



Detection of Chili Powder Adulteration with Rhodamine B in Traditional Markets of Singosari District Using Fourier Transform Infrared (FT-IR) Spectroscopy and Chemometrics

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ABSTRACT

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ABSTRACT

Introduction: Chili powder (*Capsicum annum* L.) is a spice that has many benefits as a cooking ingredient, a natural red dye, and a traditional medicinal ingredient. The high demand for chili, the short shelf life, and the fluctuations in chili prices have led to the adulteration of chili powder with economic motives, namely with Rhodamin B. Based on RI regulation No. 239/Men.Kes/Per/85, that Rhodamin B is a dangerous color substance and is prohibited for use in drugs, food, and cosmetics.

Objectives: This study aims to determine whether there are adulterated chili powder products in the Traditional Market of Singosari District, Malang Regency.

Methods: This study used Fourier Transform Infrared (FT-IR) Spectroscopy and Chemometrics in data processing and used KLT Densitometric to determine capsaicin levels in chili powder. Data processing was performed using multivariate calibration namely PLS (Partial last Square) and OPLS-DA (Orthogonal Partial Least Squares Discriminant Analysis). The samples used in this study were 10 market samples, control chili powder samples, and mixed samples of chili powder with Rhodamin B synthetic dye with a concentration of 0-50% (b/b).

Results: From the results of the study, it was found that the capsaicin content in chili powder was 624.77 µg/g, then the results of OPLS-DA processing of market samples 1 to 7 were estimated to be adulterated chili powder and samples 8 to 10 were estimated to be pure chili powder. Furthermore, market samples 1 to 7 were tested using PLS. From the PLS results, the best calibration model was obtained at wavenumbers 1800-1180 cm⁻¹ where the calibration R² value was 0.9989; RMSEC value was 0.789; R² validation of 0.9968; RMSEP of 1.93. PLS results show that in samples 1 to 4 and sample 6 it is estimated that there is a Rhodamine B as an adulterant while in samples 5 and 7 no Rhodamine B was detected in the chili powder, possibly the material added is not from synthetic dyes.

Conclusion: So it is concluded that there are pure and adulterated chili powders in the Singosari Traditional Market and the FTIR and chemometrics were successful detect the pure and adulterated chili powders.

Keyword: Chili Powder, Rhodamine B, Chemometrics, FT-IR

INTRODUCTION

Red chili (*Capsicum annum* L.) is one type of chili in Indonesia and is an important spice with a high level of consumption, as seen from data from the Central Statistics Agency (BPS) which recorded consumption reaching 636.56 thousand tonnes in 2022 (1). However, red chilies have a short shelf life so many are processed into chili powder (2). Chili powder is useful as a spicy enhancer, flavoring ingredient, natural dye, traditional medicine, and industrial raw material for livestock (3). In addition, chili powder also has health benefits due to its capsaicin content, which is antioxidant, antimicrobial, anticancer, and analgesic (4). Capsaicin has neurological effects,

a significant reduction in total, myocardial, and aortic cholesterol serum levels, and pain relief (3). The many benefits of chili powder and its high consumption have led to the adulteration of chili powder for economic motives.

Food adulteration is adding illegal substances either intentionally or unintentionally to food as an imitation of the adulterated product so that it does not comply with established official standards (5). In this case, many adulteration cases occur, namely the adulteration of chili powder with rhodamine B. Rhodamine B is a synthetic color that is declared as a hazardous substance and prohibited from being used as a mixture of drugs, food, and cosmetics according to the Indonesian Minister of Health Regulation No. 239/Men.Kes/Per/85(6). Rhodamine B has carcinogenicity, reproductive and developmental toxicity, neurotoxicity, and chronic toxicity in

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humans and animals (7). However, due to its intensive color, it is easily available, and when used as a mixture of chili powder rhodamine B does not provide a significant color difference and does not mask the distinctive aroma of chili. The detection of chili powder adulteration is very challenging due to the similarity of the colour of chili and Rhodamin B, so an analytical tool is needed to detect this. Therefore, the combination of analytical tools FTIR and chemometrics could be an attractive choice because this method was efficient, easy-to-use, fast, and cheap analysis (8,9,10,11). In addition, Fourier transform infrared (FTIR) spectroscopy combined with Partial Least Squares (PLS) chemometrics and Orthogonal Partial Least Square Discriminant Analysis (OPLS-DA) are most often used for the detection of adulteration products. The OPLS-DA was used for classifying samples (8,9,12,13) while Partial Least Squares (PLS) was used to measure the level of adulterants (8,14).

MATERIALS AND METHODS

This type of research is Descriptive Observational to detect whether chili powder sold in Singosari Market, Singosari District, Malang Regency, East Java Province contains Rhodamin B as an adulterant using Fourier Transform InfraRed (FT-IR) spectroscopy and chemometrics methods.

Sampling

The population in this study was all chili powder Illegal chili powder product and sold in the Singosari traditional market, Singosari District, Malang Regency, East Java Province. Considerations for the selection of the study population were based on data from the Central Statistics Agency (BPS) on the types of traditional markets managed by local governments, after selection, a market survey was conducted with traders selling chilli powder without BPOM registration and finally one traditional market was found, namely Singosari Market. The samples of this study were 10 samples of illegal Chili Powder product not registered by BPOM from the traditional market of Singosari District, Malang Regency, East Java. The sampling technique of the research object for laboratory tests uses the Saturated Sampling technique where sampling is based on when all members of the population are used as samples (15,16). The criteria for sampling and selection of samples were divided into inclusion criteria, namely chili powder that was not registered with BPOM and claims of chili powder statements from traders, while the exclusion criteria were chilli powder that had BPOM registration numbers and was obtained other than from Singosari Traditional Market.

Materials

The materials used in adulteration detection are red chili powder obtained from the traditional market of Singosari District, Malang Regency, East Java Province, then determined and powdered at the Materia Medika Batu; 10 samples of market chili powder obtained at the traditional market of Singosari

District, Rhodamin B (Technical Grade) (Duta Jaya Chemical Store), Acetone (EMSURE®).

Sample Preparation

Pure Chili Powder : Pure chili powder was made from chili fruit that has been determined and powdered at UPT Materia Medika Batu,

Mixed Sample : The mixed sample was a mixture of Rhodamine B and pure chili powder with a concentration range of 0-50% (w/w). The mixture samples was homogenized using vortex.

FTIR analysis

The FTIR instrument used was Qatar-S Single Bounce Diamond ATR with attenuated total reflectance (ATR) sample handling (Shimadzu, Japan), the sample area was cleaned using acetone, the basic spectrum (background) was scanned before taking measurements on the sample, the sample to be scanned was prepared, the sample was placed on the ATR crystal, the sample was measured in 32 scans and at a separation power (resolution) of 16 cm⁻¹, the scan was carried out at a wavelength of 4000-400 cm⁻¹ and replaced the sample 3 times with a replication of scanning 3 times (18,19). After being scanned, the ATR was cleaned using acetone, then dried with a tissue paper.

Data Processing

Data were processed using SIMCA UMETRICS for OPLS-DA, and then data were processed using TQ Analyst for PLS. data were entered into the software (numerical and nominal data), optimization was carried out, and score plots were obtained which illustrated the OPLS-DA clustering, and R square in PLS.

TLC Densitometry

Weighed 100 mg of sample (pure chili powder), put into a 2 mL microtube. Added 1 mL of ethanol. Vortexed for 30 seconds, sonicated for 60 minutes. Maceration for 24 hours at room temperature. Sample was vortexed and centrifuged. 10 µl of supernatant was dispensed on a silica gel 60 F254 plate, with capsaicin standards included. Inserted into a chamber containing saturated mobile phase toluene-chloroform-acetone (45:25:30). Expanded to the limit, remove and dry. Densitized at a wavelength of 228 nm. Rf. 0.60. Calculated capsaicin content.

RESULTS AND DISCUSSION

3.1 Determination

Determination of chili was carried out before the chili powder-making stage to obtain and type of chili used in the study. Determination of chili fruit was carried out at UPT Laboratorium Herbal Materia Medica, Batu. The determination of the big red chili plant is as follows:

Kingdom	: Plantae	Family	: Solanaceae
Division	: Spermatophyta	Genus	: Capsicum
Sub division	: Angiosperms	Type	: <i>Capsicum annum L.</i>
Class	: Dycotyledonae	Regional Names	: Chili, big chili.
Nation	: Solanales		

(17)

3.2 TLC Densitometry

Table 1. TLC Densitometry Chili Powder

Sample	Sample Spotting Volume	Final add of sample	Number of spottings in sample	Area	Average	Capsaicin standard in dried sample (CODEX, 2011) (µg/g)
	(µl)	(mL)	(µg)		µg/g	
Chili Powder	10,0	1,0	1045,00	3382,03	624,77	134 – 1.333
	10,0	1.0	1042,00	3350,64		

In this Densitometric KLT, the stationary phase used or the plate used is silica gel 60 F254, then the mobile phase used is toluene: chloroform: acetone in a ratio of 45:25:30, then the Densito spot capsaicin is measured at a wavelength of 228 nm. So the Rf value of 0.60 was obtained and the standard curve results were obtained with the equation $y = 3458x + 1111.9$ with a correlation coefficient (R^2) of 0.9867. By Table 1, two densitometric KLTs were carried out on the same sample and the results obtained

were 628.22 µg/g and 621.31 µg/g respectively with the average value of capsaicin compound levels in the control chili powder sample of 624.77 µg/g. Meanwhile, the capsaicin standard based on CODEX STAN 307-2011 is 134 – 1.333 µg/g. So the results of the determination of capsaicin levels in the control chili powder sample are by the standard capsaicin levels in the literature.

3.3 FTIR spectra analysis

Table 2. Typical FTIR band assignments of Chili Powder and Capsaicin

No	Chili Powder		Capsaicin		References
	Wavenumbers (cm^{-1})	vibration of functional group	Wavenumbers (cm^{-1})	vibration of functional group	
1	3316,98	O-H stretching vibration	3400-2400	-OH	(18)
2	2911,86	C-H stretching vibration	3000–2850	C-H	(18)
3	1725,96	C=O carbonyl vibration	1850-1650	C=O	(18)
4	1619,31	Overlap of C=C stretching vibrations on the benzene ring and N-H group bending vibrations	1680-1600	C=C	(18)
5			1640-1550	N-H	
6	1411,57	C-O-H Bending vibration	1440–1220	C-O-H	(18)
7	1031,99	C-O group stretching vibrations	1300-1000	C-O	(18)

In this study, the analysis of chili powder samples was carried out using Shimadzu Fourier Transform Infrared Spectroscopy, QATR-S SINGLE BOUNCE DIAMOND ATR at a wavelength of 4000-400 cm^{-1} with a resolution of 16 cm^{-1} and 32 times scanning. In Table 2, the reading of the FTIR spectra shows that the typical absorption in the chili powder sample is a capsaicin compound with the presence of -OH, -NH, -CH, C=C, C=C, and C-O-H groups.

Table 3. Typical FTIR band of Rhodamine B

No	Functional groups	Wave Numbers (cm^{-1})	Rhodamine B		References
			Wave Numbers (cm^{-1})	Description of functional group	
1	O-H	3400–2400	2556	Carboxylic acid O-H stretching vibrations overlap C-H vibrations	(18)
2	C-H				
3	N-H	Sekitar 1550	1559,58	Combination of N-H bending and C-N stretching vibrations in secondary amides	(18)
4	C-N				
5	C-O-H	1440–1220	1420,21	C-O-H bending vibrations	(18)
6	C-O	1320 –1210	1299,28	Carboxylic acid C-O stretching vibrations	(18)
7	C-Cl	730-550	627,57	C-Cl stretching vibrations	(18)

In this study, the analysis of synthetic dye samples using Shimadzu Fourier Transform Infrared Spectroscopy, QATR-S SINGLE BOUNCE DIAMOND ATR at wavelengths of 4000-400 cm^{-1} with a resolution of 16 cm^{-1} and 32 times scanning.

The reading of the spectrum in Table 3 shows that the typical absorption in the Rhodamin B sample is found in the C-O carboxylic acid group, N-H secondary amide, and C-N.

3.4 Sample Overlay

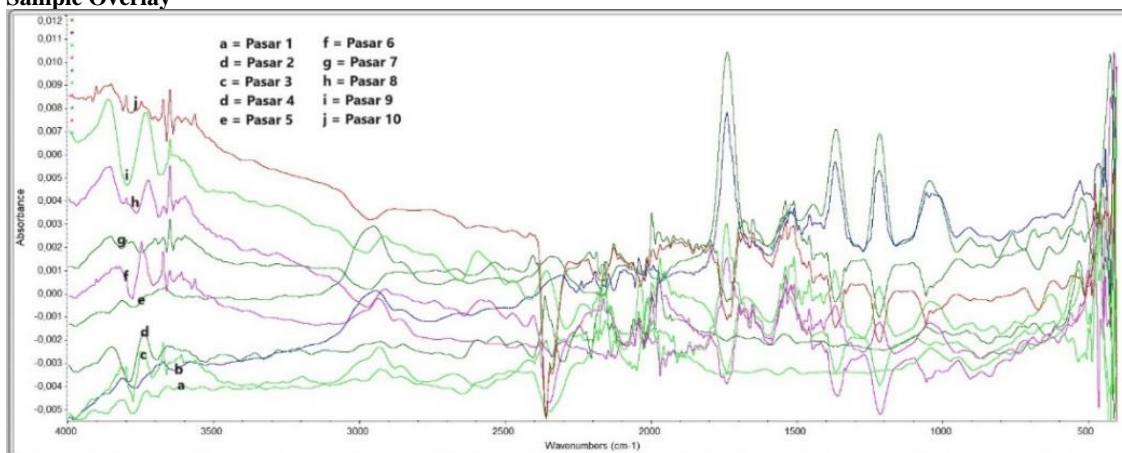


Figure 1. Overlay of Market Sample spectra

Figure 1 shows the results of overlaying market samples 1-10. All samples overlap and the spectra of all samples are almost the same.

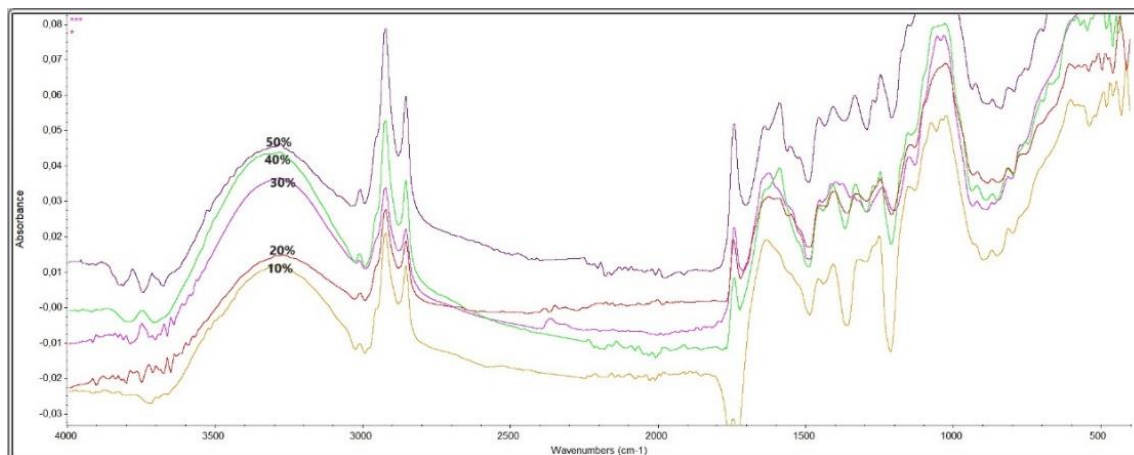


Figure 2. Overlay spectra of mixed samples

Figure 2 shows an increase as the concentration of the dye mixed with chili powder increases and obtained in the wavelength region $1800-1180\text{ cm}^{-1}$.

3.5 OPLS-DA

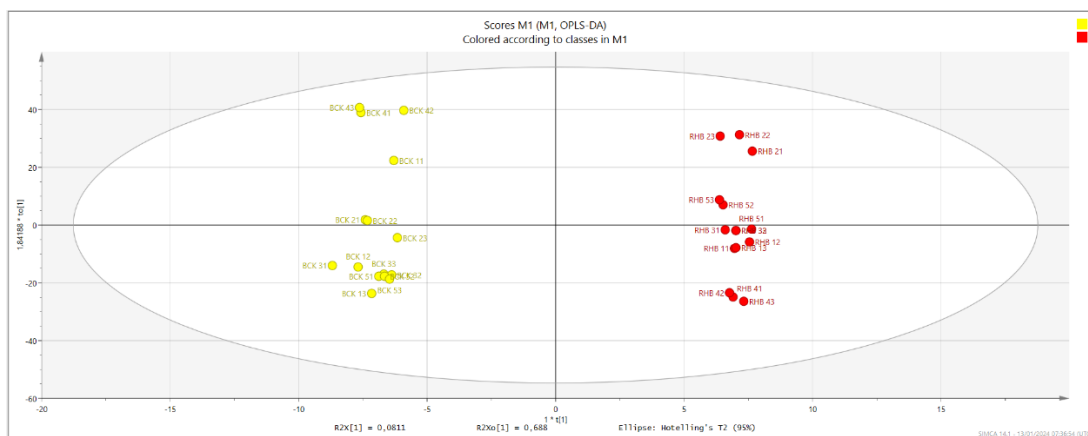


Figure 3. OPLS-DA Plot Score of Chili Powder and Rhodamine B Samples
Description: Yellow (Pure chili powder), Red (Rhodamine B)

Figure 3 is the result of OPLS-DA processing of chili powder and Rhodamine B samples. It was found that OPLS-DA was able to classify the two samples well. Furthermore, the OPLS-DA results were validated by removing the group information and changing the sample name on 1/3 of the total number of samples

for validation and 2/3 of the total number of samples for calibration (8,19). Table 3 shows that OPLS-DA is able to group samples according to their class with a 100% correctness rate.

Tabel 3. OPLS-DA Validation of Chili Powder and Rhodamine B Samples

Model	Number of samples	Calibration		Validation	
		Number of samples	Correct	Number of samples	Correct
Chili Powder	15	10	100%	5	100%
Rhodamin B	15	10	100%	5	100%
Total	30	20	100%	10	100%

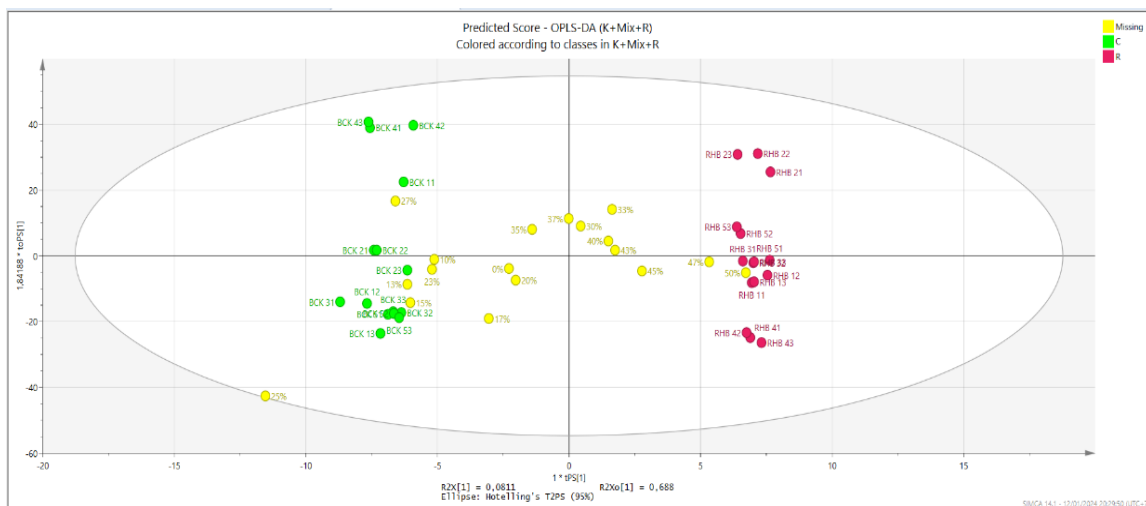


Figure 4. OPLS-DA prediction of mixed samples

Notes: Green (pure chili powder), Yellow (mixed sample), Red (Rhodamine B).

The prediction of mixed samples between chili powder and Rhodamine B using OPLS-DA, based on Figure 4, it is predicted that in mixed samples with high concentrations of 47% (w/w) and 50% (w/w) there is a true mixture detected

because the location of the grouping is in the Rhodamine B group.

Table 4. Market Sample Prediction with OPLS-DA

Sample Number	Number of Replications	Chili	Rhodamin B	Conclusion
1	9	2	7	Impure
2	9	0	9	Impure
3	9	0	9	Impure
4	9	0	9	Impure
5	9	7	2	Impure
6	9	0	9	Impure
7	9	6	3	Impure
8	9	9	0	Pure Chili
9	9	9	0	Pure Chili
10	9	9	0	Pure Chili

3.6 PLS

The wavelength used in FTIR Spectroscopy is 4000-400 which then requires optimization as in table 5 to achieve the most optimal value with the results of the R^2 value (Calibration and Validation) > 0.99 and the smallest RMSEC & RMSEP value, so that it is obtained in the following table The most optimal

wavelength that results in $R^2 > 0.99$ and the smallest RMSEC & RMSEP value to get the best prediction results (Siregar *et al*, 2018). At $1800-1180\text{ cm}^{-1}$ wavelength where the calibration R^2 value is 0.9989; RMSEC value 0.789; R^2 validation 0.9968; RMSEP 1.93.

Table 5. Quality parameters of the PLS models for quantification of Chili powder adulteration with Rhodamine B, using different sets of wavenumber

Multivariate Calibration	wavenumber (cm ⁻¹)	Calibration		Validation	
		R ²	RMSEC	R ²	RMSEP
PLS	4000-400	0,9755	3,680	0,8900	6,90
	3800-2800	0,8545	8,670	0,8627	11,0
	1800-1180	0,9989	0,789	0,9968	1,93
	1600-600	0,9987	0,861	0,9963	2,73

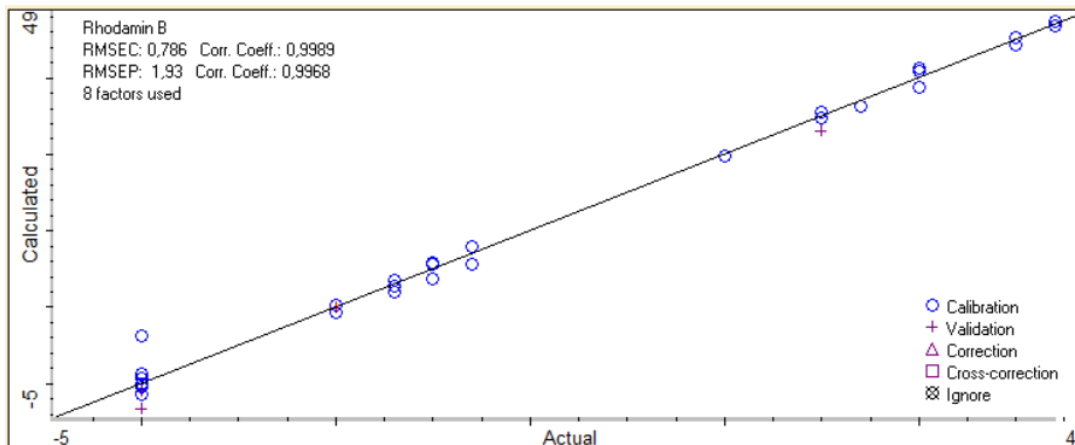


Figure 6. PLS Validation of Mixed Samples of Chilli Powder and Rhodamine B at wavelengths of 1800-1180 cm⁻¹

After multivariate calibration using TQ analysis, validation of the selected wavelengths was carried out using the Leave One Out cross-validation technique. Validation is done in PLS by dividing the data set into calibration data and validation data. Validation data consists of only one observation data, while calibration data uses all observation data except one (8,19). After multivariate calibration using the PLS method, the model developed from the PLS method was used for the prediction of Rhodamine B content in market samples 1-10. It was found that

the model developed from the PLS method at a wavelength of 1800-1180 value to get the best prediction results (22). At 1800-1180 cm⁻¹ was able to predict the counterfeit content of market samples well. Based on the results of the prediction of market samples by PLS, it was found that each of the market samples was predicted to have counterfeiters with the levels listed in Table 6.

Table 6. Prediction Results of Market Sample with PLS

Sample Name	Rhodamine B content (%b/b)			X̄ and SD (% w/w)	Conclusion
	1	2	3		
Sample 1	0,64	0,98	1,69	1,103 ± 0,44	Adulterated with Rhodamine B
Sample 2	12,06	11,67	13,27	12,47 ± 0,52	Adulterated with Rhodamine B
Sample 3	8,08	8,99	9,30	8,79 ± 0,52	Adulterated with Rhodamine B
Sample 4	20,43	20,66	21,43	20,84 ± 0,43	Adulterated with Rhodamine B
Sample 5	-1,22	-1,47	-1,14	-1,28 ± 0,14	Adulterated with other material
Sample 6	11,13	10,46	6,86	9,48 ± 1,88	Adulterated with Rhodamine B
Sample 7	-2,28	-0,78	-0,59	-1,22 ± 0,76	Adulterated with other material

DISCUSSION

Determination of chili powder was carried out before the Capsaicin content analysis stage with the aim of obtaining the identity of the sample to be used for research and ensuring that

the sample used was really a red chili. The sample of red chili fruit used in this study is a chili fruit of the species *Capsicum annum L*. The characteristics of the chili used in this study are, elongated conical fruit, straight or bent, hanging, shiny smooth

surface, 1-2 cm in diameter, 4-17 cm long, short-stemmed, red. Seeds are flat, approximately 4 mm in diameter, young yellow after old brown (17).

Calculation of capsaicin content in control chili powder samples was conducted at the Integrated Research and Testing Laboratory of Gadjah Mada University, Yogyakarta. Calculation of capsaicin levels was carried out by KLT Densitometry method. The use of the Densitometry method in determining compound levels is considered to have high specificity, the results obtained are reliable, the work is relatively easy and fast and the amount of solvent needed is relatively small (20). The results of capsaicin compound levels in the control chilli powder sample were 624.77 $\mu\text{g/g}$. Meanwhile, the capsaicin standard based on CODEX STAN 307-2011 is 134 - 1.333 $\mu\text{g/g}$ which is categorized as medium spicy. So the results of the determination of capsaicin content in the control chili powder sample are in accordance with the standard capsaicin content in the literature. The capsaicin content in chillies varies according to the type of chilli plant, the level of maturity at the time of harvesting, processing and storage, as well as the conditions of the growing area (region, climate, season).

Tests using FTIR spectroscopy on Rhodamine B samples and control chili powder. Both samples were tested with the same treatment. The samples of chili powder and Rhodamine B dye have quite distinctive differences, namely the shape of the spectrum that does not overlap and the difference in the absorption area of 3500-1500 cm^{-1} . It was found that the typical absorption in the Rhodamin B sample was found in the C-O carboxylic acid group, N-H secondary amide, and C-N. While in chilli powder that typical absorption is found in the O-H group, and C=O carbonyl.

The results of infrared spectrophotometer (IR) analysis of chili powder shows an absorption band in the wave number region of 3316.98 cm^{-1} indicating the presence of stretching vibrations of the -OH group with medium absorption intensity and a widened band shape. Then the band that appears at a wave number of 2911.86 cm^{-1} is a stretching vibration of the C-H group. The appearance of an absorption band at 1725.96 cm^{-1} indicates the presence of stretching vibrations of the C=O carbonyl group. Furthermore, there is an absorption at a wave number of 1619.31 cm^{-1} indicating the overlapping of the C=C group on the benzene ring and the vibration of the N-H group. There is also a sharp absorption band at wave number 1031.99 cm^{-1} which is the stretching vibration of C-O-H group. Based on the infrared spectrophotometer results, it is suspected that chili powder does contain a capsaicin compound with the presence of -OH, -NH, -CH, C=C, C=O, and C-O-H groups (6,25). From the results of infrared spectrophotometer (IR) analysis of Rhodamine B, it shows that the typical absorption in Rhodamine B samples is found in the C-O group of carboxylic acids, N-H secondary amides, and C-N. This shows that Rhodamine B used as a counterfeiter in this study is really a Rhodamine B compound. Furthermore, mixing between chili powder and Rhodamine B was carried out. The mixture was made in the concentration range of 0-50% (w/w), after weighing the sample was mixed using a vortex to be mixed perfectly. After conducting analysis

using FTIR on all samples, namely control chili powder samples, market chili powder samples, mixed chili powder samples, and Rhodamine B, all samples were processed by grouping to determine the presence of counterfeiters.

Clustering of samples was carried out using OPLS-DA multivariate calibration. OPLS-DA is a supervised clustering method that uses data that has been labelled or the sample group is already known. OPLS-DA clustering is based on the separation between components that are relevant for distinguishing groups (discriminant components) and components that are not relevant (orthogonal components) (19,27).

Before being used to predict the presence of counterfeiting in market samples, OPLS-DA was first validated by removing the names and eliminating the groups of 1/3 of the total samples used and then predicted 1/3 of the total samples whether they belonged to the group according to their own sample type. This treatment was carried out on chili powder and Rhodamine B samples so that 1/3 of the total samples were validated and 2/3 of the total samples were calibrated (8,11). It was found that the samples whose names were removed and the groups were correctly entered the group according to the reality of the sample type itself and the results were 100% correct in table 3. Therefore, OPLS-DA is ready to be used to predict market samples. OPLS-DA is able to separate chili powder and Rhodamine B samples well, and can be used for prediction on market samples whether there is adulteration with Rhodamine B or not. It was found that market samples 1-7 were not pure chili powder (other ingredients were added) and market samples 8-10 were predicted to be pure chili powder.

In the next stage of analysis of mixed samples and market samples using PLS, the FTIR spectra of each mixture were processed with the PLS multivariate calibration method. The selection of optimal conditions is carried out to produce the best calibration model, the selection is based on the wavelength region that produces the highest R^2 (Coefficient of determination) value for both calibration and validation to show how good the regression model is, the lowest RMSEC (Root Mean Square Error of Calibration) and RMSEP (Root Mean Square Error of Prediction) values to show the smallest prediction and calibration errors (23). In the PLS analysis, the best wavelength used was the 1800-1180 cm^{-1} wavelength where the R^2 calibration value of 0.9989 was obtained; RMSEC value of 0.789; R^2 validation of 0.9968; RMSEP of 1.93.

Next, validation of the model that has been developed is carried out using a cross-validation technique using the leave-one-out technique. In this technique, one of the calibration samples (eg a 10% sample) is removed, then this sample is modeled with the remaining samples. Next, the predicted value of the 10% sample from the remaining sample calibration model is calculated. This is done continuously until the samples are removed one by one and modeled with the remaining calibration samples (8,11). After validation, we continue to predict the level of counterfeiting in market samples 1 to 7 because in the OPLS-DA processing results it was detected that there was counterfeiting in these samples so we will continue detecting the level of counterfeiting with PLS by entering the market sample data and

setting the actual number and then the level of each sample. the market will be predicted by PLS as shown in the results of table 5.7. The results obtained from samples 1, 2, 3, 4, and sample 6 are estimated to contain Rhodamine B adulterants, while samples 5 and 7 are estimated to be adulterated with Unknown ingredients other than Rhodamine B.

According to Minister of Health Regulation (PERMENKES) no. 239/Menkes/Per/V/1985 designated Rhodamine B as one of 30 dangerous coloring substances and is prohibited from being used in medicine, food and cosmetics. This shows that samples 1,2,3,4 and 6 do not comply with regulations in Indonesia. Meanwhile, according to research conducted by Novita, it shows that the toxic effect of Rhodamine B is present at a concentration of 0.2% for a period of 21 days with histopathological studies. Therefore 0.2% can be considered the minimum level of Rhodamine B that causes health hazards (24). So the levels of Rhodamine B in market samples 1,2,3,4 and 6 exceed the minimum concentration limit which causes health hazards.

Negative impacts due to consumption of Rhodamine B will appear if the dye is consumed long term. Rhodamine B can also cause acute effects if 500 mg is ingested, which is the toxic dose. The possible toxic effect is gastrointestinal irritation (25). Long-term use of Rhodamine B in food can cause liver dysfunction or cancer. Because Rhodamine B is very toxic and it has also been reported that Rhodamine B has carcinogenicity, reproductive and developmental toxicity, neurotoxicity, and chronic toxicity in humans and animals (26).

The limitations of this study include the following:

1.Sampling was only carried out in February 2024 in one traditional market in Malang Regency, so that it can only describe conditions at one time because market conditions can change.

2.The chili fruit species used in this study is only *Capsicum annuum*, so it can only detect one chili species while other chili species cannot be detected.

3.The type of counterfeiter used in this study is only Rhodamine B, so other types of counterfeiters cannot be detected.

CONCLUSION

Based on the results of research and discussion that has been done in this study, it can be concluded that the FTIR Spectroscopy method combined with Chemometrics for multivariate calibration using PLS produces a good calibration model with a calibration value of 0.9989; RMSEC value of 0.789; validation 0.9968; RMSEP 1.93. The OPLS-DA method can classify samples well and can detect counterfeiting in chili powder samples at Singosari Traditional Market, Singosari District, Malang Regency. The samples of chili powder sold in Singosari Traditional market, Singosari Sub-district, Malang Regency contained pure chili powder (market samples 8,9,10) and there were 7 falsified samples (market samples 1 to 7) based on the results of OPLS-DA clustering chemometrics.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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