important flavors globally. It is used in a variety of applications, including as an additive in foods and beverages, such as ice cream, cakes, complementary foods, and soft drinks. In addition, vanillin also serves as a masking agent in various pharmaceutical formulations and is used in other industries as well, such as perfumes and cosmetics (Banerjee & Chattopadhyay, 2019; Fathia *et al.,* 2022; García-Bofill *et al.,* 2021; Hofmann al., 2023).

Conventionally, vanilla beans are extracted using various methods, such as solvent extraction to obtain vanilla's natural components, such as vanillin (Jadhav *et al.,* 2009). However, due to its high production cost and limited production quantity, natural vanillin is unable to meet the huge market demand. Therefore, many attempts were made to produce vanillin through several alternative methods, such as chemical synthesis and biotechnological technique, and alternative material sources (Paul *et al.,* 2021; Banerjee & Chattopadhyay, 2019). The biotechnological production of vanillin can be plant-based as well as enzyme-based by utilizing microorganisms (Chee *et al.,* 2017; Esparan *et al.,* 2015; Nagpure & Gupta, 2011). Vanillin bioproduction has also been conducted using several base materials, namely ferulic acid, lignin, eugenol, glucose, and curcumin (García-Bofill *et al.,* 2021).

Curcumin is found in the rhizome powder of turmeric plant (*Curcuma longa*) at a concentration of up to 3%. Turmeric rhizomes contain three main types of curcuminoids, namely curcumin (curcumin I), demethoxycurcumin (curcumin II), and bisdemethoxycurcumin (curcumin III). Turmeric plant, which is the main source of curcumin, is easily obtainable, especially in Indonesia. Curcumin has a molecular structure consisting of two phenolic rings at both ends, connected by two α,β unsaturated carbonyl groups. When the benzylic position on this molecule is cut off, two vanillin molecules are resulted from one curcumin molecule. This process is known as curcumin degradation. Curcumin is sensitive to alkaline conditions, light, the presence of metal ions, enzymes, and temperature. This sensitivity can be utilized to degrade curcumin into other compounds, such as vanillin. A previous study has proved that curcumin can be degraded into vanillin, vanillic acid, and ferulic acid using visible light irradiation at a wavelength of 455 nm (Hofmann *et al.,* 2023). The sensitivity of curcumin to temperature was also utilized to degrade curcumin using methanol solvent and boiling based on methanol's boiling point (Siddiqui, 2015).

Siddiqui (2015) has developed a curcumin degradation technique by treating it at the temperatures of 50, 60, and 70ºC and methanol's boiling point (64ºC). It can be degraded into vanillin by harnessing the role of temperature. His study used methanol and corn oil as solvents. The results showed that a loss of curcumin due to degradation was 47%, followed by the formation of vanillin by 17% and ferulic acid by 9% when the methanol was boiled at its boiling point. Meanwhile, the oil sample showed a loss of curcumin of 38.9%, but was not followed by the formation of ferulic acid and vanillin. His study showed that vanillin begins to form at an approximate temperature of 50ºC and the amount continues to increase until a temperature of 70ºC. Based on his study, the use of methanol solvents can be further developed, but methanol (as a solvent) is considered unfavorable due to its properties that are very toxic to humans so that it cannot be used in the food industry. As a solution, the safer types of alcohol solvents, such as ethanol, are recommended. Apart from exhibiting non-toxic properties, ethanol's boiling point is also higher compared to that of methanol. In this study, curcumin degradation process is conducted using ethanol solvent at three temperatures, namely 50, 60, and 70ºC.

2. Methods

2.1 Place and time

This study was conducted from June to July 2024 at the Laboratory of Biochemical Chemistry of Agricultural Products and Food Nutrition, Laboratory of Technology and Process Engineering of Agricultural Products, and Instrumentation Laboratory of the Faculty of Agricultural Technology, Andalas University.

2.2 Materials and tools

The materials used in this study were curcumin (84% purity, Merck) and vanillin (100% purity, Merck) as high-performance liquid chromatography (HPLC) standards. Other materials used were absolute ethanol as solvent and 100% ethanol for HPLC sample dilution. Acetonitrile (HPLC grade) and acetic acid (CH_3COOH) 98% (HPLC grade) were used as HPLC mobile phase solvent. The tools used were glassware (pyrex), spatula, aluminum foil, ultrasonic bath (Elma), micropipette, heating mantle (Joanlab), colorimeter (ColorFlex EZ), spectrophotometer (Shimadzu), and HPLC instrument (Shimadzu).

2.3 Experimental design

This study was conducted using the experimental method by looking at the differences in color, curcumin content, and vanillin content from each treatment. The treatment given was the heating temperature using ethanol solvent to degrade the curcumin compound. Based on a study by Siddiqui (2015), the treatment was conducted as follows:

Treatment A = heating at a temperature of 50°C

Treatment B = heating at a temperature of 60°C

Treatment C = heating at a temperature of 70°C

2.4 Research implementation

2.4.1 Degradation reaction process of curcumin through heating (modified from Siddiqui (2015))

Curcumin degradation reaction process through heating comprised several steps. First, 100 mL of solvent (absolute ethanol) was heated to a certain temperature until it was stable. The solvent was then heated at several temperatures, namely 50, 60, 70, and 80°C. Next, 10 mg of curcumin was dissolved in the heated solvent to obtain a concentration of 100 ppm. All samples were heated on a heating device with controlled temperature. The mixture was then refluxed for 30 minutes. After that, the mixture was put into a dark bottle for color analysis and the determination of curcumin and vanillin contents.

2.5 Analysis

2.5.1 Colorimetric analysis (modified from Anisuzzaman et al. (2014))

The color change test used a HunterLab digital colorimeter using the CIE-L*a*b* method so that the values of L*, a*, and b* were obtained and the color change was expressed in ΔE. Data were entered and analyzed using Microsoft Excel. The CIE L*a*b* value was used to calculate the color change value (ΔE) using the following equation:

$$\Delta E = [(\Delta L^*)^{(2)} + (\Delta a^*)^2 + (\Delta b^*)^{(2)}]^{½}$$

Description:
E = Total color changes
L* = Brightness, ranging from 0 (black) to 100 (white)
a* = Color chromatic, ranging from +100 (red) to -80 (green)
b* = Color intensity, ranging from +70 (yellow) to -70 (blue)

2.5. 2. Analysis of curcumin content determination using spectrophotometry (modified from Daulay et al. (2019))

2.5.2.1 Preparation of curcumin standard stock solution

First, 20 mg of standard curcumin was carefully weighed and put into a 100 ml volumetric flask. The flask was then shaken after ethanol was added into it so that the curcumin dissolved. Lastly, the solution was diluted again with ethanol until it reached the mark line (C = 200 ppm)—this was the first standard stock solution (SSS). Next, 2.5 ml of first SSS was pipetted and put into a 50 ml volumetric flask, then diluted with ethanol until the solution reached the mark line (C = 10 ppm)—this was the second SSS.

2.5.2.2 Determination of maximum wavelength

1 ml of second SSS was pipetted and put into a 50 ml flask, then diluted with ethanol until the solution reached the mark line (C = 0.2 ppm). This solution was then measured at the wavelengths of 400–800 nm.

2.5.2.3 Determination of calibration curve linearity

The concentrations of the solution were 1, 2, 3, 4, and 5 ppm. The absorption of each solution was then measured at the maximum wavelength. Next, the data were plotted, with concentration on x axis and peak area on y axis, then the regression equation was calculated. The equation of a linear regression line is generally formulated in the form y = mx + by, where y is the peak area, x is the concentration, m is the line slope, and b is the intercept (intersection point with the y axis).

2.5.2.4 Determination of curcumin content

1 ml of degraded extract (100 ppm) was pipetted, put into a 100 ml volumetric flask, then diluted with ethanol until the solution reached the line mark (C = 1 ppm). The absorbance of the solution was then measured and calculated using a linear regression equation.

2.5.3 HPLC analysis of vanillin content (modified from Hofmann et al. (2023))

HPLC was used in both qualitative and quantitative analysis. Qualitative analysis was performed by looking at the differentiation of HPLC profiles seen from the peaks that appeared at each retention duration. Quantitative analysis was performed by making a calibration curve to see the amount of vanillin formed. Vanillin content was determined using an HPLC system with a C18 column, where 5 µL of vanillin sample was injected and eluted at a flow rate of 0.2 mL/min at 40°C.

2.5.3.1 Determination of calibration curve linearity

Calibration of each compound was evaluated using solvent A at a wavelength of 308 nm for vanillin. The concentrations of the solution were 0.6, 0.7, 0.8, 0.9, and 1 ppm. The absorption of each solution was then measured at the maximum wavelength. Next, the data were plotted, with concentration on x axis and peak area on y axis, then the regression equation was calculated. The equation of a linear regression line is generally formulated in the form y = mx + by, where y is the peak area, x is the concentration, m is the line slope, and b is the intercept (intersection point with the y axis).

2.5.3.2 Preparation of mobile phase

For sample analysis using HPLC, the mobile phase was determined in advance. The solvent consisted of 0.3% vol. of acetic acid in water (solvent A) and acetonitrile (solvent B).

Table 1. Gradients applied to the mobile phase during HPLC measurements.

Duration (Min.)	Solvent A (% Vol.)	Solvent B (% Vol.)
0	5	95
5	15	85
10	25	75
15	15	85
20	5	95

2.5.3.3 Determination of vanilin content

1 ml of degraded extract (100 ppm) was pipetted and put into a 2 mL vial. The absorbance of the extract was then measured and calculated using a linear regression equation.

3. Results and Discussion

3.1 Colorimetric analysis

Colorimetric analysis using the CIE L*a*b* color space is a quantitative method to measure and describe the colors of a sample. The analysis is performed using color parameters in the CIE L*a*b* color space, namely L* (lightness), a* (green-red axis), and b* (blue-yellow axis). The CIE L*a*b* color space represents the brightness and the hue of curcumin degradation reaction results. L* values range from 0 (black) to 100 (white). It indicates how light or dark the color is. Positive a* values indicate that the colors shift more towards red, while negative values indicate that the colors shift more towards green. Positive b* values indicate that the colors shift more towards yellow, while negative values indicate that the colors shift more towards blue. To understand the color change, the values of ΔL*, Δa*, Δb*, and ΔE (total color changes) were also calculated. Table 2 presents the observation and calculation results of the color changes of degraded curcumin.

Table 2. Color changes of curcumin degradation reaction results compared to that of control (without heating).

Treatment Temperature	Value				
	L*	a*	b*	ΔE	°h
Control	7.15 ± 0.05	1.47 ± 0.09	3.15 ± 0.06	-	64.01
50°C	9.94 ± 0.50	1.19 ± 0.01	2.08 ± 0.13	2.99	59.71
60°C	9.79 ± 1.20	1.37 ± 0.08	2.32 ± 0.25	2.77	60.34
70°C	6.64 ± 0.19	1.86 ± 0.11	3.41 ± 0.21	0.70	61.82

Description:

E = Total color changes

L* = Brightness, ranging from 0 (black) to 100 (white)

a* = Color chromatic, ranging from +100 (red) to -80 (green)

b* = Color intensity, ranging from +70 (yellow) to -70 (blue)

°h = Degree of hue

The observation and calculation results of the color changes of the degraded curcumin shows that heating treatment affected the color brightness of curcumin. The color changes were measured using the CIE L*a*b* color space, where the L* value represents the brightness level. L* values range from 0 (black) to 100 (white), where the higher the L* value, the lighter the color. In control condition, where curcumin was not heated, the L* value was recorded at 7.15. This value indicates that curcumin exhibits a fairly dark color in its natural state without heating.

When curcumin was heated at 50°C, the L* value increased to 9.94 ± 0.50. This increase indicates that the color of curcumin becomes lighter due to heating at this temperature. At 60°C, the L* value of

curcumin decreased slightly to 9.79, but was still higher compared to that of control. Although there was a slight decrease compared to that of heating at 50°C, the color brightness of curcumin still increased compared to that of control.

However, when the heating temperature was further increased to 70°C, the L* value dropped to 6.64. This change in L* value suggests that heating temperature affected the color brightness of curcumin. At moderate temperatures, such as 50 and 60°C, curcumin tended to become brighter. However, at higher temperatures, such as 70°C, curcumin became darker. Heating caused curcumin in turmeric to darken due to chemical changes (Song *et al.,* 2018). The color of curcumin becomes darker due to its fluorescence properties. Curcumin emits low quantum yield fluorescence in the visible region, which causes variations in its light absorption and reflection properties (Sravani *et al.,* 2022).

The a* value in the CIE L*a*b* color space describes the chromatic color dimension that ranges from green to red. The range of a* values is from -80 (green) to +100 (red). In control condition, where curcumin was not heated, the a* value was recorded at 1.47 ± 0.09. This positive value indicates that curcumin has a slight red nuance in its natural state. This color reflects the natural characteristics of curcumin without the influence of heating. When curcumin was heated at 50°C, the a* value decreased to 1.19 ± 0.01. This decrease indicates that the color of curcumin shifted slightly towards a greener direction, although it remained on the red side of the color spectra.

Furthermore, at 60°C, the a* value of curcumin increased slightly to 1.37 ± 0.08. Although there was a slight increase compared to that of heating at 50°C, this value is still lower compared to that of control condition. This shows that at 60°C, curcumin still had shades of red, but its red intensity increased slightly again. When the heating temperature was further increased to 70°C, the a* value increased significantly to 1.86 ± 0.11. This increase indicates that at high temperatures, curcumin became redder. This small increase may occur due to the heating process that affected the chemical bonds in curcumin, thereby slightly changing its chromatic color. Curcumin can turn into other compounds, such as vanillin (Siddiqui, 2015). The vanillin formed can bind to diketone compounds to create a reddish color (Levine & Taterka, 2004). This diketone compound can be curcumin itself, which—as revealed in this study—was not completely degraded due to heating treatment.

The b* value in the CIE L*a*b* color space describes the color dimension that ranges from blue to yellow. The range of b* values is from -70 (blue) to +70 (yellow). In control condition, where curcumin was not heated, the b* value was recorded at 3.15 ± 0.06. This positive value indicates that curcumin has a fairly high yellow color intensity in its natural state. This yellow color is a natural characteristic of curcumin without the influence of heating (Akbik *et al.,* 2014).

At 50°C, the b* value of the sample was 2.08 ± 0.13. Furthermore, at 60°C, the b* value of curcumin slightly increased to 2.32 ± 0.25 compared to that of heating at 50°C. Although this value is still lower compared to that of control, this increase indicates that at this temperature, the intensity of the yellow color slightly increased again. When the heating temperature was further increased to 70°C, the b* value increased significantly to 3.41 ± 0.21. This indicates that an increase in temperature also increased the dominance of curcumin's yellow color intensity (Song *et al.,* 2018).

The ^{o}h or hue value in the CIE L*a*b* color space describes the nuances of a color that results from the combination of the a* and b* parameters. The hue value is expressed in degree, which indicates the color position on the color wheel. Analysis of the hue value provides an understanding of the changes in the color nuances of curcumin that had undergone heating-induced degradation. The results show that the ^{o}h value changed at the control temperature as well as after heating at 50, 60, and 70°C. The color type grouping results of the degraded curcumin are presented in Table 3.

Table 3. Color types of degraded curcumin sample.

Temperature Treatment	°h	Color Type
50°C	59.71°	Reddish yellow
60°C	60.34°	Yellow
70°C	61.82°	Yellow

Description:
Red = 0–60 degrees
Yellow = 61–120 degrees
Green = 121–180 degrees
Cyan = 181–240 degrees
Blue = 241–300 degrees
Magenta = 301–360 degrees

In control condition, where curcumin was not heated, the °h value was recorded at 64.01 degrees. This value indicates that the color of curcumin in its natural state is between yellow and red on the color wheel. When curcumin was heated at 50°C, the °h value slightly decreased to 59.71 degrees. This value indicates that the color nuance of curcumin shifted slightly closer towards the red color compared to that of control. This shift may occur due to changes in curcumin's chemical structure that affected the way it reflected and absorbed the light (Boyanapalli & Kong, 2015).

Furthermore, heating at 60°C caused the °h value of curcumin to slightly increase to 60.34 degrees compared to that of heating at 50°C. This value indicates that the color nuance of curcumin shifted slightly back towards yellow, although it remained redder compared to that of control. This small change may occur due to the chemical structure modification that occurred at 60°C, which affected the overall color nuance of curcumin. When the heating temperature was further increased to 70°C, the °h value slightly increased to 61.82 degrees. This value indicates that at high temperatures, the color nuance of curcumin shifted more towards yellow, approaching that of control.

3.2 Analysis of curcumin content determination using spectrophotometry

Determination of curcumin content in this method began with reading the standard solution to obtain the maximum wavelength. Next, various concentrations were read using spectrophotometry to obtain the regression equation of the calibration curve used to calculate the curcumin content of the samples. The linear regression line equation is generally formulated in the form y = mx + by, where y is the absorbance value obtained from the sample absorption value. Figure 1 shows the maximum wavelength seen from the absorption of curcumin standard solution.

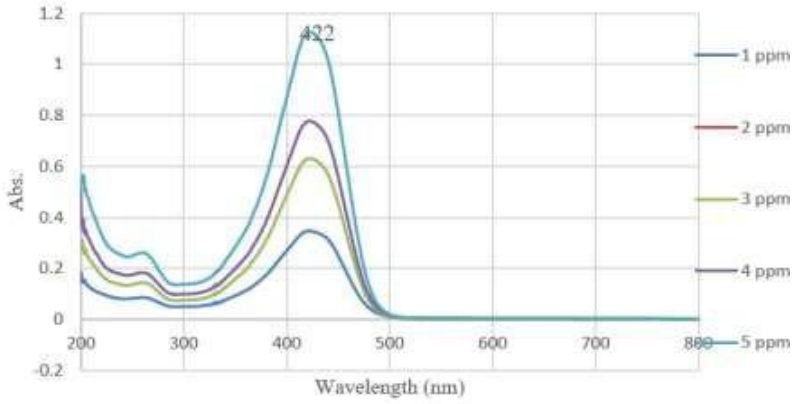


Figure 1. Absorption curve of curcumin standard solution (200–800 nm)

As seen in Figure 1, the absorption of curcumin standard solution at different concentrations was obtained. It is also obvious that the maximum wavelength of curcumin was obtained at a wavelength of 422 nm. This means all concentrations of curcumin standard solution produced the highest absorption at this wavelength. Figure 2 displays the calibration curve of curcumin standard solution.

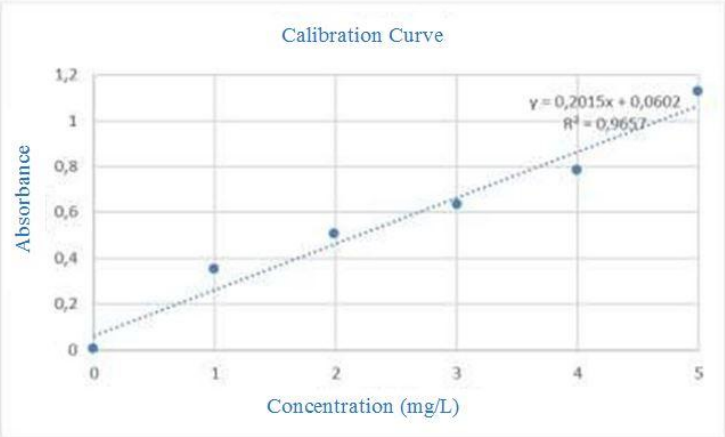


Figure 2. Calibration curve of curcumin standard solution

Dilution of curcumin standard solution was conducted at five concentrations, namely 1, 2, 3, 4, and 5 mg/L. These five concentrations produced a linear regression equation of y = 0.2015x + 0.0602, which then was used to calculate the curcumin content based on the levels of curcumin degradation reaction results. Table 4 presents the calculation results of curcumin degradation reaction levels measured using spectrophotometry.

Table 4. Curcumin content based on degradation reaction results compared to that of control.

Temperature Treatment	Absorbance	Curcumin Content (µg/mL)
Control	0.497	2.39 ± 0,37
	0.629	
	0.503	
50ºC	0.456	1.99 ± 0,03
	0.457	
	0.469	
60ºC	0.450	1.89 ± 0,06
	0.429	
	0.449	
70ºC	0.398	1.74 ± 0,06
	0.412	
	0.423	

Table 4 shows the curcumin content after undergoing degradation reactions due to heating at several temperatures (50, 60, and 70°C) compared to that of control. Curcumin content was measured using spectrophotometry, with the results summarized as follows: in control condition, the absorbance value was 0.497 with a curcumin content of 2.18 µg/mL. Treatment at 50°C produced absorbance values of 0.456 to 0.469 with an average curcumin content of 1.99 ± 0.03 µg/mL, indicating a 8.72% decrease in curcumin content compared to that of control. At 60°C, the absorbance ranged from 0.429 to 0.450 with an average curcumin content of 1.89 ± 0.06 µg/mL, indicating a 13.30% decrease in curcumin content compared to that of control. At 70°C, the absorbance decreased even more, ranging from 0.398 to 0.423

with an average curcumin content of 1.74 ± 0.06 µg/mL, indicating a 20.18% decrease in curcumin content compared to that of control.

These calculation results suggest that an increase in treatment temperature caused a noticeable decrease in curcumin content, meaning that curcumin underwent significant degradation due to heating. At 50°C, the absorbance value decreased slightly compared to that of control, indicating that several curcumin had been degraded. The curcumin content at this temperature decreased by 0.19 µg/mL or about 8.72% compared to that of control. This indicates that heating at 50°C caused less degradation of curcumin.

At 60°C, the absorbance value decreased further, indicating greater degradation. The curcumin content at this temperature decreased by 0.29 µg/mL or about 13.30% compared to that of control. This decrease indicates that heating at 60°C caused more significant degradation of curcumin compared to that of 50°C. This indicates that curcumin was less stable at higher temperatures, and its degradation increased with increasing temperature.

At 70°C, the absorbance value showed the most significant decrease compared to that of control. Curcumin content at this temperature decreased by 0.44 µg/mL or about 20.18% compared to that of control. This decrease shows that heating at 70°C caused a very significant degradation of curcumin, which means curcumin was very unstable at high temperatures, since its degradation at 70ºC reached the highest level in this study. Degradation of curcumin due to heating occurs due to the disconnection of the dicarbonyl bond of the curcumin compound, enabling the transformation of curcumin into other compounds, such as ferulic acid and vanillin (Siddiqui, 2015). This causes the detected curcumin content to decrease.

3.3 HPLC analysis of vanillin content

Determination of vanillin content in this method is similar to the steps of sample content determination using the spectrophotometric method, which begins with determining the maximum wavelength and establishing a linear regression equation using a standard solution of the compound being analyzed, namely vanillin. The maximum wavelength was determined by observing which of the given wavelengths produced the highest absorbance value. Table 5 shows the absorbance values of vanillin at several wavelengths.

Table 5. Absorbance value of vanillin standard.

Wavelength (nm)	Absorbance (mAU)
230	702.07
280	518.15
310	478.11
306	435.35

Based on Table 5, the highest absorbance value of the vanillin standard was produced at a wavelength of 230 nm. Furthermore, the wavelength of 230 nm was used to read the vanillin chromatogram data. Figure 3 presents the chromatogram of standard vanillin.

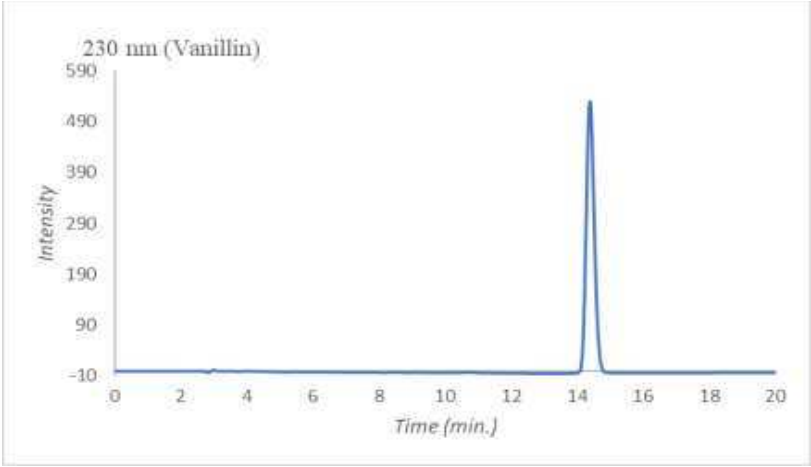
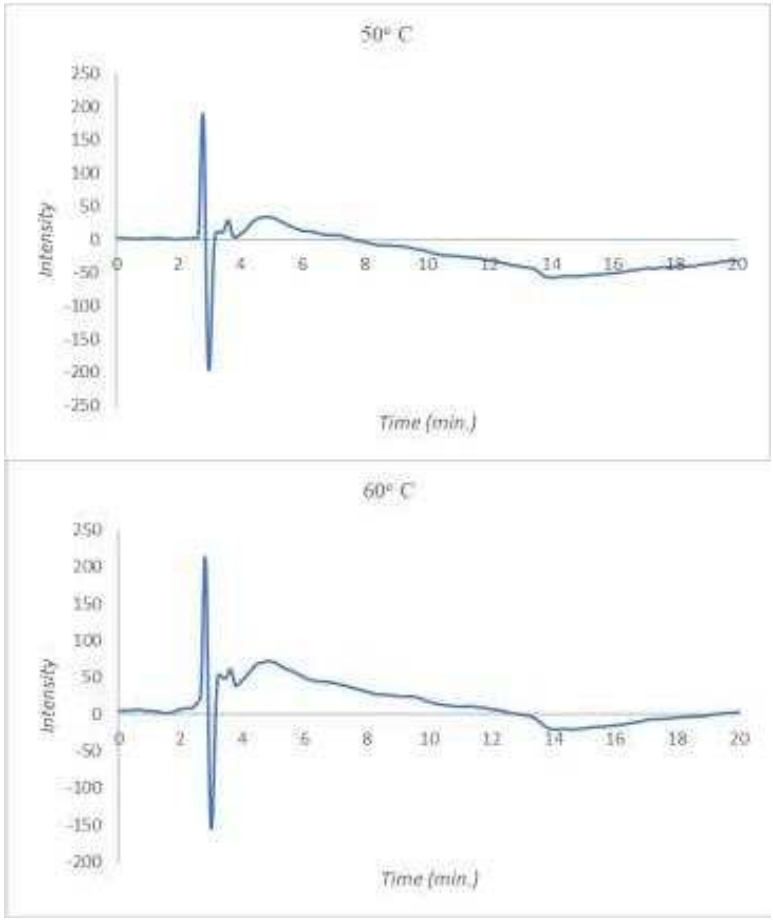


Figure 3. Chromatogram of standard vanillin at a wavelength of 230 nm

Figure 3 shows the chromatogram of standard vanillin at a wavelength of 230 nm. It is obvious from the figure that the standard vanillin shows an absorption peak at a retention duration of 14 minutes. This retention duration was then used as a reference for sample identification to see the appearance of vanillin compound. Figure 4 presents the chromatogram of the curcumin sample after underwent heating treatment at 50, 60, and 70ºC.



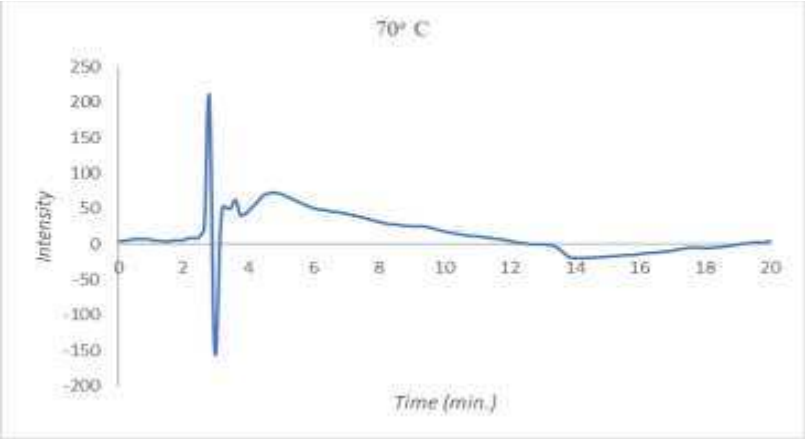


Figure 4. Chromatogram of curcumin sample

Figure 4 shows the chromatogram of curcumin sample after heating treatment at the temperatures of 50, 60, and 70°C. It can be seen from the figure that all treatments did not succeed in producing the appearance of the expected compound, namely the vanillin compound in accordance with the retention duration of the previous standard chromatogram. This indicates that vanillin compound was not formed from the degradation process of curcumin using heating treatment.

The heating treatment was actually successful in degrading curcumin, indicated by the decrease of curcumin content as the temperature increased. However, it is suspected that the degradation of curcumin due to heating was not able to continue to form vanillin compound. According to Esatbeyoglu *et al.* (2015), the heating process can gradually convert curcumin into vanillin compound: in the first stage, curcumin will turn into ferulic acid; in the second stage, ferulic acid will turn into 4-vinyl guaicol; and in the last stage, 4-vinyl guaicol will turn into vanillin. It is suspected that in the heating process that has been conducted, the curcumin compound did not succeed in entering the advanced stage of conversion into vanillin. This can be caused by the heating duration that was still not optimal to convert curcumin into vanillin. Therefore, further optimization is needed to obtain the optimal heating duration to form vanillin compound.

4. Conclusion and Suggestion

4.1 Conclusion

Based on this study's results on the effect of heating temperature on the formation of vanillin from curcumin, the following conclusions are drawn:

1. Increasing the treatment temperature caused a significant decrease in curcumin content and an increase in vanillin content.
2. The heating temperature of curcumin affected the curcumin content, although it did not affect the color intensity and vanillin content formed.
3. Vanillin compound was not formed by heating curcumin at the temperatures of 50, 60, and 70°C.
4. A temperature of 60°C resulted in the formation of significant vanillin content.

4.2 Suggestion

Based on this study's results and limitations, future studies are encouraged to determine the optimal heating duration for vanillin formation, calculate the yields, and use real turmeric as base material for vanillin formation.

5. Acknowledgement

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