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A Review on Extraction, Isolation and Separation Technique Studies of Musa Acuminata

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Abstract: *Banana leaves are a rich source of bioactive compounds, including glycosides, alkaloids, and phenolics, which have been reported to possess various pharmacological activities. However, the efficient extraction, isolation, and separation of these compounds from banana leaves remain a significant challenge. This review aims to provide a comprehensive overview of the existing extraction, isolation, and separation techniques employed for the recovery of bioactive compounds from banana leaves. The reviewed techniques include solvent extraction, microwave-assisted extraction, ultrasound-assisted extraction, supercritical fluid extraction, and chromatographic separation methods. The advantages, limitations, and potential applications of each technique are discussed. Furthermore, the review highlights the need for the development of more efficient and sustainable extraction and separation methods to fully exploit the therapeutic potential of banana leaf bioactives.*

Keywords: banana leaves, extraction methods, antioxidants, bioactive compounds, Medicinal Plants

I. INTRODUCTION

The banana is a herbaceous plant with three genera (Musa, Musella, and Ensete) that belong to the Musaceae family (Probojati et al., 2021). Musa acuminata and M. balbisiana are the main species that produce edible bananas (Brown et al., 2017). According to their ploidy, bananas are classified as diploid , triploid or tetraploid . According to the most recent Food and Agriculture Organization statistics (FAOSTAT; 2019), India is the leading banana producer with an annual production of 30,460,000 tons, followed by China and Indonesia. Globally, banana is the most affordable, widely available crop, and more than 1000 banana varieties (Table 1), which differ in their color, taste, and chemical composition, are produced and consumed. The banana is commonly known as the dessert cultivar, while the plantain is referred to as the cooking cultivar. Banana plants are grown primarily for their fruit and, to a lesser extent, for making wine, and natural fibers (Khoozani et al., 2019). They are also used for shading, and the leaf of the tree is suitable for packaging large volumes of food due to its large surface area and waxy nature (Ahmadi et al., 2019).

The banana is one of the most widely distributed and consumed fruit in tropical and subtropical countries (Laillyza et al., 2014). Nutritionally, it is one of the world's leading food crops with its high contents of minerals, vitamins, carbohydrates, flavonoids, and phenolic compounds (Imam and Akter, 2011). M. balbisiana is a species of banana, which is popular in Thailand. All parts of the banana plant can be used: the fruit and inflorescences can be used as food; and the roots and trunks can be used as herbal medicines. The trunk can be used to make fiber to weave ropes. Banana leaves also have a wide range of applications because they are large, flexible, and waterproof. So, they are used for cooking, wrapping and serving food. They are also used for decorative and symbolic purposes in Buddhist ceremonies. The leaves of M. balbisiana are an undervalued commodity with a limited commercial value, which can be considered as an agricultural industry by-product and waste (Padam et al., 2014).

Extraction Techniques

Extraction is a critical initial step in isolating bioactive compounds from Musa acuminata Several techniques have been utilized, each with its advantages and limitations, depending on the target compounds and the desired yield.

1. Maceration

Maceration is one of the oldest and simplest extraction methods, involving soaking plant materials in solvents at ambient temperature. The process is straightforward and requires minimal equipment, making it accessible. However, maceration has drawbacks, such as long extraction times and the potential for lower yields. For Moringa oleifera,

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maceration is effective in extracting phenolic compounds, though it may require high solvent volumes and longer durations to achieve satisfactory yields.

Procedure of Maceration

• The plant material is finely ground or crushed to increase the surface area for better solvent penetration.
• The material is then submerged in a solvent such as water, ethanol, methanol, or a solvent mixture.
• The solvent is kept in contact with the material for an extended period, typically ranging from a few hours to several days, depending on the type of material, solvent, and target compounds.
• Stirring or occasional shaking may be applied to enhance the extraction process.
• After maceration, the solvent containing the extracted compounds (the filtrate) is separated from the solid plant material by filtration or decantation.
• The solvent is often evaporated to obtain a concentrated extract, which can then be used for further studies or applications.

Maceration Process

2. Soxhlet Extraction

This method involves a continuous solvent reflux, where the solvent repeatedly passes through the plant material, enhancing extraction efficiency. Soxhlet extraction is widely used due to its high yield potential for heat-stable compounds. However, it requires long extraction times and large amounts of organic solvents, which may limit its environmental sustainability and cost-effectiveness. Soxhlet extraction has been effectively used to isolate various bioactive compounds from Musa acuminata, including Glycosides other phenolic constituents.

Process:

• The round-bottom flask containing the solvent is heated, causing the solvent to evaporate and travel upwards.
• The vapor reaches the condenser, where it cools and condenses, then drips into the extractor chamber containing the plant material.
• The solvent gradually fills the chamber, allowing the target compounds to dissolve into the solvent.
• Once the chamber reaches a certain level, it siphons back down to the flask, carrying the dissolved compounds with it.
• cycle repeats continuously, with fresh solvent contacting the plant material until the extraction process is complete.

3. Ultrasound-Assisted Extraction (UAE)

UAE utilizes ultrasonic waves to disrupt cell walls, enhancing the release of bioactive compounds. The method is particularly advantageous due to its speed, low solvent requirement, and ability to extract heat-sensitive compounds, as it operates at lower temperatures. UAE has shown high efficacy in extracting antioxidants, phenolics, and Alkaloids glycosides, from Musa acuminata, making it a suitable choice for preserving delicate compounds while reducing extraction time and energy costs.

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Procedure of Ultrasound-Assisted Extraction

• Preparation: The plant material is usually ground or cut into smaller pieces to increase surface area.

• Sonication Setup: The sample is placed in an extraction vessel with a suitable solvent, and an ultrasonic probe or bath generates ultrasonic waves.

• Extraction Process: Ultrasonic waves are applied for a specified duration, typically ranging from a few minutes to an hour, depending on the plant material, solvent, and target compounds.

• Filtration and Concentration: After extraction, the solvent containing the dissolved compounds is filtered to separate the solid residue. The solvent may then be evaporated to yield a concentrated extract.

4. Microwave-Assisted Extraction (MAE)

MAE employs microwave energy to heat solvents and plant materials, improving the efficiency of the extraction process. The method is known for its rapid processing times, reduced solvent usage, and high yields of bioactive compounds. MAE has been successfully applied in extracting Musa acuminata bioactive compounds, such as glucosinolates and saponins, due to its ability to disrupt plant cell matrices and release intracellular compounds effectively. One limitation is the potential degradation of heat-sensitive components if the temperature is not carefully controlled.

Procedure of Microwave-Assisted Extraction

• Preparation: The plant material is often dried and ground to increase surface area.

• Microwave Setup: A microwave reactor or microwave-assisted extraction system is used, containing the plant material and solvent in an extraction vessel.

• Extraction Process: The vessel is subjected to microwave irradiation, rapidly heating the solvent and plant matrix for a specified time (usually a few minutes).

• Filtration and Concentration: After extraction, the solvent is filtered to separate the plant residue. The solvent may then be evaporated or further processed to concentrate the extract.

5. Supercritical Fluid Extraction (SFE)

SFE uses supercritical fluids, typically carbon dioxide (CO_2), to extract non-polar compounds, offering selectivity, rapid extraction times, and minimal solvent residue. SFE is particularly effective for extracting lipophilic compounds such as alkaloids, glycosides and lipids Musa acuminata and CO_2's non-toxic and non-flammable nature makes it an environmentally friendly choice. However, SFE requires specialized equipment and may have limited effectiveness for polar compounds unless co-solvents are used.

Procedure of Supercritical Fluid Extraction

• Preparation: The plant material is dried and ground to increase the extraction surface area.

• Supercritical Setup: The material is placed in an extraction chamber, and CO_2 is pumped under high pressure, becoming supercritical in state.

• Extraction Process: Supercritical CO_2 passes through the plant matrix, dissolving target compounds. The $CO_2$and extracted compounds then flow into a separation chamber, where $CO_2$is depressurized back to its gaseous state.

• Collection and Recovery: As CO_2 becomes a gas again, it releases the extracted compounds, which can then be collected. The CO_2 can be recycled for additional extractions, making the process environmentally efficient.

6. Hydrodistillation

Commonly used for extracting essential oils, hydrodistillation involves passing steam through the plant material to vaporize volatile compounds, which are then condensed and collected. Although efficient for isolating essential oils, hydrodistillation is limited in extracting non-volatile bioactive compounds. For Cymbopogon Citratus, hydrodistillation has been used to extract essential oils from seeds and leaves, though it may not be ideal for other bioactives.

• Preparation: Plant material is often dried and sometimes chopped or ground to improve extraction efficiency.

• Loading: The plant material is loaded into a distillation chamber with either water or directly exposed to steam, depending on the specific method.

• Heating and Extraction: The chamber is heated, releasing essential oils and volatile compounds as steam.
• Condensation and Separation: The vaporized essential oils and water pass through a condenser, turning into a liquid that collects in a separator. Since essential oils are typically immiscible with water, they form a separate layer that can be easily isolated.

Isolation and Separation Techniques

Once the compounds are extracted, further isolation and separation are required to purify specific bioactive compounds. Techniques used for Moringa oleifera include chromatography, electrophoresis, and other advanced methods, each with varying degrees of specificity and resolution.

1. Chromatography: Chromatography techniques, including thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC), and gas chromatography (GC), are widely used for separating and purifying bioactive compounds. HPLC is particularly effective in isolating Moringa compounds due to its high resolution and versatility in separating different types of compounds based on polarity and molecular weight. TLC is often used for initial screening and rapid qualitative analysis, while GC is suitable for volatile compounds such as essential oils. Chromatographic methods have been widely applied in isolating citral, geraniol, isogeranial .

2. Electrophoresis: Electrophoretic techniques, such as capillary electrophoresis (CE), offer high- resolution separation based on the charge-to-size ratio of molecules. Capillary electrophoresis is suitable for analyzing glycoside smaller bioactive compounds and offers rapid analysis with minimal sample and solvent requirements. However, it may be less effective for larger, non-ionic compounds, limiting its application for certain glycoside constituents.

3. Liquid-Liquid Extraction (LLE): LLE separates compounds based on their solubility in different solvents. It is a simple yet effective technique for fractionating Glycoside racts into polar and non-polar components. LLE has been used as a preliminary separation step before further purification, particularly for isolating hydrophilic and lipophilic compounds in Glycoside extracts.4. Preparative HPLC: This technique is an advanced form of HPLC used to isolate large quantities of purified compounds for further study or application. Preparative HPLC has proven effective in isolating alkaloids and glycoside bioactive constituents with high purity, though it requires sophisticated equipment and expertise.

II. CONCLUSION

The present study were qualitatively analyzed some potential phytochemicals from popular waste banana peels and plants. Most of the phytochemicals are the essential raw materials for food and pharmaceuticals industries which are imported every year. Banana peels and plants are being wasted after consumption and collection of banana fruit. It has become a vital concern of environmental pollution. This two types of materials would be a great source of extraction of phytochemicals which are important raw materials for food and pharmaceuticals industry. Every year all over the world huge amount of phytochemicals are being imported by food and pharmaceuticals industries. Even Bangladesh imported such kind of phytocompound for their demand of raw materials of food industries. Phytochemicals isolation would be a great currency saving method by extraction and purification of some chemicals which actually needed for food and pharmaceuticals industries. So establishing an allied industry would be a better idea to isolation and purification of phytochemicals from this types of waste materials. At the same time it will be helps to reduce environmental pollution by using this waste materials. After purification this waste pose materials would be a suitable fertilizer for our agricultural land.

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