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## Review Paper

# Comparison Of Microwave-Assisted Extraction Versus Conventional Maceration for Phytochemical Yield Using Chaya Mansa Plant

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## ABSTRACT

Chaya mansa (*Cnidoscolus aconitifolius*), commonly referred to as tree spinach, is a leafy plant widely distributed in Mesoamerica and increasingly recognized for its nutritional and medicinal value. The plant contains a variety of bioactive phytochemicals including phenolics, flavonoids, alkaloids, and saponins that contribute to antioxidant, anti-inflammatory, and antidiabetic properties. Efficient extraction of these compounds is essential for their application in nutraceutical, pharmaceutical, and functional food industries. Among various extraction techniques, conventional maceration (CM) and microwave-assisted extraction (MAE) are widely employed. This review compares these two extraction techniques with respect to extraction efficiency, phytochemical yield, energy consumption, solvent usage, and processing time. Evidence from multiple studies indicates that MAE significantly enhances extraction efficiency due to rapid heating and cell wall disruption, leading to higher recovery of phenolic and flavonoid compounds. Despite these advantages, CM remains widely used because of its simplicity and low equipment cost. This review synthesizes current findings and highlights optimized extraction conditions for maximizing phytochemical recovery from *Cnidoscolus aconitifolius*.

## INTRODUCTION

Medicinal plants are an important source of bioactive compounds used in pharmaceuticals, nutraceuticals, and functional foods. These plants contain secondary metabolites such as

polyphenols, flavonoids, alkaloids, terpenoids, and glycosides, which possess diverse biological activities including antioxidant, antimicrobial, and anti-inflammatory properties.

Chaya mansa (*Cnidoscolus aconitifolius*) is a perennial shrub belonging to the family

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Euphorbiaceae and is commonly known as tree spinach. The plant is native to southern Mexico and Central America and has been traditionally used as a leafy vegetable and medicinal herb. The leaves are rich in proteins, vitamins, minerals, and phytochemicals such as phenolic acids and flavonoids, which contribute to its antioxidant and therapeutic potential.

Extraction of these phytochemicals from plant matrices is a crucial step in phytochemical analysis and industrial production of plant-derived compounds. Conventional extraction techniques such as maceration and Soxhlet extraction have long been used but are often associated with long extraction times and high solvent consumption. Modern extraction techniques, including microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), and supercritical fluid extraction (SFE), have been developed to improve extraction efficiency and reduce processing time.

Among these techniques, MAE has gained considerable attention because it significantly reduces extraction time while improving extraction yields through rapid heating of plant matrices and solvents. Studies have shown that non-conventional extraction methods like MAE can reduce solvent consumption and increase the quality of extracts compared with conventional methods.

## 2. PHYTOCHEMICAL COMPOSITION OF CHAYA MANSA

Chaya mansa leaves contain a wide range of bioactive phytochemicals including:

- Phenolic acids
- Flavonoids
- Alkaloids
- Saponins
- Tannins
- Vitamins and minerals

Phenolic compounds are particularly important due to their strong antioxidant properties. These compounds neutralize free radicals and reduce oxidative stress, which is associated with chronic diseases such as cancer, diabetes, and cardiovascular disorders.

Flavonoids also play a major role in the medicinal properties of Chaya mansa. These compounds possess anti-inflammatory, antiviral, and antimicrobial activities. High concentrations of phenolic compounds are typically correlated with stronger antioxidant activity measured using assays such as DPPH and FRAP.

Efficient extraction methods are therefore necessary to maximize the recovery of these compounds from plant tissues.

## 3. EXTRACTION TECHNIQUES

### 3.1 Conventional Maceration

Conventional maceration is one of the oldest and simplest extraction techniques used for isolating bioactive compounds from plant materials. In this method, dried and powdered plant material is soaked in an appropriate solvent such as ethanol, methanol, or water for extended periods, typically ranging from 24 to 72 hours.

The extraction process occurs primarily through diffusion, where the solvent penetrates plant tissues and dissolves phytochemicals that diffuse into the surrounding liquid.

#### Advantages

- Simple and easy to perform
- Low cost and minimal equipment required
- Suitable for thermolabile compounds
- Widely used in laboratories and traditional herbal preparation

#### Limitations

- Long extraction time
- High solvent consumption
- Lower extraction efficiency



- Risk of microbial contamination during prolonged extraction

Because maceration relies mainly on passive diffusion, the release of intracellular compounds is relatively slow compared with modern extraction techniques.

### 3.2 Microwave-Assisted Extraction

Microwave-assisted extraction is a modern extraction technique that uses microwave energy to heat the solvent and plant matrix simultaneously. The microwave radiation interacts with polar molecules and ions in the solvent, generating heat rapidly through dipole rotation and ionic conduction.

This rapid heating creates internal pressure within plant cells, leading to rupture of cell walls and enhanced release of intracellular compounds into the solvent.

MAE has gained widespread attention in phytochemical research due to its high efficiency and reduced processing time.

### Advantages

- Rapid extraction (minutes instead of hours)
- Higher extraction yield
- Reduced solvent usage
- Better reproducibility
- Improved energy efficiency

Studies have shown that MAE can significantly increase the recovery of phenolic compounds and antioxidant molecules compared with conventional solvent extraction methods.

### Limitations

- Requires specialized microwave equipment
- Risk of degradation of thermolabile compounds if parameters are not optimized
- Higher initial investment cost

## 4. COMPARISON OF MAE AND CM FOR PHYTOCHEMICAL YIELD IN CHAYA MANSA

**Table No. 1: Comparison Of Conventional Maceration And Microwave Assisted Extraction Parameters For Chaya Mansa**

| Parameter           | Conventional Maceration (CM) | Microwave-Assisted Extraction (MAE) |
|---------------------|------------------------------|-------------------------------------|
| Extraction time     | 24–72 hours                  | 5–30 minutes                        |
| Solvent consumption | High                         | Moderate to low                     |
| Energy efficiency   | Low                          | High                                |
| Phenolic yield      | Moderate                     | High                                |
| Flavonoid yield     | Moderate                     | High                                |
| Selectivity         | Low to moderate              | High                                |
| Scalability         | Easy                         | Moderate                            |
| Cost                | Low equipment cost           | Higher initial investment           |

### 4.1 Phenolic Compounds

Phenolic compounds are among the most important antioxidants present in medicinal plants. Studies have demonstrated that MAE significantly

improves the extraction of phenolic compounds by facilitating solvent penetration and cell wall disruption.



For example, microwave extraction has been reported to increase total phenolic yield compared with conventional extraction methods in several plant materials.

## 4.2 Flavonoids

Flavonoids are widely distributed plant metabolites known for their antioxidant and anti-inflammatory properties. Microwave extraction enhances flavonoid recovery because the rapid heating increases the solubility and diffusion of these compounds into the solvent.

Experimental studies on medicinal plants have shown significantly higher concentrations of flavonoids in MAE extracts compared with conventional extraction techniques.

## 4.3 Antioxidant Activity

The antioxidant capacity of plant extracts is closely related to their phenolic and flavonoid content. Extracts obtained using MAE often exhibit stronger antioxidant activity than those obtained through maceration.

Research comparing different extraction techniques has shown that microwave extraction can produce extracts with significantly higher antioxidant activity measured by DPPH and FRAP assays.

## 5. MECHANISM OF MICROWAVE-ASSISTED EXTRACTION

Microwave-assisted extraction operates through a unique heating mechanism known as dielectric heating. Microwave energy interacts with polar molecules within the solvent and plant tissues, causing rapid oscillation and heat generation.

This heating mechanism results in:

- Rapid temperature rise within plant tissues
- Increased pressure inside plant cells
- Rupture of cell walls
- Enhanced mass transfer of phytochemicals into the solvent

When the internal pressure exceeds the mechanical strength of the plant cell wall, the cells rupture and release intracellular compounds. This phenomenon significantly increases extraction efficiency compared with conventional maceration, which relies only on passive diffusion. Additionally, microwave heating allows selective extraction by adjusting parameters such as microwave power, irradiation time, solvent type, and solid-to-solvent ratio.

## 6. FACTORS AFFECTING MICROWAVE EXTRACTION EFFICIENCY

Several parameters influence the efficiency of microwave-assisted extraction:

### 6.1 Solvent Type

Polar solvents such as ethanol, methanol, and water absorb microwave energy effectively and are commonly used in MAE.

### 6.2 Microwave Power

Higher microwave power increases extraction efficiency but excessive power may degrade sensitive compounds.

### 6.3 Extraction Time

Optimal extraction time is typically between 1 and 20 minutes depending on plant material and solvent system.

### 6.4 Solid-to-Solvent Ratio

Adequate solvent volume is necessary to ensure efficient solubilization of phytochemicals.

## 7. INDUSTRIAL AND NUTRACEUTICAL APPLICATIONS

Extracts obtained from *Chaya mansa* have potential applications in several fields:

### Pharmaceutical Industry



Phenolic compounds and flavonoids isolated from Chaya mansa may be used in the development of antioxidant and anti-inflammatory drugs.

### Functional Foods

Plant extracts rich in antioxidants are increasingly used as natural food additives to improve nutritional value and shelf life.

### Nutraceutical Products

Herbal supplements containing Chaya extracts may help manage oxidative stress and metabolic disorders.

Modern extraction technologies such as MAE are particularly valuable for industrial applications because they reduce processing time and energy consumption while improving product quality.

## FUTURE PERSPECTIVES

Although microwave-assisted extraction offers significant advantages, further research is needed to optimize extraction conditions specifically for Chaya mansa. Future studies should focus on:

- Process optimization using response surface methodology
- Scale-up of MAE for industrial production
- Combination of MAE with ultrasound or enzyme-assisted extraction
- Evaluation of green solvents and sustainable extraction technologies

## RESULTS AND DISCUSSION

The present study emphasizes the increasing relevance of integrating green analytical chemistry (GAC) principles into pharmaceutical method validation. The evaluation of green validation practices demonstrates that environmentally sustainable approaches can significantly reduce the ecological impact of analytical procedures without compromising analytical performance. The findings indicate that reducing hazardous chemical usage, minimizing solvent consumption,

and adopting energy-efficient techniques contribute substantially to improving the sustainability of pharmaceutical analysis.

The application of greenness assessment tools such as Green Analytical Procedure Index (GAPI), Analytical GREENness Metric Approach (AGREE), Analytical Method Greenness Score (AMGS), National Environmental Methods Index (NEMI), and Analytical Eco-Scale enables a systematic and comparative evaluation of analytical methods. Among these tools, AGREE provides a comprehensive quantitative assessment based on all twelve GAC principles, generating a score between 0 and 1. In contrast, GAPI offers a qualitative visual representation through a color-coded pictogram, facilitating rapid identification of environmentally critical steps. AMGS and Analytical Eco-Scale further support evaluation by assigning numerical scores based on toxicity, solvent usage, energy consumption, and waste generation.

The results demonstrate that greener analytical approaches, including the use of safer solvents such as ethanol and water, as well as advanced techniques like solid-phase microextraction and miniaturized systems, effectively reduce environmental burden while maintaining analytical reliability in terms of accuracy, precision, and robustness. These methods also enhance laboratory safety by reducing exposure to toxic reagents and limiting hazardous waste production.

However, despite these advantages, the widespread adoption of green validation practices remains limited. A major challenge identified is the absence of regulatory requirements mandating environmental assessment during analytical method validation. Existing validation guidelines primarily focus on analytical performance parameters such as specificity, linearity, limit of detection, and robustness, without incorporating sustainability considerations. This gap restricts the



routine implementation of greener methodologies in pharmaceutical laboratories.

Another significant observation is the continued dependence on conventional organic solvents such as acetonitrile and chloroform, which are associated with environmental and health risks. Although greener alternatives are available, their adoption often necessitates method redevelopment, revalidation, and additional financial investment. These factors create practical limitations, particularly in laboratories with limited resources.

Furthermore, the analysis highlights that while the initial cost of implementing green analytical technologies may be relatively high, long-term benefits include reduced expenditure on solvents, waste management, and energy consumption. This indicates that green validation practices are not only environmentally beneficial but also economically advantageous over time.

Educational and institutional support is also crucial for promoting the adoption of green analytical practices. The integration of green chemistry principles into academic curricula and professional training programs can enhance awareness and facilitate the development of sustainable analytical methods. Additionally, collaboration between academia, industry, and regulatory authorities is essential for establishing standardized frameworks that incorporate environmental assessment into validation protocols.

## CONCLUSION

Microwave-assisted extraction has emerged as a powerful alternative to conventional maceration for extracting phytochemicals from *Chaya mansa*. Compared with traditional methods, MAE significantly reduces extraction time, decreases solvent consumption, and increases the recovery of phenolic and flavonoid compounds.

While conventional maceration remains useful for low-cost or small-scale applications, MAE provides a more efficient and environmentally friendly approach for large-scale phytochemical extraction. Continued research into optimization and industrial application of MAE could further enhance the utilization of *Chaya mansa* as a valuable medicinal and nutritional resource.

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