FUDMA Journal of Engineering and Technology
ISSN: 3092-9385
https://fjet.fudutsinma.edu.ng/index.php/fjet/
Volume 2, Issue 2, 2026, 471-479

Determination of the Physicochemical Composition of Processed Powdered Pepper (*Capsicum spp.*) Sold in Selected Markets in Makurdi, Benue State, Nigeria

Paul A. OMALE[1*], Hammed O. SALAUDEEN[2], Sunday S. IGILA[3], Enoch T. CHIN[4]

[1*,2,3,4]Department of Agricultural and Biosystems Engineering, Joseph Sarwuan Tarka University Makurdi, Benue State, Nigeria

[1*]omale.paul@uam.edu.ng, [2]hammed.salaudeen@uam.edu.ng, [3]igilasodisunday@gmail.com, [4]chinenoch610@gmail.com

Abstract
The physicochemical quality of processed powdered pepper influences its nutritional value, shelf stability, safety, and consumer acceptability. However, information on the molecular characteristics of commercially processed powdered pepper sold in Nigerian markets remains limited. This study characterized processed powdered pepper (Capsicum spp.) obtained from three major markets in Makurdi, Benue State, Nigeria. Wurukum, Modern, and North Bank markets using a laboratory-prepared sample as a control. Fourier Transform Infrared Spectroscopy (FTIR) was employed to identify major functional groups within the spectral range of 4000–400 cm⁻¹. Characteristic absorption bands associated with hydroxyl groups, proteins, lipids, phenolic compounds, and pigment-related conjugated structures were detected in all samples. Protein-associated Amide I and Amide II bands occurred at approximately 1637 and 1542 cm⁻¹, while lipid-related absorption bands were observed between approximately 3011 and 1745 cm⁻¹. Variations in peak positions and spectral intensities among samples indicated differences in moisture-associated, protein-associated, and pigment-related spectral responses, which may reflect differences in processing and storage conditions. Statistical analysis showed significant differences ($p < 0.05$) in moisture-, protein-, and pigment-related spectral responses, whereas lipid- and phenolic-related responses did not differ significantly among the samples. The North Bank sample exhibited relatively stronger pigment- and phenolic-associated spectral features, while the control and Modern Market samples showed comparatively stronger moisture- and protein-related features. The results demonstrate the influence of commercial processing and post-harvest handling on the molecular characteristics of powdered pepper and highlight the potential of FTIR spectroscopy as a rapid, non-destructive tool for comparative quality assessment of processed spices.

Keywords: *Capsicum spp.; powdered pepper; Fourier Transform Infrared Spectroscopy; physicochemical characterization; food quality; post-harvest processing.*

1.0 Introduction

Peppers (Capsicum spp.) are among the most widely cultivated and economically important spice crops worldwide and are valued for their culinary, nutritional, and medicinal properties. They are consumed fresh or processed into powders, flakes, sauces, and seasonings for domestic and industrial applications. In addition to providing characteristic colour, flavour, and pungency, peppers contain carbohydrates, proteins, dietary fibre, vitamins, minerals, carotenoids, flavonoids, phenolic compounds, and capsaicinoids with antioxidant, antimicrobial, anti-inflammatory, and other health-promoting properties [1], [2].

In Nigeria, pepper is an important component of household diets and food-processing industries. To extend its shelf life and ensure year-round availability, fresh pepper is commonly dried and milled into powder. Powdered pepper is convenient for storage, transportation, and incorporation into food products. However, its quality may be affected by post-harvest handling, drying conditions, milling, packaging, and storage. Inadequate processing and storage can promote moisture uptake, degradation of pigments and other bioactive compounds, microbial deterioration, and loss of sensory quality [3], [4]. Carotenoids, phenolic compounds, and capsaicinoids are particularly important because they contribute to the characteristic colour, antioxidant capacity, and functional properties of pepper but may be affected by heat, oxygen, light, and prolonged storage [5], [6].

Reliable analytical techniques are therefore required to evaluate the molecular characteristics of processed pepper. Conventional physicochemical analyses may require extensive sample preparation, chemical reagents, and relatively long analytical periods. Fourier Transform Infrared (FTIR) spectroscopy provides a rapid, non-destructive alternative for identifying molecular functional groups and generating characteristic spectral fingerprints of food materials. The technique has been applied in food quality assessment, compositional characterization, authenticity verification, and adulteration studies because it requires minimal sample preparation and permits simultaneous examination of several chemical constituents [7], [8].

Previous studies have investigated the effects of drying, processing, and storage on the nutritional and physicochemical properties of pepper products [4], [9], [10]. However, comparatively limited information is

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026

available on the molecular characterization of commercially processed powdered pepper obtained directly from Nigerian retail markets using FTIR spectroscopy. This gap is particularly relevant in Makurdi, Benue State, where powdered pepper is widely consumed and may be subjected to varying processing, packaging, storage, and market-handling conditions. Such variations may influence the spectral characteristics and overall quality attributes of commercially available products.

Therefore, this study employed FTIR spectroscopy to characterize processed powdered pepper obtained from selected markets in Makurdi, Benue State, Nigeria. Specifically, the study compared the spectral profiles of commercial and laboratory-prepared samples and evaluated variations in functional groups associated with moisture, proteins, lipids, phenolic compounds, and pigment-related constituents. The findings provide baseline information on the molecular characteristics of commercially processed powdered pepper and demonstrate the potential application of FTIR spectroscopy as a rapid tool for comparative quality assessment of processed spices.

2.0 Materials and Methods

2.1 Study Area

This study was conducted in Makurdi, the capital city of Benue State, Nigeria. Makurdi is a major commercial centre in North-Central Nigeria where processed agricultural products, including powdered pepper (*Capsicum* spp.), are widely traded and consumed. Three major retail markets Wurukum Market, Modern Market, and North Bank Market were selected because of their substantial commercial activities and the availability of processed powdered pepper from different vendors.

2.2 Sample Collection

Processed powdered pepper samples were obtained from Wurukum Market (WM), Modern Market (MM), and North Bank Market (NBM) in Makurdi. Approximately 250 g of powdered pepper was purchased from each market from three independent vendors to account for possible variations in processing and handling practices. Samples were immediately transferred into clean, airtight containers to minimize external contamination and moisture uptake during transportation and storage before analysis.

A laboratory-prepared powdered pepper sample was used as the control (CT). The control sample was prepared from dried pepper and ground into a fine powder using a clean, sterilized grinder to obtain a relatively uniform sample for comparison with the commercially processed products.

2.3 Sample Preparation

Before FTIR analysis, each powdered pepper sample was homogenized to ensure uniform particle distribution. The grinding equipment used for preparing the control sample was cleaned thoroughly before and after use to minimize cross-contamination. Representative portions of the homogenized samples were subsequently used for FTIR spectral characterization.

2.4 Fourier Transform Infrared Spectroscopy (FTIR) Analysis

The molecular characteristics of the processed powdered pepper samples were evaluated using Fourier Transform Infrared Spectroscopy (FTIR). FTIR analysis was used to identify characteristic absorption bands and functional groups associated with major constituents of the pepper samples.

Spectral measurements were performed over the mid-infrared region of 4000–400 cm^{-1} using an FTIR spectrometer equipped with an Attenuated Total Reflectance (ATR) accessory. Before analysis, the instrument was calibrated according to the manufacturer's recommendations, and a background spectrum was collected to minimize atmospheric interference.

Approximately 2-3 g of each homogenized sample was placed directly on the ATR crystal to ensure adequate contact with the crystal surface. Spectra were recorded at a resolution of 4 cm^{-1}, and multiple scans were averaged to improve the signal-to-noise ratio. Each sample was analyzed in triplicate to improve analytical precision and reproducibility.

2.5 Interpretation of Selected FTIR Spectral Regions

The FTIR spectra were interpreted based on characteristic absorption bands associated with major molecular constituents of food materials. The spectral evaluation focused on moisture-related hydroxyl groups, protein-associated amide bands, lipid-associated functional groups, phenolic-related bands, and pigment-related spectral features.

Importantly, these spectral regions were used for comparative characterization of functional-group responses and should not be interpreted as direct quantitative measurements of absolute chemical concentrations without appropriate calibration models.

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026

2.5.1 Moisture-Related Functional Groups

Moisture-associated spectral features were evaluated primarily from the broad O–H stretching region, approximately 3700–3000 cm^{-1}, with maximum absorption commonly occurring near 3400 cm^{-1}. Variations in the intensity of this broad absorption region were used to compare relative differences in water-associated hydrogen bonding among the samples.

2.5.2 Protein-Related Functional Groups

Protein-associated spectral features were identified primarily from the Amide I and Amide II absorption regions. The Amide I band, approximately 1700–1600 cm^{-1}, is mainly associated with C=O stretching vibrations of peptide bonds, whereas the Amide II region, approximately 1560–1500 cm^{-1}, is associated with N–H bending and C–N stretching vibrations. These bands were used for comparative assessment of protein-related spectral characteristics among the samples.

2.5.3 Lipid-Related Functional Groups

Lipid-associated functional groups were identified from characteristic absorption bands within the aliphatic C–H stretching region, approximately 2955–2845 cm^{-1}, and the ester carbonyl region, approximately 1745–1735 cm^{-1}. These spectral regions were used to identify the presence and relative spectral characteristics of lipid-associated constituents, including fatty acids and triglyceride-related compounds.

2.5.4 Phenolic-Related Functional Groups

Phenolic-associated spectral features were evaluated from characteristic oxygen-containing and aromatic functional-group vibrations within the fingerprint region, particularly between approximately 1700 and 1000 cm^{-1}. The spectral features were used for qualitative comparison of phenolic-related functional groups among the processed pepper samples.

2.5.5 Pigment-Related Functional Groups

Pigment-associated spectral features were evaluated from characteristic conjugated molecular structures and relevant fingerprint regions associated with carotenoid-related compounds. These spectral features were used to compare the relative preservation and variation of pigment-associated molecular structures among the samples.

2.6 Statistical Analysis

All FTIR measurements were performed in triplicate, and the data were expressed as mean ± standard deviation. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS), Version 25.

One-way Analysis of Variance (ANOVA) was used to evaluate differences in the selected FTIR spectral responses among samples obtained from Wurukum Market, Modern Market, North Bank Market, and the laboratory-prepared control. Where significant differences were detected, Duncan's Multiple Range Test (DMRT) was used for post hoc mean separation. Statistical significance was established at $p < 0.05$, corresponding to a 95% confidence level.

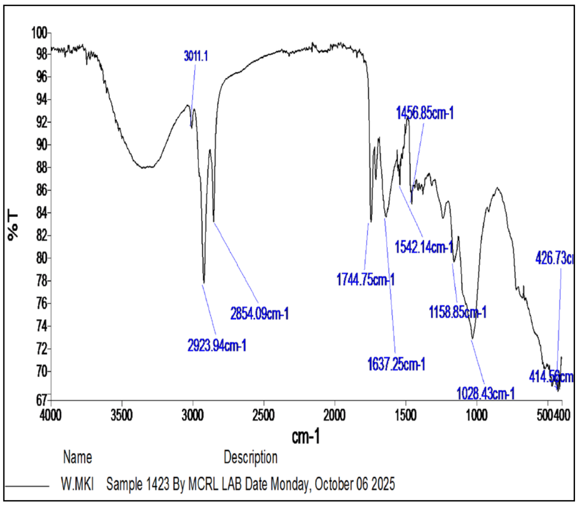
3.0 Results and Discussion

3.1 Fourier Transform Infrared (FTIR) Spectral Characteristics of Processed Powdered Pepper Samples

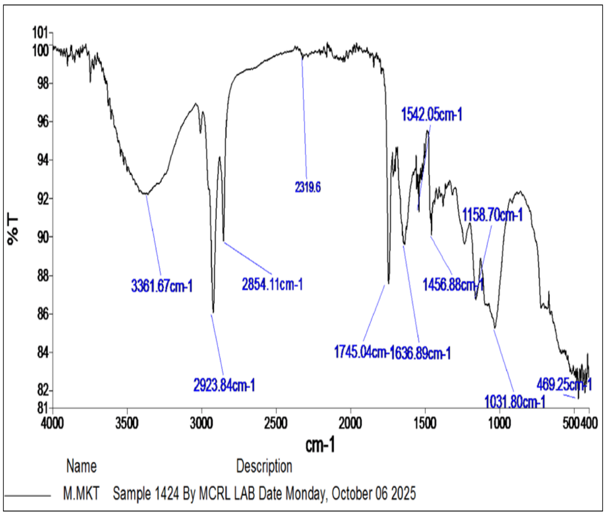
The Fourier Transform Infrared (FTIR) spectra of processed powdered pepper samples obtained from Wurukum Market (WM), Modern Market (MM), North Bank Market (NBM), and the laboratory-prepared control (CT) were analysed over the mid-infrared spectral region (4000–400 cm^{-1}). The spectra revealed characteristic absorption bands associated with hydroxyl (O–H), aliphatic hydrocarbons (C–H), carbonyl (C=O), amide (N–H and C–N), phenolic (C–O), and conjugated aromatic functional groups, indicating the presence of moisture, proteins, lipids, phenolic compounds, and pigment-related constituents in all samples.

Although the four samples exhibited generally similar spectral profiles, variations in peak positions and absorbance intensities were observed, suggesting differences in physicochemical composition attributable to processing conditions, drying efficiency, storage environment, and handling practices.

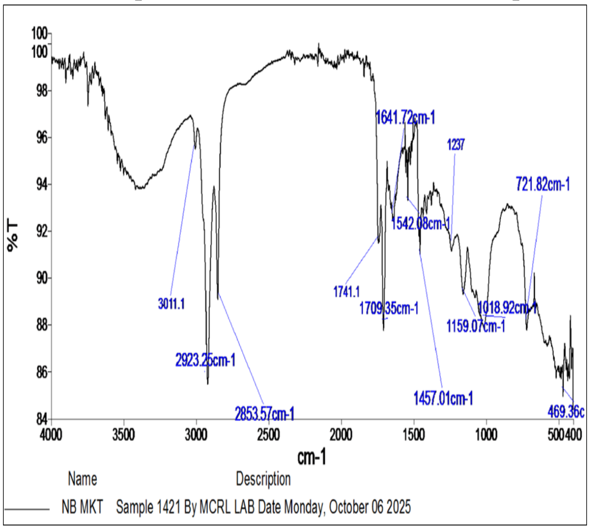
Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026



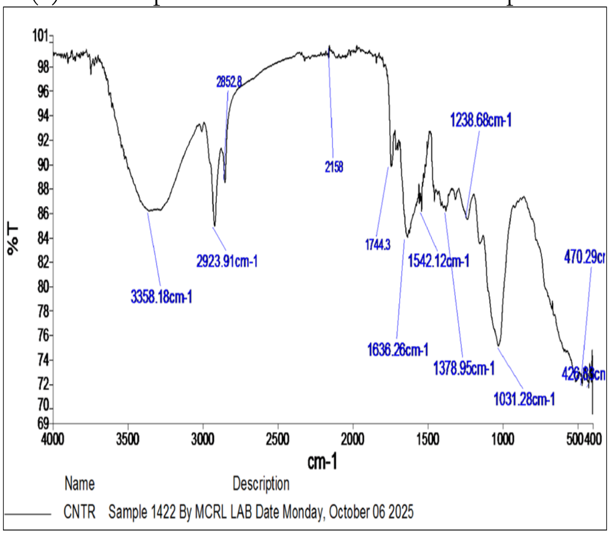
(a) FTIR Spectra for Wurukum Market Sample



(b) FTIR Spectra for Modern Market Sample



(c) FTIR Spectra for North Bank Market sample



(d) FTIR Spectra for Control Sample

Figure 1. Comparative FTIR spectra of processed powdered pepper samples collected from Wurukum Market (a), Modern Market (b), North Bank Market (c), and the laboratory-prepared control (d).

3.2 Comparative FTIR Peak Assignments

The principal FTIR absorption bands identified in all samples and their corresponding functional group assignments are summarized in Table 1.

Table 1. Characteristic FTIR absorption bands of processed powdered pepper samples.

Functional group	Wurukum	Modern	North Bank	Control	Assignment
O–H stretching	3358.34	3361.67	3359.02	3358.18	Moisture/hydroxyl groups
=C–H stretching	3011.10	3010.85	3011.11	3011.08	Unsaturated lipids
CH_2 asymmetric stretching	2923.94	2923.91	2923.88	2923.97	Lipids
CH_2 symmetric stretching	2854.09	2853.99	2854.01	2854.07	Lipids
Ester carbonyl (C=O)	1744.75	1744.61	1744.69	1744.73	Triglycerides/fatty acids
Amide I	1637.25	1636.84	1641.72	1637.18	Proteins
Amide II	1542.14	1542.08	1541.93	1542.11	Proteins
CH bending	1456.85	1456.78	1457.03	1456.81	Lipids/proteins
Phenolic C–O	1238.40	1237.92	1239.10	1238.05	Phenolic compounds
C–O stretching	1028.43	1030.61	1018.57	1029.31	Carbohydrates/phenolics

All peak positions are expressed in cm⁻¹.

As shown in Table 1, the O–H stretching bands occurred between 3358.18 and 3361.67 cm^{-1}, indicating hydroxyl-containing and moisture-associated molecular structures. Lipid-associated bands were consistently observed at approximately 3011, 2924, 2854, and 1745 cm^{-1}. The Amide I and Amide II bands occurred within

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026

1636.84–1641.72 cm⁻¹ and 1541.93–1542.14 cm⁻¹, respectively, confirming protein-associated spectral features in all samples.

Phenolic- and carbohydrate-related C–O absorption bands were observed between approximately 1018.57 and 1239.10 cm⁻¹. Overall, the results demonstrate that the four samples possessed broadly similar molecular signatures, with minor variations in peak positions among market sources.

3.3 Comparative Spectral Characteristics of Processed Powdered Pepper Samples

The comparative assessment of the FTIR spectra showed that all samples exhibited moisture-associated hydroxyl, protein-associated amide, lipid-associated, phenolic-related, and pigment-related spectral features. However, differences in relative spectral intensity and peak characteristics were observed among the samples.

As summarized in Table 2, the Modern Market and control samples exhibited relatively stronger moisture-related spectral responses. Protein-associated amide bands were detected in all samples, although the North Bank sample showed a slight shift in the Amide I band to 1641.72 cm⁻¹, indicating a variation in the local molecular environment of protein-associated structures.

Lipid-associated C–H stretching and ester carbonyl bands were consistently observed across all samples. Phenolic- and pigment-related spectral features were comparatively more pronounced in the North Bank sample. These observations suggest that, despite broadly similar molecular profiles, differences in commercial processing and post-harvest handling may have influenced the relative spectral characteristics of specific functional groups.

Table 2. Comparative physicochemical characteristics of processed powdered pepper samples.

Parameter	Wurukum	Modern	North Bank	Control
Moisture-related bands	Moderate	High	Moderate	High
Protein-related bands	High	High	Moderate	High
Lipid-related bands	High	Moderate	High	High
Phenolic compounds	Moderate	Moderate	High	Moderate
Pigment compounds	Moderate	Moderate	High	Low

3.4 Statistical Comparison of Selected FTIR Spectral Responses

The statistical analysis showed significant differences among samples for selected moisture-, protein-, and pigment-related spectral responses, whereas lipid- and phenolic-related spectral responses did not differ significantly (Table 3).

Table 3. Analysis of variance of physicochemical characteristics.

Physicochemical property	p-value	Significance
Moisture	0.045	Significant
Protein	0.025	Significant
Lipids	0.465	Not significant
Phenolics	0.165	Not significant
Pigments	0.045	Significant

Significance was determined at $p < 0.05$.

As presented in Table 3, moisture-related ($p = 0.045$), protein-related ($p = 0.025$), and pigment-related ($p = 0.045$) spectral responses differed significantly among the samples. Conversely, lipid-related ($p = 0.465$) and phenolic-related ($p = 0.165$) spectral responses showed no statistically significant differences.

These results indicate that the FTIR spectral characteristics associated with moisture, protein, and pigment-related functional groups varied more substantially among the samples than those associated with lipids and phenolic compounds. The statistical findings provide the basis for the interpretation presented in the Discussion section.

4.0 Discussion

4.1 Moisture-Related Spectral Characteristics

The broad O–H stretching bands observed between 3358.18 and 3361.67 cm⁻¹ in Figure 1 and Table 1 indicate the presence of hydroxyl-containing and moisture-associated molecular structures in all powdered pepper samples. Although the peak positions were relatively similar, variations in spectral responses were observed among the samples. As summarized in Table 2, the Modern Market and control samples exhibited relatively stronger moisture-related spectral features. Statistical analysis in Table 3 further showed significant differences among the samples ($p = 0.045$).

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026

The observed variation may be associated with differences in drying efficiency, packaging, storage conditions, and exposure to environmental humidity. Moisture is an important quality factor in powdered spices because excessive water availability may accelerate microbial deterioration and reduce storage stability. Previous studies have similarly demonstrated that drying and storage conditions influence moisture retention and the physicochemical stability of pepper products [3], [4]. However, the FTIR results should be interpreted as differences in moisture-associated spectral responses rather than direct measurements of absolute moisture content. Nevertheless, the significant variation observed in Table 3 suggests differences in the molecular environment associated with hydroxyl groups among the commercially processed samples.

4.2 Protein-Related Spectral Characteristics

The Amide I and Amide II bands identified in Figure 1 and Table 1 occurred within the ranges of 1636.84–1641.72 cm^{-1} and 1541.93–1542.14 cm^{-1}, respectively. These absorption bands are characteristic of protein-associated peptide structures. Although all samples exhibited these bands, slight differences in peak position and spectral response were observed. Notably, the North Bank sample showed a shift in the Amide I band to 1641.72 cm^{-1}.

The statistical analysis presented in Table 3 indicated significant differences in protein-associated spectral responses among the samples ($p = 0.025$). Such variation may reflect differences in protein molecular environments resulting from processing conditions, particularly drying and thermal exposure. Heat treatment can influence hydrogen bonding and protein conformation, thereby producing changes in amide-related FTIR bands [9], [10].

The results do not necessarily indicate differences in absolute protein concentration. Rather, they suggest variations in protein-associated molecular structures or interactions. The presence of distinct Amide I and Amide II bands in all samples nevertheless indicates that protein-associated constituents remained detectable following commercial processing.

4.3 Lipid-Related Spectral Characteristics

Lipid-associated absorption bands were consistently observed in all samples, as presented in Figure 1 and Table 1. These included bands near 3011 cm^{-1}, associated with unsaturated C–H stretching, bands around 2924 and 2854 cm^{-1} corresponding to aliphatic CH_2 vibrations, and an ester carbonyl band near 1745 cm^{-1}. The similarity of these absorption bands indicates broadly comparable lipid-associated molecular features among the samples.

As shown in Table 2, only minor differences were observed in the relative lipid-related spectral responses. This observation was supported by the statistical analysis in Table 3, which showed no significant difference among the samples ($p = 0.465$). The absence of significant variation suggests that the commercial processing and handling conditions may not have substantially altered the lipid-associated spectral characteristics of the powdered pepper samples. Similar stability of lipid-related components during conventional pepper processing has been reported previously [11]. However, because the present study was based on comparative FTIR characterization, the findings should not be interpreted as direct evidence of equal lipid concentrations.

4.4 Phenolic-Related Spectral Characteristics

The fingerprint region of the spectra contained C–O absorption bands associated with oxygen-containing molecular structures, including phenolic-related functional groups. As shown in Table 1, these bands occurred at approximately 1237.92–1239.10 cm^{-1} and 1018.57–1030.61 cm^{-1}. The North Bank sample exhibited relatively more pronounced phenolic-related spectral features, as summarized in Table 2. Despite these differences, the statistical analysis in Table 3 showed no significant variation among the samples ($p = 0.165$). This finding suggests that the phenolic-associated spectral characteristics were relatively similar across the commercially processed and control samples.

Phenolic compounds contribute to the antioxidant potential and functional quality of pepper. Their stability during processing depends on several factors, including drying temperature, oxygen exposure, and storage duration [1], [2]. The lack of statistically significant differences in the present study may indicate that the processing conditions did not produce substantial variation in the phenolic-related spectral features detectable under the applied FTIR procedure. Nevertheless, quantitative determination of total phenolic content would require complementary chemical analysis.

4.5 Pigment-Related Spectral Characteristics

Differences in pigment-related spectral features were observed among the samples in Figure 1 and Table 2. The North Bank sample exhibited relatively stronger pigment-associated spectral responses, whereas the control

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026

sample showed comparatively weaker responses. Statistical analysis in Table 3 confirmed significant differences among the samples ($p = 0.045$).

The observed variation may be associated with differences in the preservation of carotenoid-related molecular structures. Carotenoids, including capsanthin and capsorubin, contribute substantially to the characteristic colour of red pepper and are susceptible to degradation during processing and storage. Their stability may be influenced by drying temperature, oxygen exposure, light, packaging conditions, and storage duration [5], [6].

The stronger pigment-associated spectral response observed in the North Bank sample may therefore suggest comparatively better preservation of pigment-related molecular structures. However, this observation should not be interpreted as direct quantification of carotenoid concentration because no calibration model or complementary quantitative assay was employed. The significant spectral variation nevertheless demonstrates the sensitivity of FTIR spectroscopy for detecting differences in molecular characteristics among commercially processed pepper samples.

4.6 Overall Implications for Processing Quality and FTIR-Based Characterization

The comparative FTIR spectra presented in Figure 1, together with the peak assignments in Table 1, demonstrate that all samples possessed broadly similar molecular signatures characteristic of processed powdered pepper. The major functional groups associated with hydroxyl-containing compounds, proteins, lipids, and oxygen-containing molecular structures were detected in both commercial and laboratory-prepared samples.

However, the comparative results in Table 2 and statistical findings in Table 3 revealed differences in selected moisture-related, protein-related, and pigment-related spectral responses. These variations may reflect differences in processing, drying, packaging, storage, and market handling practices. The findings highlight the potential application of FTIR spectroscopy as a rapid and non-destructive tool for comparative characterization and preliminary quality assessment of processed spices. Unlike conventional analytical procedures, FTIR permits simultaneous examination of multiple functional groups with minimal sample preparation. However, the technique should be complemented with validated quantitative chemical analyses where absolute concentrations of moisture, proteins, phenolic compounds, lipids, or carotenoids are required.

Overall, the study provides baseline spectral information on commercially processed powdered pepper sold in Makurdi and demonstrates that market samples may exhibit detectable differences in molecular characteristics. Such information may support future development of rapid screening procedures for spice quality monitoring, processing evaluation, and food authentication.

5.0 Conclusion

Processed powdered pepper is widely consumed as a culinary spice and represents an important source of proteins, lipids, phenolic compounds, carotenoids, and other bioactive constituents that contribute to its nutritional, functional, and sensory qualities. However, variations in post-harvest processing, drying, packaging, and storage practices may alter its physicochemical composition and overall quality. Therefore, this study investigated the physicochemical characteristics of processed powdered pepper obtained from major markets in Makurdi, Benue State, Nigeria, using Fourier Transform Infrared (FTIR) spectroscopy integrated with statistical analysis to evaluate the molecular composition of the samples and assess the influence of commercial processing on key quality attributes.

The FTIR spectra successfully identified characteristic absorption bands corresponding to hydroxyl (O–H) stretching at 3358.18–3361.67 cm^{-1}, unsaturated lipid (=C–H) stretching at 3010.85–3011.11 cm^{-1}, aliphatic CH_2 stretching at 2923.88–2923.97 cm^{-1} and 2853.99–2854.09 cm^{-1}, ester carbonyl (C=O) groups at 1744.61–1744.75 cm^{-1}, protein-associated Amide I and Amide II bands at 1636.84–1641.72 cm^{-1} and 1541.93–1542.14 cm^{-1}, respectively, together with phenolic C–O stretching bands within 1237.92–1239.10 cm^{-1} and carbohydrate/phenolic-related bands between 1018.57 and 1030.61 cm^{-1}. The fingerprint region (1500–400 cm^{-1}) further confirmed the presence of phenolic compounds and carotenoid-related molecular structures, demonstrating that the processed pepper samples retained the characteristic biochemical constituents of *Capsicum* spp.

Comparative evaluation of the FTIR spectra showed that, although all samples exhibited similar molecular profiles, differences existed in the intensity of moisture-related, protein-related, and pigment-related functional groups. Statistical analysis further demonstrated significant differences in moisture ($p = 0.045$), protein ($p = 0.025$), and pigment-related ($p = 0.045$) functional groups among the market samples, whereas lipid ($p = 0.465$) and phenolic ($p = 0.165$) functional groups showed no significant differences. These findings indicate that commercial drying, milling, packaging, and storage practices primarily influenced moisture retention, protein conformation, and carotenoid stability while exerting comparatively little effect on lipid composition and phenolic constituents.

The study further demonstrates that FTIR spectroscopy is a rapid, reliable, and non-destructive analytical technique for assessing the physicochemical characteristics and molecular quality of processed powdered pepper.

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026

Compared with conventional analytical methods, FTIR offers rapid compositional assessment with minimal sample preparation while simultaneously identifying multiple biochemical constituents, making it a valuable tool for routine quality control, authenticity verification, adulteration detection, and quality assurance within the spice industry.

Overall, this study provides important baseline information on the molecular characteristics of commercially processed powdered pepper marketed in Makurdi and highlights the need for standardized drying procedures, improved hygienic processing practices, moisture-resistant packaging, and controlled storage conditions to preserve nutritional quality, antioxidant compounds, and colour stability. The findings also demonstrate the potential application of FTIR spectroscopy as a routine quality assessment tool for regulatory agencies, food industries, and research institutions.

References

Adedayo, M. R., Ojo, O. M., & Ogunbanwo, S. T. (2021). Assessment of nutritional and microbial quality of dried pepper sold in Nigerian markets. *Journal of Food Quality*, 2021, 1–8. https://doi.org/10.1155/2021/6631953

Ajayi, I. A., Ojewumi, M. E., & Afolabi, A. O. (2021). *Biochemical and antioxidant properties of five Nigerian pepper varieties. Nigerian Food Journal*, 39(1), 24–32. https://doi.org/10.4314/nifoj.v39i1.4

Alewijn, M., Akridopoulou, V., Venderink, T., Müller-Maatsch, J., & Silletti, E. (2023). Fusing one-class and two-class classification–A case study on the detection of pepper fraud. *Food Control*, *145*, 109502.

Aremu, M. O., Olaofe, O., & Akintayo, E. T. (2020). Comparative study on the nutritional and physicochemical properties of pepper varieties commonly consumed in Nigeria. *Heliyon*, 6(2), e03399. https://doi.org/10.1016/j.heliyon.2020.e03399

Azeez, L., Alabi, O., & Adedosu, O. T. (2020). *Quality assessment of dried and ground chili peppers sold in selected Nigerian markets. International Journal of Food Properties*, 23(1), 1300–1313. https://doi.org/10.1080/10942912.2020.1793852

Bosland, P. W., & Votava, E. J. (2018). *Peppers: Vegetable and Spice Capsicums* (2nd ed.). CABI Publishing.

Deepa, N., Kaur, C., George, B., Singh, B., & Kapoor, H. C. (2019). Antioxidant constituents in some sweet pepper (*Capsicum annuum L.*) genotypes during maturity. *LWT - Food Science and Technology*, **41**(3), 557–563.

Holden, A. C., Cohen, H., Berry, H. M., Rickett, D. V., Aharoni, A., & Fraser, P. D. (2024). Carotenoid retention during post-harvest storage of *Capsicum annuum*: The role of the fruit surface structure. *Journal of Experimental Botany, 75*(7), 1997–2012. https://doi.org/10.1093/jxb/erad482

Nwankwo, J. O., Chukwujindu, M. A., & Obi, M. E. (2021). *Quality assessment of ground pepper sold in Nigerian markets. International Journal of Agricultural and Food Science*, 11(4), 230–236.

Oladipo, I. C., Omojowo, F. S., & Adelowo, F. E. (2017). *Effect of drying methods on functional and microbial quality of ground pepper. International Journal of Food Science and Biotechnology*, 2(6), 116–122.

Olatunde, O. O., Ogunsola, M. O., & Bello, O. (2020). Retention of vitamin C in pepper processed under different drying conditions. *Journal of Culinary Science & Technology*, 18(2), 130–141

Olatunji, T. L., & Afolayan, A. J. (2019). *The suitability of wild and cultivated Capsicum species for food and medicinal applications. Foods*, 8(10), 456. https://doi.org/10.3390/foods8100456

Olawale, A. S., & Akinola, A. A. (2018). *Comparative study of sun and solar drying techniques on the physicochemical properties of dried chili pepper. Journal of Applied Sciences and Environmental Management*, 22(9), 1425–1430.

Olawuyi, A. T., Salami, A. O., & Adebayo, O. T. (2019). Influence of traditional processing methods on the physicochemical properties of food condiments: A case of dried pepper. *International Journal of Food Science and Nutrition*, 4(1), 29–35.

Onuorah, S. C., Agbo, J. U., & Eze, E. (2021). *Comparative study on microbial and sensory quality of locally processed and packaged ground pepper in South-Eastern Nigeria. Journal of Food Safety and Hygiene*, 7(1), 52–59.

Ramos-Aguilar, O. P., de Jesús Ornelas-Paz, J., Ruiz-Cruz, S., Zamudio-Flores, P. B., Cervantes-Paz, B., Gardea-Béjar, A. A., ... & Reyes-Hernández, J. (2015). Effect of ripening and heat processing on the physicochemical and rheological properties of pepper pectins. *Carbohydrate Polymers*, *115*, 112-121.

Robson, K., Dean, M., Haughey, S., & Elliott, C. (2021). A comprehensive review of food fraud terminologies and food fraud mitigation guides. *Food Control*, *120*, 107516.

Rybak, K., Wiktor, A., Pobiega, K., Witrowa-Rajchert, D., & Nowacka, M. (2021). Impact of pulsed light treatment on the quality properties and microbiological aspects of red bell pepper fresh-cuts. *Lwt*, *149*, 111906.

Sanatombi, K., & Rajkumari, S. (2020). Effect of processing on quality of pepper: A review. *Food Reviews International*, *36*(6), 626-643.

Sanatombi, K., & Sharma, G. J. (2021). *Capsaicin in chili peppers: Pharmacological and food industry perspectives. Frontiers in Nutrition*, 8, 706732. https://doi.org/10.3389/fnut.2021.706732

Sharangi, A. B., Upadhyay, T. K., Alshammari, N., Saeed, M., & Al-Keridis, L. A. (2022). Physico-chemical properties of red pepper (Capsicum annuum L.) as influenced by different drying methods and temperatures. *Processes*, *10*(3), 484.

Sung, M. S., Kang, H. J., & Kim, Y. S. (2012). Relationship between physicochemical and sensorial properties of red pepper powder under different storage conditions. *Journal of The Korean Society of Food Science and Nutrition*, *41*(10).

Tyohemba, R. L., Agbe, C. O., & Abu, S. T. (2019). Assessment of food crop marketing in selected markets in Makurdi, Benue State. *Nigerian Journal of Agriculture, Food and Environment*, 15(3), 60–66.

Van Ruth, S. M., Huisman, W., & Luning, P. A. (2017). Food fraud vulnerability and its key factors. *Trends in Food Science & Technology*, *67*, 70-75.

Woldemariam, H. W., Admassu Emire, S., Getachew Teshome, P., Toepfl, S., & Aganovic, K. (2021). Physicochemical, functional, oxidative stability and rheological properties of red pepper (Capsicum annuum L.) powder and paste. *International Journal of Food Properties*, *24*(1), 1416-1437.

Yilmaz, E., Güneşer, O., & Gültekin-Özgüven, M. (2021). Fatty acid composition and nutritional evaluation of red pepper seed oil. *Journal of Food Processing and Preservation*, 45(6), e15450

Zhang, Q., Huang, S., Soladoye, O. P., Zhang, Y., & Fu, Y. (2024). Preparation, pungency, and bioactivity of capsaicin: A review. *International Journal of Food Science & Technology, 59*(9), 6659–6687. https://doi.org/10.1111/ijfs.17291

Received: 11/08/2026; Revised: 30/08/2026; Accepted: 31/08/2026; Published: 07/09/2026