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Research Paper

Analysis of Hydrolyzed Collagen in Facial Serum for Halal Authentication Using FTIR Spectroscopy and Multivariate Calibration

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Abstract
Cosmetic trends in Indonesia are on the rise, particularly for facial serum products. However, most of these products lack halal certification, posing an important concern for Muslim consumers due to the potential use of haram substances, such as pork gelatin. This study seeks to identify the source of gelatin in serum products using the Fourier Transform Infrared (FTIR) spectroscopy and chemometric analysis. The samples used in this study include a reference facial serum formulated with pure bovine and porcine gelatin concentrations in the ratios of 1:0, 8:2, 5:5, 2:8, and 0:1, three hydrolyzed collagen serums that are not yet labeled halal and available on Shopee, and one serum that is labeled halal. The method used was FTIR combined with PLS chemometrics and PCA. The isolation of facial serum gelatin was performed using acetone at -20°C, followed by analysis via FTIR at wave numbers ranging from 4000 to 400 cm^{-1}. FTIR results indicated the presence of functional groups in gelatin constituents, including C=O, N−H, C−N, and C−H aliphatic. The wavelengths employed for PLS and PCA analysis ranged from 1631 to 1430 cm^{-1}. Calibration results showed R^2=0.9936 and RMSEC=3.0445%. Internal validation yielded RMSECV=0.1674% and R^2=0.9994 whilst external validation yielded RMSEP=0.9981% and R^2=0.9910. Lastly, PCA analysis revealed that one halal-labeled serum sample contained bovine gelatin, whereas the three examined commercial serums were free from both pork and bovine gelatin.

Keywords
Facial Serum, Gelatin, Halal, FTIR, Chemometrics

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1. INTRODUCTION

In 2023, the Muslim population reaches 2.18 billion, constituting around 27% of the global population. Indonesia, with a population of 241.7 million, representing 87.02% of its overall population, is the largest market for halal products according to 2022 demographic statistics. This signifies a substantial demand for halal products (Almunawar et al., 2025). The halal sector covers multiple domains, including medicine, cosmetics, and others (Hanim Yusuf et al., 2016; Noordin et al., 2014).

Currently, Indonesia's cosmetics industry is witnessing an influx of foreign cosmetic products. There is insufficient oversight concerning their halal status. The products frequently lack ingredient listings in Indonesian, resulting in consumer unawareness of the ingredients used, particularly in facial serum cosmetics (Khan et al., 2023). Numerous products remain on the market with unclear halal status, especially concerning their ingredients (Nugrahaeni et al., 2023). This is a significant issue to investigate, given that the majority of the Indonesian population is Muslims; thus, the uncertainty regarding their halal status can affect consumer purchasing decisions (Othman et al., 2016; Rafifasha, 2022).

Illicit ingredients in cosmetics, especially facial serums, are often derived from specific substances like gelatin and its derivative compounds. Gelatin is made from the hydrolysis of collagen, which is obtained via the extraction of fresh animal bones and skin. The polymer gelatin, derived from the partial denaturation of collagen taken from animal bones, skin, and connective tissue, has multiple functions as a gelling, binding, coating, and stabilizing agent (Nikzad et al., 2017; Ismarti et al., 2022). The commercially available gelatin comprises 80% porcine skin, 15% bovine skin, and 5% porcine bones (Sani et al., 2021; Gina et al., 2024).

Research on halal detection in cosmetics predominantly employ molecular methods using real-time PCR devices. Particularly, research on halal authentication of cosmetic products

using FTIR methods remains limited, mostly focusing on food product analysis. Table 1 presents several recent studies analyzing pork in cosmetic products using FTIR methods. No known FTIR methods for analyzing gelatin components in cosmetic products have addressed the analysis of pork gelatin in facial serum products available in Indonesia. Current studies employ the real-time PCR method. Therefore, the analysis of gelatin in cosmetic products requires further development to improve existing methods.

In addition to facial serum products, collagen is found in several lipsticks and lotions (Hussaini et al., 2024). Typically, gelatin (hydrolyzed collagen) serves as a thickening ingredient, gelling agent, emulsifier, and stabilizer in numerous products (Hamid et al., 2020). Porcine gelatin is frequently used as a cost-effective alternative to bovine gelatin due to its comparable functionalities (Cebi et al., 2019).

The FTIR method is employed to identify the functional groups in a sample by analyzing the wave number and absorbance values. Nevertheless, due to the analogous functional group properties of bovine and porcine gelatin, this method is unable to properly distinguish their sources. Therefore, a combination with chemometrics is necessary, as it is a multivariate analytical technique adept at processing spectral data from FTIR (Belchior et al., 2020). This study included two chemometric techniques, viz. Partial Least Squares (PLS) for calibration and validation, and Principal Component Analysis (PCA) for sample classification. This study seeks to identify the type of gelatin in commercial facial serums and determine whether the gelatin used complies with halal standards.

2. EXPERIMENTAL SECTION

2.1 Materials

Facial serum samples were selected from three different brands sold on Shopee, which lack halal certification and contain hydrolyzed collagen (codes SG, PRCS, and SDY), one halal-certified facial serum sample containing hydrolyzed collagen (code SYB), bovine gelatin (Sigma Aldrich), pork gelatin (Sigma Aldrich), acetone (Merck), niacinamide (Sigma Aldrich), vitamin C (Sigma Aldrich), vitamin E (Sigma), Tween 20 (Merck), propylene glycol (Brataco), carboxymethyl cellulose (Sigma), disodium EDTA (Merck), phenoxyethanol (Sigma Aldrich), NaOH (Merck), distilled water (Brataco), and aluminum foil.

2.2 Methods

2.2.1 Preparation of Reference Facial Serum

All ingredients were measured according to the formula listed in Table 2. Gelatin was liquefied in a porcelain dish using a water bath at 75°C. The serum was formulated by mixing all ingredients into water. The initial ingredients mixed were disodium EDTA, vitamin B3 (niacinamide), vitamin C, vitamin E, polysorbate 20 (tween 20), propylene glycol, and phenoxyethanol, which were then stirred continuously until a clear solution was formed. Sodium carboxymethyl cellulose was subsequently added into the water, followed by the addition of NaOH. The mixture was stirred until homogeneous, after which the serum was stored in a container and labeled (Amnuaikit et al., 2022).

2.2.2 Isolation of Gelatin from the Reference Facial Serum and the Hydrolyzed Collagen Facial Serum

Five grams of facial serum were measured and diluted in 5 mL of distilled water at 60°C, then stirred until completely dissolved. 3 mL of the solution was extracted, followed by the addition of 12 ml of acetone at -20°C. The mixture was stored in a test tube, vortexed for 5 minutes, and subsequently stored in a freezer at -20°C for 24 hours. The process produced a precipitate, which was then washed three times with 3 mL of acetone at -20°C. The washed precipitate was placed to a porcelain cup, coated in aluminum foil, and perforated. Afterwards, the precipitate was dried in a 105°C oven for one day to remove the residual distilled water. The precipitate was further analyzed using FTIR (Arifah et al., 2022).

2.2.3 FTIR Analysis of Gelatin in Facial Serum

Each gelatin in both reference and facial serum was isolated and analyzed using FTIR within the wave number range of 4000-500 cm^{-1} (Putri et al., 2025). The FTIR instrument used in this study was the FTIR Spectrum One, Perkin Elmer USA, Bruker Alpha II Spectrophotometer.

2.2.4 Data Analysis with Chemometrics Through PLS (Partial Least Squares)

PLS was used to validate the absorbance data and to generate a calibration model. The PLS method aims to optimize covariance by linking variance and data through the decomposition of data using spectral and concentration information. The advantage of PLS regression lies in its ability to illustrate the correlation between the x and y variables through the construction of PLS regression components. In FTIR spectroscopic analysis, PLS is often employed to extract information from complex spectra characterized by overlapping peaks, contaminants, and noise generated by FTIR spectrophotometers (Rahayu et al., 2021).

2.2.5 Data Analysis with Chemometrics Through PCA (Principal Component Analysis)

Principal component analysis (PCA) is a multivariate data reduction technique capable of condensing and extracting substantial data as correlations exist (Farid et al., 2021). PCA is typically used to categorize samples according to similarities in their physical and chemical properties (Rohman et al., 2020).

3. RESULTS AND DISCUSSION

Facial serum is a cosmetic preparation characterized by a higher concentration of active substances and low viscosity, facilitating easy application on the skin's surface (Khan et al., 2023; Novika et al., 2024). FTIR is a method employed to identify functional groups, notable for its rapid, straightforward, and uncomplicated analysis (Hassan et al., 2020). Furthermore, FTIR is a fingerprint spectroscopy wherein no two distinct compounds

Table 1. FTIR-Chemometric Methods Reported for the Analysis of Porcine-Derived Cosmetic Products

Non-Halal Components	Issue	Infrared (Spectroscopy Condition)	Chemometrics Techniques	Results	References
Lard	Analysis of lard in lipstick	ATR-FTIR spectra were measured at 1200-800 cm^{-1}	Classification of lard in lipstick using PCA, while quantification of lard was performed using PLS regression	PCA could classify lipstick with lard and without lard while PLS is capable of predicting the amount of lard in lipstick formulation	(Waskitho et al., 2016)
Porcine gelatin	Differ entiation between porcine gelatin and bovine gelatin	Gelatin direct analysis using ATR at combined region of 3290-3280 and 1660-1200 cm^{-1}	PCA and DA	DA based on the Cooman's plot obtained using the software TQ Analyst could classify and distinguish gelatins without any misclassification exploiting the same peaks used in PCA analysis	(Rohman et al., 2020)
Porcine gelatin	Toothpaste	ATR-FTIR was measured at 3600-2300 cm^{-1}	PLS and PCA	Measurements of toothpaste containing 100% porcine gelatin and 100% bovine gelatin show similarities in spectrum patterns	(Rahayu et al., 2021)
Porcine gelatin	Face Mask	ATR-FTIR was measured at 1235-1077 cm^{-1} PLS dan PCA	PLS and PCA	Based on the PCA plot results, the DU sample was in the porcine gelatin quadrant, while the other two samples were not in the porcine and bovine quadrants, suggesting the unknown origin of the gelatin	(Salamah et al., 2025)

Table 2. Reference Facial Serum Formulation (Amnuaikit et al., 2022)

Ingredients	Ingredients Component Formula (gram)					Function
	F1 (1:0)	F2 (8:2)	F3 (5:5)	F4 (2:8)	F5 (0:1)	
Niacinamide	2	2	2	2	2	Active substance
Vitamin C	0.3	0.3	0.3	0.3	0.3	Active substance
Vitamin E	0.5	0.5	0.5	0.5	0.5	Active substance
Bovine Gelatin	2.5	2	1.25	0.5	–	*Gelling agent*
Porcine Gelatin	–	0.5	1.25	2	2.5	*Gelling agent*
Carboxymethyl cellulose	0.5	0.5	0.5	0.5	0.5	*Thickener*
Disodium EDTA	0.1	0.1	0.1	0.1	0.1	*Stabilizer Agent*
Tween 20	0.3	0.3	0.3	0.3	0.3	Emulsifier
Propylene glycol	20	20	20	20	20	Humectant
Phenoxyethanol	0.5	0.5	0.5	0.5	0.5	Preservative
NaOH	0.5	0.5	0.5	0.5	0.5	pH regulator
Aquades ad	100	100	100	100	100	Solvent

or samples exhibit identical IR spectrum. The IR spectrum of one compound can be distinguished from another based on its intensity, peak count, and wave number of each peak, making FTIR spectroscopy a common method for identifying chemical compounds through their functional groups (Rohman et al., 2020; Brereton et al., 2018). Functional group analysis was performed by scanning in the mid-IR region (4000-400 cm^{-1}). Figure 1 illustrates the results of the functional group analysis of porcine and bovine gelatin.

Figure 1 indicates that the spectra of bovine and porcine gelatin show similarities. The difference is in the absorption intensity. Gelatin is a protein consisting of functional groups, such as carbonyl (C=O), hydroxyl group (O−H), amine group (N−H), carbon-hydrogen group (C−H), and aliphatic C−H

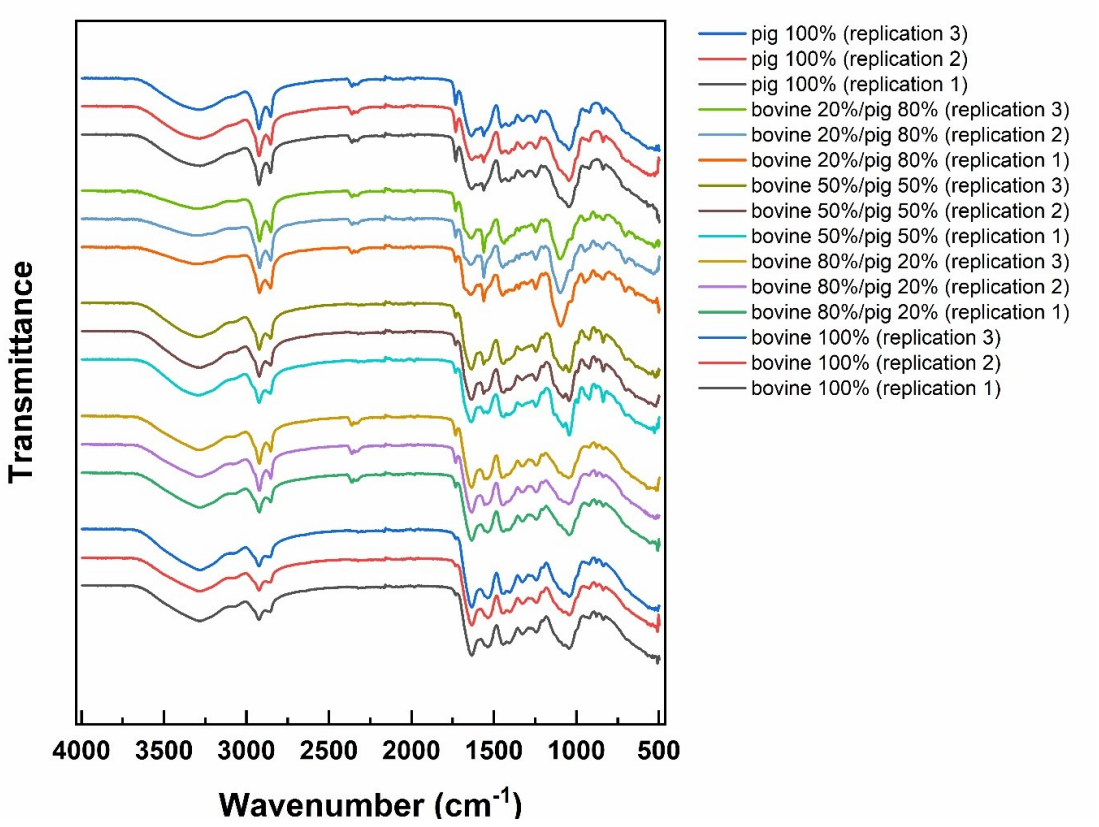

Figure 1. IR Spectrum of Gelatin Reference Facial Serum with Five Different Concentrations of Porcine and Bovine Gelatin, Each Replicated 3 Times

Table 3. Wave Numbers Optimization Results on Reference Facial Serum for PLS Calibration

Wave Numbers (cm^{-1})	R^2	Regression Equation	RMSEC (%)
1641–1401	0.9863	y = 0.9901x + 0.3709	3.1150
1641–1500	0.9930	y = 0.9930x + 0.3479	3.1833
1631–1430	0.9936	y = 0.9936x + 0.3181	3.0445
1522–1430	0.9910	y = 0.8939x + 0.1413	4.2497
1461–1340	0.9549	y = 0.9549x + 2.2557	8.1075
1235–1077	0.9686	y = 0.9686x + 0.6926	3.9970

group. These groups were detected at wave numbers listed in Table 4. The table indicates that the wave numbers of porcine and bovine gelatin exhibit O-H groups within the range of 3400-3200 cm^{-1}, specifically 3299-3000 cm^{-1} for porcine gelatine and 3286-3000 cm^{-1} for bovine gelatin, characterized by a stretching vibration model, medium intensity, and broadening (Pavia et al., 2009). This aligns with the study conducted by Zilhadia et al. (2018) on bovine and porcine gelatin in vitamin C gummies. It showed that there was an N−H bond in the hydrogen bond of the amide group, exhibiting a wide absorption in the 3600-2900 cm^{-1} range. In addition, an aliphatic C−H bond was present at 2923 cm^{-1} within the 3000-2850 cm^{-1} range. Carbonyl groups (C=O) were identified in the wave number range of 1680-1630 cm^{-1} as carbonyl amides, namely at 1635 cm^{-1} in porcine gelatine and at 1633 cm^{-1} in bovine gelatin. The peaks observed in the wave number range of 1680-1630 cm^{-1} corresponded to the amide I region, indicating a C=O carbonyl bond along with contributions of NH and C−N bonds. The amide I region encompassed the typical spectrum of gelatin (Zilhadia et al., 2018). The wave number range of the C−N group at 1350-1000 cm^{-1} showed medium to strong intensity. Porcine and bovine gelatin were detected at 1246 cm^{-1} and 1243 cm^{-1}, respectively.

Furthermore, the sample's spectrum was also assessed. The results of the FTIR spectrum exhibited a peak analogous to that of the reference sample. According to Figure 2, the samples comprised three different brands and one sample of halal-labeled hydrolyzed collagen facial serum. The facial serum codes used were PRCS, SG, SDY, and SYB. The analysis carried out on the facial serum samples sold in Shopee followed

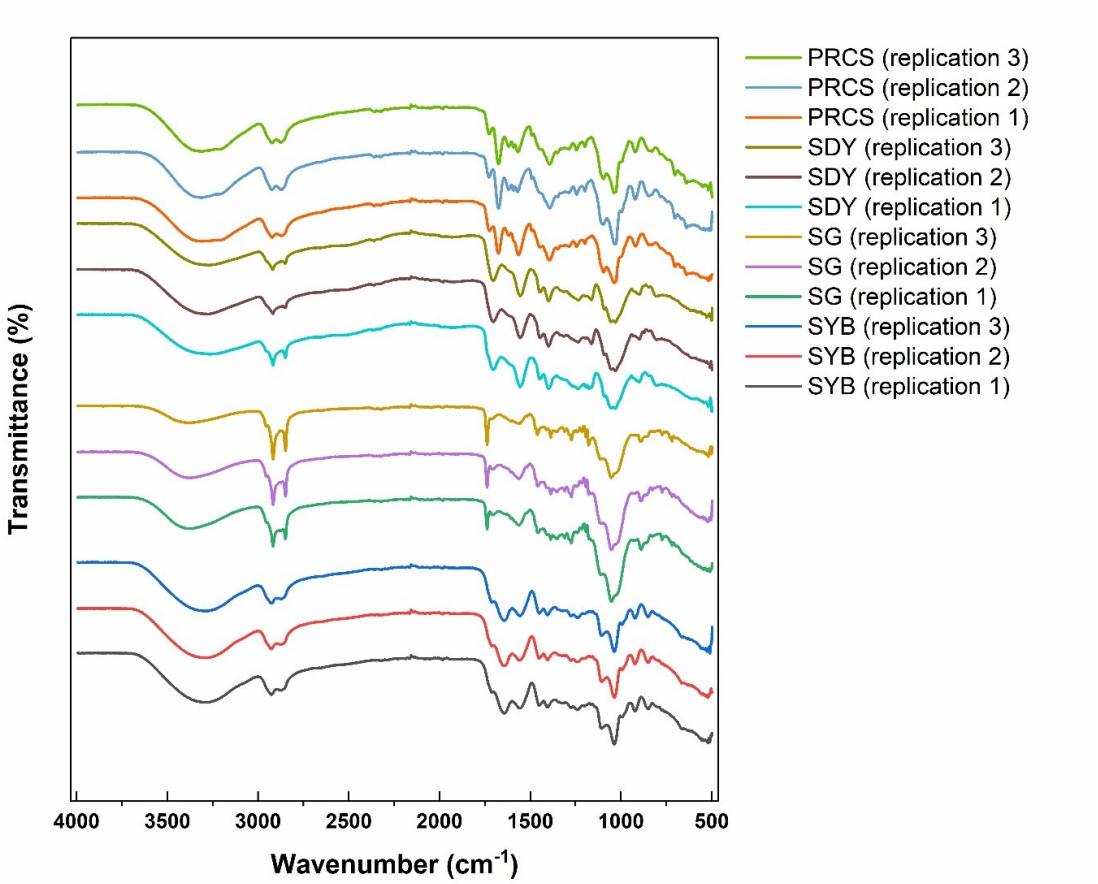

Figure 2. IR Spectra of Halal-Labeled Facial Serum Samples SYB Code; Facial Serum PRCS Code; SDY Code; SG Code, with Three Replications Each

Table 4. Functional Group Spectra of Bovine Gelatin and Porcine Gelatin 100% Reference Facial Serum

Band	Reference Source (Pavia et al., 2009)	Wave Numbers (cm^{-1}) Porcine Gelatin	Wave Numbers (cm^{-1}) Bovine Gelatin	Function Group	Vibration Model	Intensity
a	3400-3200	3299-3000	3286-3000	O−H	Stretching	Medium, broadened
b	3000-2850	2923	2923	C−H aliphatic	Stretching	Strong
c	1680-1630	1635	1633	C=O amide	Stretching	Strong
d	1640-1550	1561	1538	N−H	Bending	Medium to strong
e	1350-1000	1246	1243	C−N	Stretching	Medium to strong

the identical procedure as that of the reference samples. The spectral results of the hydrolyzed collagen facial serum samples depicted in Figure 2 indicate that the peaks were analogous, although exhibited variations in intensity. Table 5 displays the predicted functional groups present in the hydrolyzed collagen facial serum sample.

The functional groups identified in the hydrolyzed collagen facial serum exhibited similarities to the 100% reference bovine and porcine gelatin, albeit difference in intensity. The functional groups appearing included hydroxyl (O−H), car-

Table 5. Function Group Prediction of Porcine and Bovine Gelatin in Hydrolyzed Collagen Facial Serum Samples

Band	Wave Numbers (cm^{-1})					Text	Vibration Model	Shape/Intensity
	Reference Source (Pavia et al., 2009)	SYB	PRCS	SDY	SG			
a	3400–3200	3300–3000	3311–3000	3299–3000	3387–3000	O–H	Stretching	Medium, broadened stretching
b	3000–2850	2926	2922	2918	2917	C–H aliphatic	Stretching	Strongly stretched
c	1680–1630	1643	1676	1703	1738	C=O	Stretching	Strongly stretched
d	1640–1550	1557	1565	1556	1560	N–H	Bending	Medium to strong
e	1350–1000	1037	1038	1053	1052	C–N	Stretching	Medium to strong

bonyl (C=O) amide, carbonyl (C=O) carboxylate, N−H,C−H aliphatic, and C−N groups. The O−H group showed a medium intensity stretching vibration within the range of 3400-3200 cm^{-1}, characterized by broadening. The O−H group in the serum SYB code ranged from 3300 to 3000 cm^{-1}, the PRCS code ranged from 3311 to 3000 cm^{-1}, the SDY code ranged from 3299 to 3000 cm^{-1}, and the SG code ranged from 3387 to 3000 cm^{-1}. Aliphatic C−H groups within the 3000-2850 cm^{-1} range were identified in the SYB code serum at 2926 cm^{-1}, in the PRCS code at 2922 cm^{-1}, in the SDY at 2918 cm^{-1}, and in the SG at 2917 cm^{-1}, exhibiting a strong intensity stretching vibration model. Within the wave number range of 1680-1630 cm^{-1}, the identified functional groups were carbonyl (C=O) amides, specifically SYB code at 1643 cm^{-1} and PRCS at 1676 cm^{-1}. Nevertheless, in serums with SDY and SG codes, a shift occurred, resulting in peaks at 1703 $cm^{-}1$ and 1738 cm^{-1}, respectively, which showed the presence of carbonyl (C=O) carboxylate functional groups. Within the wave number range of 1640-1550 cm^{-1}, the N−H cluster exhibited a medium to strong intensity bending vibration model, with specific peaks observed at 1557 cm^{-1} in the SYB serum, 1565 cm^{-1} in the PRCS, 1556 cm^{-1} in the SDY, and 1560 cm^{-1} in the SG. A further cluster identified was C−N within the range of 1350-1000 cm^{-1}, characterized by stretching vibrations of medium to strong intensity, viz. at 1037 cm^{-1} in the SYB, 1038 cm^{-1} in the PRCS, 1053 cm^{-1} in the SDY, and 1052 cm^{-1} in the SG.

Since FTIR analysis solely identified functional groups without being able to specifically differentiate between bovine and porcine gelatin due to the similarity of their functional group structures, the method was combined with Partial Least Squares (PLS) chemometrics and Principal Component Analysis (PCA). PLS was used for data calibration and validation, whilst PCA was used for data categorization based on similar properties, represented through quadrant score plots.

3.1 Calibration and Validation Using PLS

In PLS analysis, as illustrated in Figure 3, data optimization was carried out by identifying specific wave numbers for calibration and validation models. The selected wave numbers must have the characteristics of the functional groups present in the gelatin compound. The optimum wave numbers were selected based on the highest coefficient of determination (R^2) value, approaching 1. The calibration model was also predicted on the lowest error value, represented as Root Mean Squared Error of Calibration (RMSEC). The R^2 value describes the proximity of the predicted value to the actual value, whereas a smaller RMSEC value signifies reduced calibration model error (Salamah et al., 2025).

Optimization was conducted using the correlation coefficient between the predicted value (x) and the actual value (y) in regard to the value of content vs fits. The modeling results in PLS employed a linear regression equation $y = bx + a$, where y represents the predicted value derived from FTIR, b denotes the slope of the gradient, x signifies the actual analyte content, and a indicates the intercept on the y-axis (Rohman et al., 2020). Table 3 illustrates the wave number optimization for porcine and bovine gelatin.

The selected wave number optimization ranged from 1631 to 1430 cm^{-1}. A linear regression equation of $y = 0.9936x + 0.3181$ was obtained, with an R^2 value of 0.9936. The RMSEC value recorded was 3.0445%. The results indicated that the R^2 value was favorable as it approached 1, while RMSEC demonstrated the optimal value as it was nearest to 0 compared to others.

The prediction model was executed using the cross-validati on method with the leave-one-out technique in Minitab 21. This technique can exclude certain data and generate a new model using the remaining data; this process is referred to as internal validation. This model is deemed valid if the Root Mean Square Error of Cross-Validation (RMSECV) value is low and the R^2 value approaches 1. The measurement of the RMSECV yielded an R^2 value of 0.9994 and an RMSECV value of 0.1674%. A smaller RMSECV value indicated superior accurate in the predictive capability of the constructed model.

In addition, an external validation process was also carried out, referred to as the Root Mean Square Error of Prediction (RMSEP) value. External validation outcomes indicated the equation $y = 0.8787x + 11.939$, with an R^2 value of 0.9910 and an RMSEP value of 0.9981%. The R^2 value serves an accuracy

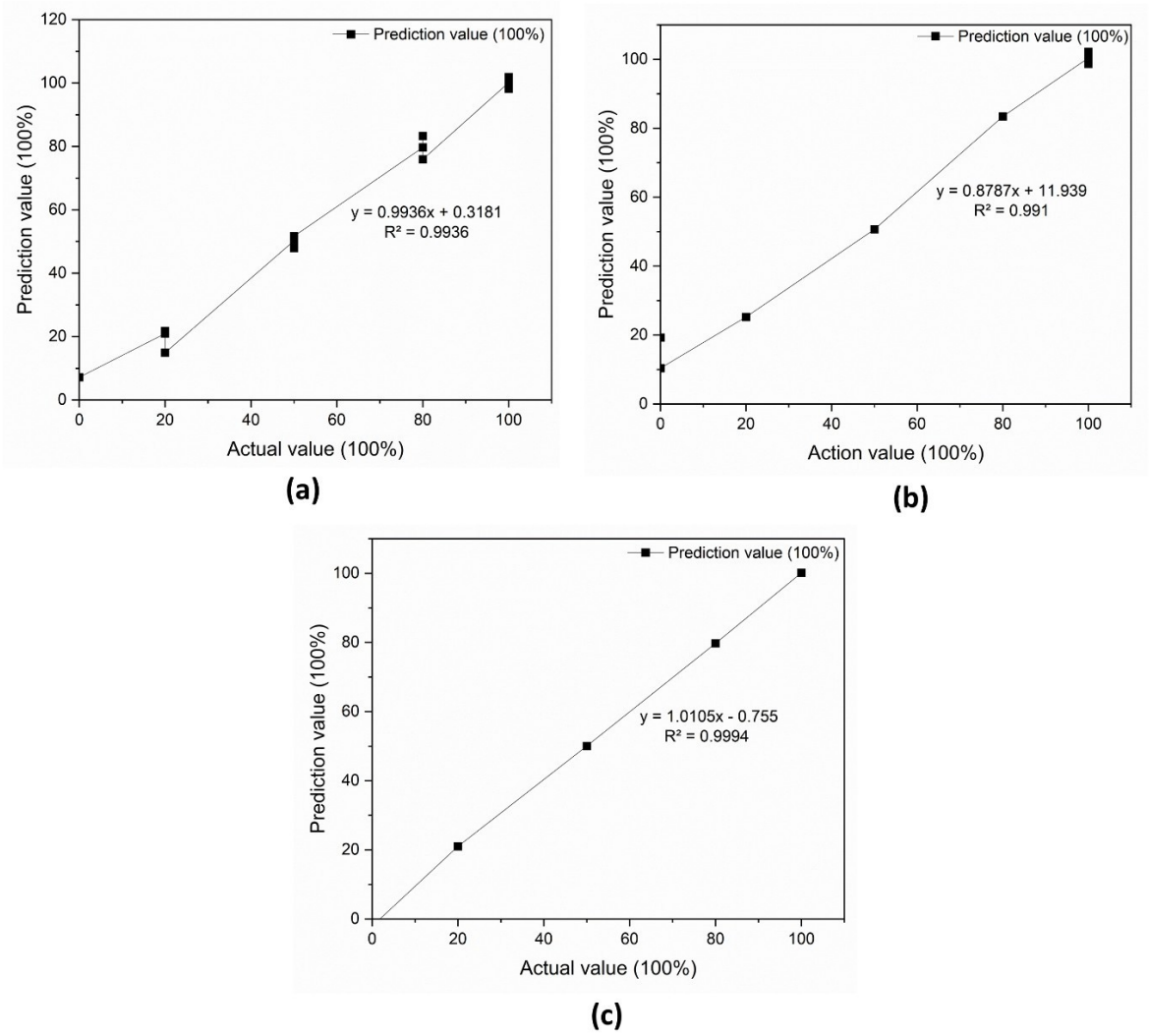

Figure 3. Relationship Curve Between the X-Axis (Actual Value) and The Y-Axis (Predicted Value) Wave Numbers 1631-1430 cm^{-1} (A) RMSEC (B) RMSECV and (C) RMSEP

Table 6. PCA Analysis Results in the Form of Eigen analysis of the Covariance Matrix

Eigenvalue	89.354	5.765	2.039	1.058	0.425	0.126	0.100	0.083	0.023
Proportion	0.903	0.058	0.021	0.011	0.004	0.001	0.001	0.000	0.000
Cumulative	0.903	0.961	0.981	0.992	0.996	0.998	0.999	0.999	1.000

metric, with a value approaching 1 signifying a strong correlation between the actual value and the predicted value, thus enhancing precision. Moreover, a smaller RMSEC, RMSECV, and RMSEP values indicated less model error.

3.2 PCA Analysis

PCA analysis was performed using the Minitab 21 application by inputting absorbance data from three samples of hydrolyzed collagen facial serum, halal-labeled serum samples, and reference facial serum samples derived from porcine and bovine gelatin at the optimized wave numbers, namely within the range of 1631-1430 cm^{-1}. Table 6 presents the results of the PCA analysis.

Data were acquired in the form of eigenvalues, proportions, and cumulative. The impact of each variable was indicated by the eigenvalue, which reflects the variance of each principal component (PC). The contribution of each PC to the variable variation was indicated by the proportion value, whilst the cumulative sum of these proportions was represented by

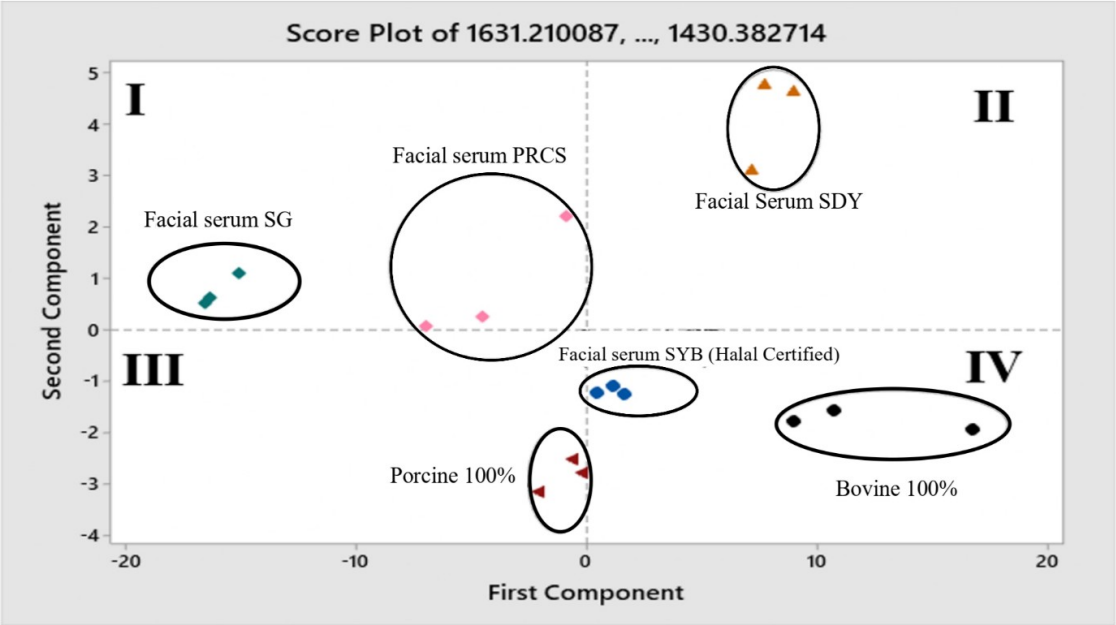

Figure 4. PCA Analysis Results Presented as a Score Plot of 100% Porcine Gelatin and 100% Bovine Gelatin Reference Facial Serums, Three Hydrolyzed Collagen Facial Serum Products, and One Sample of Halal-Labeled Facial Serum

the cumulative value. Table 3 displays the distribution of total variance across the 100 principal components in the first row and each variance as a proportion of the overall variance in the second raw, indicating that PC_1 accounted for a variance of 89.354 or 90.3% of the total variance. This value represented the largest proportion compared to the original variable. PC_2 accounted for 5.8% of the total variation. The last row of the first block presents the cumulative proportion. It is evident that up to PC4, the achieved variance was 99.2%; hence, PCA could condense data originally comprising 100 variables (absorbance at 100 wave numbers) into four new variables (Breton, 2003; Syahruni et al., 2024). The results of PCA analysis are presented as a score plot in Figure 4.

PCA analysis will yield a score plot that categorizes samples into quadrants based on the similarity of their physical and chemical properties (Nurani et al., 2022). The analysis revealed four distinct quadrants. The reference porcine gelatin from the facial serum was in quadrant III, whereas the reference bovine gelatin was in quadrant IV. The serum sample containing hydrolyzed collagen and labeled as halal was in the same quadrant as the 100% reference bovine gelatin. This indicated that the halal-labeled sample possessed physicochemical properties akin to those of bovine gelatin. The score plot results of the other facial serum samples occupied different quadrants compared to the reference porcine and bovine gelatin. The facial serum samples with SG and PRCS codes were in the same quadrant, i.e., in quadrant I. This indicated that the facial serum samples (code SG and PRCS) had similar physicochemical properties. Meanwhile, the facial serum with the SDY code was in quadrant II. Neither quadrant I nor quadrant II contained bovine gelatin and porcine gelatin references, suggesting that the facial serum product likely did not contain either bovine or porcine gelatin, but might contain other gelatin ingredients, such as fish gelatin.

4. CONCLUSIONS

The functional groups of bovine and porcine gelatin, including C=O amide, N−H, C−H aliphatic, and C−N, can be identified and categorized using the combined method of FTIR and chemometrics. The results of PCA chemometrics analysis can classify halal and non-halal gelatin using a quadrant score plot, which indicates that the halal-labeled serum sample (SYB serum) occupied the same quadrant as bovine gelatin. Among three facial serum samples, two (serum SG and PRCS) were in the same quadrant, while the three serum samples (serum SG, PRCS, and SDY) were not in the quadrant of bovine or porcine gelatin, suggesting that the gelatin material used might originate from other sources.

5. ACKNOWLEDGMENT

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