Original Research Article

Analysis Structure of Paracetamol in Traditional Drugs with Fourier Transform Infrared (FTIR)

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ABSTRACT

The increasing consumption of traditional medicines in Indonesia has raised major safety concerns due to the adulteration of herbal products with pharmaceutical chemicals such as paracetamol. Such practices are carried out illegally to enhance therapeutic effects, yet they violate national regulations and pose serious health risks. This study aimed to investigated the presence of undeclared paracetamol in traditional medicine samples using Fourier transform infrared (FTIR) spectroscopy. Two herbal samples (Sample A and Sample B) were analyzed in the spectral range of 400–4000 cm^{-1} and compared with a paracetamol reference standard. Characteristic absorption bands of paracetamol were identified at 3300-3600 cm^{-1} (O–H), 3100-3500 cm^{-1} (N–H), 1600-1820 cm^{-1} (C=O), 1475-1600 cm^{-1} (aromatic C=C), and 1375-1450 cm^{-1} (CH_3). The spectrum of Sample A showed no evidence of these key bands, indicating the absence of paracetamol. In contrast, Sample B exhibited strong concordance with the reference, including distinct peaks at 3396 cm^{-1} (O–H), 3232 cm^{-1} (N–H), 1616 cm^{-1} (C=O), and 1436 cm^{-1} (CH_3), confirming adulteration. Sample A was free of paracetamol, whereas Sample B contained it, pointing to the need for stricter quality control of traditional medicines. FTIR offers a rapid and practical screening method, but confirmatory techniques or quantitative analytical techniques such as thin layer chromatography (TLC), UV–visible spectrophotometry, and high-performance liquid chromatography (HPLC) remain essential to ensure accuracy and consumer safety are still required to ensure accurate results and consumer safety.

Keywords: Paracetamol, FTIR, Pharmaceutical chemical, Traditional drugs

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1.0 Introduction

Traditional medicine is one of Indonesia's cultural heritages that remains widely utilized by the community, primarily because it is perceived as more natural, relatively safe, and affordable. It is regarded as an indigenous formulation of Indonesia, typically derived from natural ingredients, particularly plants, although in certain cases animal-derived substances may also be employed (1). For generations, traditional medicines have been prepared and consumed in various dosage forms, including infusions, powders, liquids, pills, and capsules. According to national health research data, the use of traditional medicine in Indonesia has steadily increased. This trend is largely attributed to the declining purchasing power of the population toward synthetic drugs, as well as the widespread perception that traditional drug is generally safer and more natural compared to synthetic alternatives (2).

The World Health Organization (WHO) reports that in many countries across Asia, Africa, and the Americas, herbal medicine is commonly used as a secondary form of treatment. In fact, in Africa, nearly 80% of the population relies on herbal remedies as their primary form of healthcare(3). Similarly, data from Indonesia's Basic Health Research (RISKESDAS) indicate that traditional medicine continues to be highly valued, with approximately 59.12% of Indonesians still consuming traditional remedies, of which 95.6% use them for therapeutic purposes (4). However, alongside this increasing demand, the problem of adulteration has also emerged, namely the addition of pharmaceutical chemical substances (*Bahan Kimia Obat,* BKO) into traditional medicines to enhance efficacy and boost sales. Surveillance conducted by the Indonesian National Agency of Drug and Food Control (BPOM) in 2024 revealed that the circulation of illegal traditional medicines (OBA) adulterated with BKO has continued to occur year after year. Between 2021 and 2023, more than 700 cases of illegal OBA were recorded, most of which contained BKO and were distributed without marketing authorization. The circulation of such adulterated products was not only concentrated domestically, particularly in East Java, Jakarta, and West Java, Indonesia but also extended to international markets, with cases reported in 14 countries (5). This practice poses serious health risks, particularly due to potential contraindications in patients with certain medical conditions (6). These findings highlight that adulteration constitutes a significant public health problem that requires strict regulatory oversight.

Among the synthetic drugs frequently detected, paracetamol is one of the most common adulterants found in traditional medicines. This is due to its wide availability, low cost, and rapid analgesic–antipyretic effects. Nevertheless, uncontrolled use of paracetamol can result in severe adverse effects, ranging from hepatotoxicity to renal failure (6). Indonesian regulations, as stipulated in the Ministry of Health Regulation No. 246/Menkes/Per/V/1990 on Licensing of Traditional Medicine Industries and Registration of Traditional Medicines, explicitly prohibit the addition of pharmaceutical chemical substances into traditional medicines (7). On the other hand, WHO emphasize quality and safety assurance in herbal medicines, particularly through contaminant monitoring, prevention of adulteration, and implementation of good manufacturing practices (GMP). This approach aligns with Indonesian regulations, which strictly prohibit the incorporation of pharmaceutical compounds into traditional medicine (8).

To detect the presence of synthetic adulterants, various analytical methods have been developed, one of which is Fourier transform infrared (FTIR) spectroscopy. FTIR is an analytical technique used to identify compounds based on the absorption of infrared radiation

by molecular bonds, which induces vibrational changes and produces a characteristic infrared spectrum (9). FTIR has been widely applied in the study of herbal adulteration due to several advantages, including rapid analysis, minimal sample destruction, and the ability to identify mixtures within complex matrices (10). Although generally considered a non-destructive technique, its application depends on the sample preparation method. According to Patkowska *et al.* (2025) (11) the use of attenuated total reflectance (ATR) enables direct sample analysis and is relatively non-destructive, whereas the KBr pellet method may alter or damage the sample. Several previous studies have reported the successful application of FTIR in detecting paracetamol in traditional drug, confirming that this compound is among the most frequently encountered pharmaceutical adulterants in traditional medicine (12–14). The present study reinforces these findings by highlighting FTIR as a rapid screening method for the qualitative identification of paracetamol in traditional medicines, thereby contributing to quality control and regulatory monitoring efforts.

2.0 Materials and methods

The analysis was carried out using a FTIR spectrophotometer (Shimadzu IRPrestige-21) equipped with an ATR accessory. Operational parameters were set at a resolution of 4 cm^{-1}, with 32 scans per spectrum, covering the range of 400–4000 cm^{-1}. Paracetamol tablets were finely ground using a porcelain mortar and pestle, and a small portion of the powder was directly placed on the ATR crystal for spectrum acquisition. Herbal product samples (Sample A and Sample B) were first dried at room temperature, pulverized into fine powder, and analyzed under the same conditions. Each measurement was performed in triplicate to ensure repeatability.

The recorded spectra were compared to that of the standard paracetamol tablet, with emphasis on identifying characteristic absorption bands corresponding to functional groups of paracetamol (O–H/N–H stretching ~3325 cm^{-1}, amide C=O stretching ~1655 cm^{-1}, and C–N stretching ~1250 cm^{-1}). This study applied a qualitative approach; therefore, while FTIR is suitable for detecting functional groups, it does not provide quantitative confirmation of paracetamol content. As such, the findings should be interpreted as preliminary, and complementary confirmatory techniques such as thin layer chromatography (TLC) or high-performance liquid chromatography (HPLC) are recommended to validate results.

3.0 Results

Based on the functional group conformation results obtained through FTIR analysis of Paracetamol tablets, Sample A, and Sample B, it was found that Sample B likely contains paracetamol, whereas Sample A does not contain paracetamol as a pharmaceutical chemical substance. This conclusion is supported by comparing the FTIR spectra and the functional group identification descriptions of the Paracetamol tablet, Sample A, and Sample B, as shown in Tables 2, 3, and 4 respectively. In the paracetamol tablet, all functional groups corresponding to the molecular formula $C_8H_9NO_2$ were successfully identified using FTIR. These include 8 carbon atoms, 9 hydrogen atoms, 2 oxygen atoms, and 1 nitrogen atom, consistent with the structure of paracetamol as shown in Table 1 and Figure 1 (15). The identified functional groups include C–H, C=C, C=O, N–H, O–H, and CH_3 as seen in Figure 1 and Figure 2 which are the spectral forms of paracetamol standards and paracetamol tablets. In contrast, Sample A showed only the presence of C–H, C=C, C=O, and O–H groups, while N–H and CH_3 were not detected as showed in the results

of the spectrum analysis in Figure 3. Sample B, however, showed all the characteristic functional groups of paracetamol: C–H, C=C, C=O, N–H, O–H, and CH_3 as evidenced by the spectrum analysis in Figure 4. According to studies by Nakkeran *et al*. (2016) (16) and Permatasari *et al*. (2022) (14), that these functional groups typically appear at the following infrared wavelengths: the C–H group is observed around 790 cm^{-1}, 800 cm^{-1}, and 3000 cm^{-1}; the O–H group around 3300 cm^{-1}; the C=O group around 1600 cm^{-1} and 1700 cm^{-1}; the CH_3 group near 1400 cm^{-1}; and the C=C group around 1500 cm^{-1} and 1600 cm^{-1}. Lastly, the N–H group is also detected near 3286 cm^{-1} (14,16).

The results indicate that the sample A does not contain the $C_8H_9NO_2$ compound found in paracetamol. The functional groups present in sample A show no similarity to those in paracetamol, particularly due to the absence of the N–H and CH_3 groups, which are characteristic of paracetamol. In contrast, the sample B was found to contain paracetamol, as evidenced by the presence of functional groups that closely match those of paracetamol, including the specific functional groups and their corresponding wavelengths listed in Table 3. Therefore, sample B is deemed unsuitable for consumption, as the use of BKO, such as paracetamol, is not permitted under traditional drug standards (14).

Table 1: FTIR reference guideline for paracetamol functional groups.

Functional Group	Range Number
C – H (Stretching)	750 – 810 cm^{-1}
C – H (Stretching)	2853 – 2962 cm^{-1}
C – H (Stretching)	3010 – 3095 cm^{-1}
C = C (Aromatic)	1475 – 1600 cm^{-1}
C = C (Aromatic)	1600 – 1680 cm^{-1}
C = O (Carbonyl)	1600 – 1820 cm^{-1}
N – H (Amide)	3100 – 3500 cm^{-1}
O – H (Hydroxyl)	3300 – 3600 cm^{-1}
CH_3 (Metyl)	1375 – 1450 cm^{-1}

Table 2: Functional group conformation results of paracetamol tablets.

Functional Group	Wave Number
C – H (Stretching)	796,08 cm^{-1}; 807,56 cm^{-1}
C – H (Stretching)	2931,17 cm^{-1}
C – H (Stretching)	3036,60 cm^{-1}
C = C (Aromatic)	1505,39 cm^{-1}; 1562,05 cm^{-1}
C = C (Aromatic)	1651,70 cm^{-1}
C = O (Carbonyl)	1609,38 cm^{-1}
N – H (Amide)	3110,47 cm^{-1}
O – H (Hydroxyl)	3322,04 cm^{-1}
CH_3 (Metyl)	1437,26 cm^{-1}

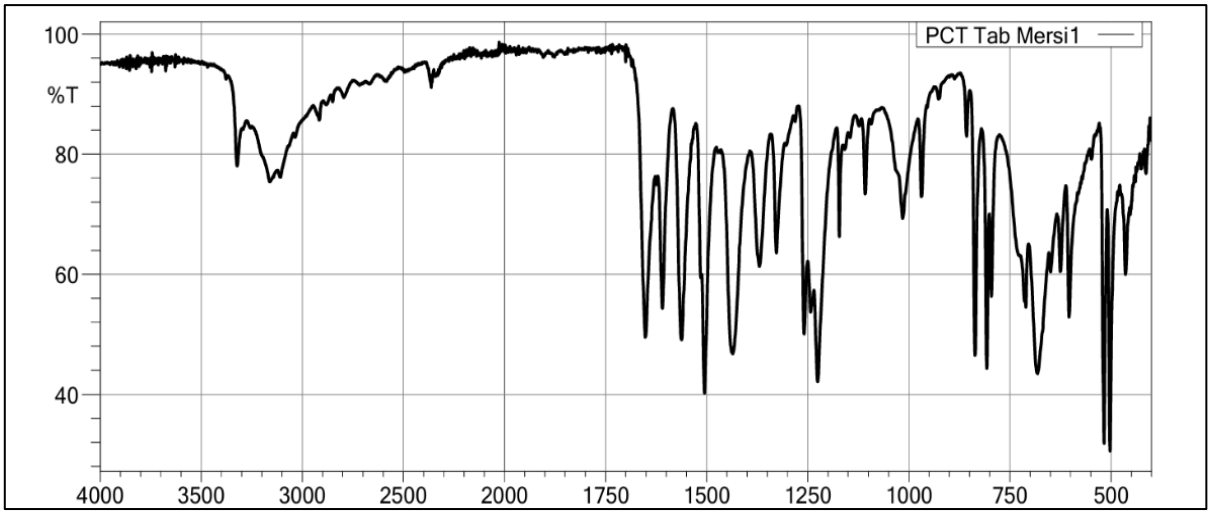

Fig. 1: Spectrum of paracetamol tablet.

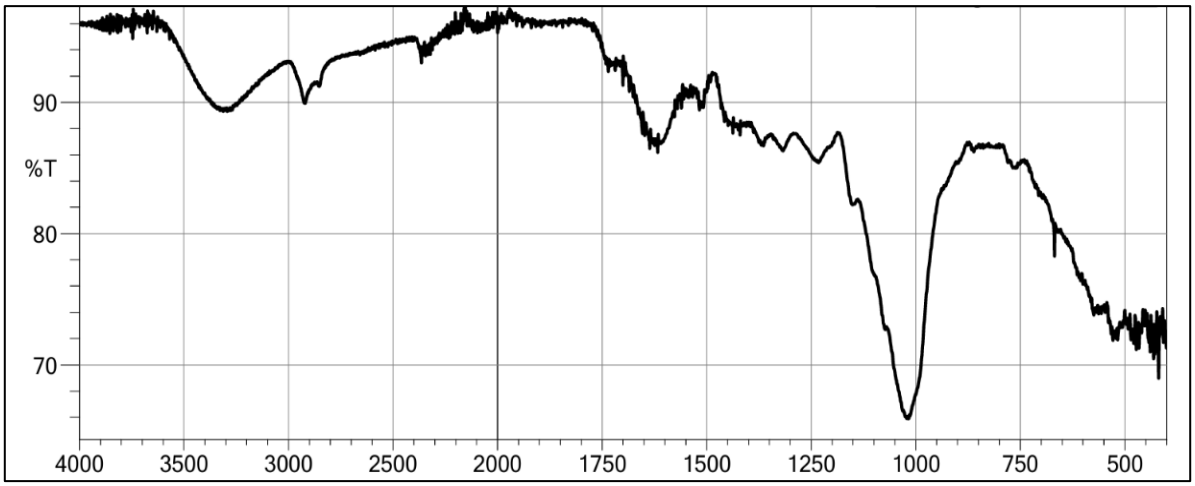

Fig. 2: Spectrum of Sample A.

Table 3: Functional group conformation results of sample A.

Functional Group	**Wave Number**
C – H	768,11 cm^{-1}
C = C (Aromatic)	1512,56 cm^{-1}
C = O	1612, 25 cm^{-1}
N – H	-
O – H	3305,54 cm^{-1}
CH_3	-

Table 4: Functional group conformation results of sample B.

Functional Group	Wave Number
C – H	720,06 cm^{-1}
C – H (Stretching)	2914,67 cm^{-1}; 2941,93 cm^{-1}
C = C (Aromatic)	1506,82 cm^{-1}; 1576,39 cm^{-1}
C = C	1675,36 cm^{-1}
C = O	1616,55 cm^{-1}
N – H	3232,39 cm^{-1}
O – H	3396,91 cm^{-1}
CH_3	1436,54 cm^{-1}

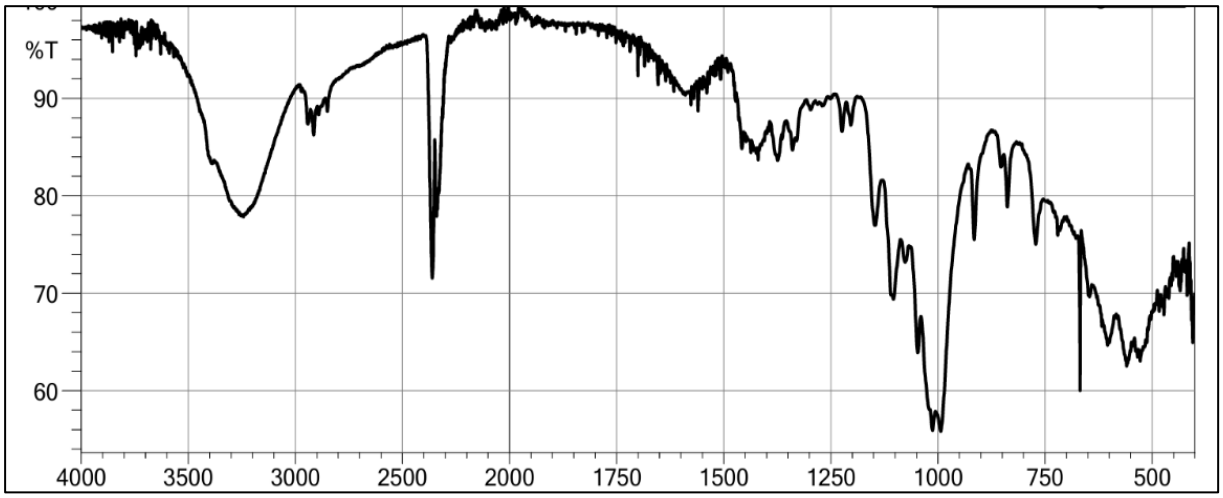

Fig. 3: Spectrum of sample B.

4.0 Discussion

Traditional medicine is a form of traditional medicine that has been passed down through generations and remains an integral part of Indonesian health culture. In principle, traditional medicine is formulated using natural ingredients derived from medicinal plants such as ginger (*Zingiber officinale*), clove (*Syzygium aromaticum*), and aromatic ginger (*Kaempferia galanga*), etc, without the addition of synthetic compounds or BKO. According to research by Oktoviani *et al.* (2023) (17), the inclusion of BKO in traditional medicine is strictly prohibited, as the dosage is often unknown, posing a significant risk of harmful side effects. Excessive levels of BKO in traditional medicine can lead to serious health issues, including liver, kidney, and heart damage, as well as digestive problems such as nausea and vomiting. Moreover, long-term consumption may cause severe organ damage and, in extreme cases, even death.

Packaged traditional medicines are often supplemented or adulterated with chemicals. Anti-inflammatory drugs, or analgesic, such as paracetamol, are often illegally mixed into traditional medicines by manufacturers who violate the law to make herbal medicines more effective. Based on various findings regarding traditional medicine to treat pain and disease that have been reported and published by the BPOM, paracetamol is frequently found in traditional medicine. If consumed excessively and for long periods, paracetamol can cause fatal side effects, including visual disturbances, diarrhea, skin rashes, blood disorders, kidney failure, hypersensitivity reactions, and liver damage due to overdose, nausea, dizziness, chest pain, and even death (18).

FTIR has many advantages, such as the ability to work with samples in various physical forms, non-destructive analysis, and high sensitivity, however, a critical review of this technique is also necessary. FTIR spectroscopy is used to identify similarities between a sample and a reference standard by analyzing the correspondence of specific functional groups in the compound. Compared to other methods such as CNMR and HNMR spectroscopy, which provide more in-depth information about the molecular structure because they can identify the chemical shifts of different types of carbon atoms, NMR is not only used to determine the structure and number of functional groups in a chemical compound, but also has broad applications in advanced medical imaging. The accuracy of FTIR analysis results is highly dependent on certain factors such as the choice of experimental conditions, sample preparation, and spectrum interpretation. However, research using the FTIR method has several limitations including its sensitivity to impurities and solutions. The presence of certain impurities or solvents can affect the accuracy of the analysis results. Therefore, careful sample preparation and selection of experimental conditions are key to optimizing FTIR performance (19). FTIR spectra are often complex and require specialized expertise for accurate interpretation. Multiple peaks in a spectrum can overlap, and variations in experimental conditions can produce significant differences in the spectra. FTIR spectra of complex biological materials or mixtures often exhibit overlapping peaks. This complicates the identification of specific functional groups and can lead to misinterpretation of the data (20).

5.0 Conclusion

In this study, we concluded that FTIR spectroscopy confirmed that paracetamol tablets contain functional groups that match the molecular structure of $C_8H_9NO_2$. Sample A was shown not to contain paracetamol, as no matching functional groups were identified. In contrast, Sample B was found to contain paracetamol, as indicated by the presence of functional groups similar to those in the reference

paracetamol sample. These findings highlight the need for stricter quality control of traditional medicines. FTIR can be applied as a rapid and practical screening tool, but confirmatory methods or quantitative analytical techniques such as TLC, UV–visible spectrophotometry, and HPLC remain essential to ensure accuracy and consumer safety.

Authorship contribution statement

PEP: Conceptualization, Investigation, Data collection, Writing-original draft. **HJP:** Data collection, Data analysis, Writing–review & edit. **HAZ:** Data collection, Data Analysis, Writing–review & edit. **NBL:** Data collection, Data Analysis, Writing–review & edit. **FNL:** Data collection, Data Analysis, Writing–review & edit. **FAR:** Correspondent, Methodology, and Data Analysis.

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Conflict of Interest

The authors declared that they have no conflicts of interest to disclose.

References

1. Mei Nanda Zavitra S, Ajeng Listyani T, Hidayat R. *Tingkat Pengetahuan Masyarakat Terhadap Penggunaan Obat Herbal sebagai Pengganti Pengobatan Konvensional di Kelurahan Nusukan, Kecamatan* Banjarsari, Surakarta. J Sci Mandalika. 2025;6(7):1850–61.

2. Kamar I, Fazrina Zahara1 DY, Umairah RU. *Identifikasi Parasetamol dalam Jamu Pegal Linu Menggunakan Metode Kromatografi Lapis Tipis (KLT) Quimica : Jurnal Kimia Sains dan Terapan.* J Kim Sains dan Terap. 2021;3(April):1.

3. World Health Organization (WHO). WHO Traditional Medicine Strategy 2014-2023. World Heal Organ. 2013;1–76.

4. *Kementrian Kesehatan Republik Indonesia. Riset Kesehatan Dasar* (Riskesdas) 2010. *Repository Kemenkes RI [Internet]. Badan Kebijakan Pembangunan Kesehatan*; 2010 [cited 2025 Sep 25]. Available from: URL: https://repository.badankebijakan.kemkes.go.id/id/eprint/4417

5. *Direktorat Cegah Tangkal. Laporan Tahunan 2024 Direktorat Cegah Tangkal. Badan Pengawas Obat dan Makanan RI* [Internet]; 2024 [cited 2025 Sep 30]. Available from: URL: https://www.pom.go.id/storage/sakip/Laporan%20Tahunan%20Direktorat%20Cegah%20Tangkal%20Tahun%202024.pdf

6. Khan Z, Abumedian M, Ibekwe M, Musa K, Mlawa G. Acute renal impairment in patients due to paracetamol overdose in the absence of hepatic impairment. Cureus. 2021;13(12):1–5.

7. *Kementrian Kesehatan Republik Indonesia. Peraturan Menteri Kesehatan Nomor* 246/Menkes/Per/V/1990 *tentang lzin Usaha lndustri Obat Tradisional dan Pendaftaran Obat Tradisional. Direktorat Jenderal Farmalkes* 1990 [Internet]. Kementrian Kesehatan RI; 1990 [cited 2025 Sep 26]. Available from: URL: https://farmalkes.kemkes.go.id/unduh/permenkes-246-1990/

8. World Health Organization. Guidelines for Assessing Quality of Herbal Medicines with Reference to Contaminants and Residues. WHO IRIS [Internet]. World Health Organization; 2007 [cited 2025 Sep 27]. Available from: URL://www.who.int/publications/i/item/9789241594448

9. Abriyani E, Syalomita D, Apriani IP, Puspawati I, Adiputra S. *Pengaruh Pengolahan Termal Terhadap Struktur Molekul Material Polimer Studi Dengan Spektroskopi* FTIR. Innov J Soc Sci Res. 2024;4(1):3424–32.

10. Smith BC. Introduction to infrared spectroscopy. In: Foundamentals of Fourier transform infrared spectroscopy 2nd ed. Boca Raton: CRC Press; 2011. p. 1–18.

11. Pasieczna-Patkowska S, Cichy M, Flieger J. Application of Fourier transform infrared (FTIR) spectroscopy in characterization of

green synthesized nanoparticles. Molecules. 2025;30(3):1–36.

12. Wahyuningsih E, Dessidianti R. *Aplikasi FT-IR ATR Spektroskopi untuk Identifikasi Parasetamol pada Jamu Sediaan Serbuk Application of FT-IR ATR Spectroscopy to Identificate Paracetamol in Herbal Powder Preparations.* Clin Pharm Anal Pharm Community J. 2022;1(2):56–60.

13. Azminah A, Ahmad I, Fikri JAN, Jumadil MI, Erza NAF, Abdullah S, *et al.* Rapid detection of synthetic adulterants in Indonesian herbal medicines using ATR-FTIR spectroscopy combined with chemometrics. J Res Pharm. 2023;27(1):184–95.

14. Permatasari DAI, Setyowati R, Mahardika MP. Qualitative and quantitative analysis of paracetamol contamination in rheumatic pain traditional medicine. J Farm Sains dan Prakt. 2022;8(1):48–59.

15. Saragih S, Suprianto S, Samran S. *Analisis Parasetamol Tablet dengan Metode Fourier Transform Infra Red (FTIR)*. J Indah Sains dan Klin. 2024;5(3):24–30.

16. Nakkeeran C, Selvakumari P, Kasthury T, Kumar RT. FTIR analysis on nilavembu kudineer churanam and acetominaphen. J Chem Pharm Res. 2016;8(3):634–9.

17. Oktoviani, Taurina H, Gunusari LFV, Oktiarni D. *Edukasi peredaran obat tradisional mengandung bahan kimia obat (BKO) berbahaya pada generasi Z di* Madrasah Sanawiah Negeri 02 Kota Bengkulu. J Abdimas Saintika. 2023;5(1):11–5.

18. UZ LZ, Pomalingo DR. *Analisis kandungan paracetamol pada jamu pegal linu di kawasan bintaro dengan metode*. Pros SEMLITMAS Disem Penelit Pengabdi Masy. 2025;2(1):54–60.

19. Yang X, Wei X, Yu K, Wan C, Wang Y, Huang S, *et al*. Identification of myocardial fibrosis by ATR-FTIR spectroscopy combined with chemometrics. Spectrochim Acta Part A Mol Biomolcular Spectrosc. 2022;264:120238.

20. Nugroho I, Putri N, Adji JEP, Nur SR, Nadya AS. *Tinjauan kritis kemampuan Fourier transform infrared spectroscopy (FTIR) dalam analisis dan karakterisasi senyawa obat.* J Ilm Wahana Pendidik. 2014;10(15):332–44.