Performance comparison of maceration method, soxhletation method, and microwave-assisted extraction in extracting active compounds from soursop leaves (*Annona muricata*): A review

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**Abstract.** Soursop (*Annona muricata*) is a plant that is widely available in Indonesia. Of all parts of the soursop plant, the leaves are the most interesting parts to be studied. Soursop leaves are the most interesting part to be investigated because soursop leaves have many benefits and benefits that have been applied in the health sector, both traditional and modern. This is because soursop leaves contain many active compounds such as alkaloids, terpenoids, flavonoids, tannins, saponins, acetogenins, and others. The purpose of this review is to compare the best methods commonly used to extract active compounds from soursop leaves. The methods studied were maceration, soxhletation and microwave assisted extraction (MAE). The mechanism of the extraction processes and the percentage of yield achieved from the three methods are also reviewed. The results of the review show that MAE is the method that produces the highest yield of the three methods with a yield of 33.98%. This method also has another advantage that is a shorter extraction time.

1. Introduction
Soursop (*Annona muricata*) is a tropical plant found in several countries including Indonesia, and in Indonesia, this plant is called Sirsak. Soursop plants generally contain active compounds such as alkaloids, terpenoids, flavonoids, tannins, saponins, and others [1]. Soursop has many benefits, and the greatest benefits are found in the leaves [2].

![Figure 1. Soursop leaves](image)
The most beneficial application of active compounds from soursop leaves in the health sector is hypotension [3], anti-cancer [1], antineoplastic [4], antibacterial [5], antimicrobial [6], anti-tumor and anti-ovarian cancer [7], and others. Other active compounds found in soursop leaves that play a role in the health sector are acetonegins [8]. The process of taking active compounds contained in soursop leaves is carried out through an extraction process. Extraction is the process of taking compounds needed from raw material with various treatments [9]. Extraction plays an important role in producing health products and in other fields. The extraction process has been known for a long time and until now new methods continue to emerge that make the researchers have many choices for applying the extraction of various active components found in soursop leaves. This option offers various levels of ease of use. The researchers continue to optimize the extraction method to be able to obtain optimal results in a short time. This problem is not only a matter of time but also how to use and utilize environmentally friendly supporting materials so that it is safe for the environment and provides the best solution for extracting soursop leaves.

Unconventional extraction techniques do not forget the true extraction principle but instead focus on convenience. One of the conveniences offered by non-conventional methods is to shorten the extraction time. Soursop leaf extraction is generally carried out by several methods such as maceration, soxhletation, and microwave-assisted extraction (MAE). In this review, the three methods mentioned above will be reviewed based on the results of research conducted by several researchers, so it can be determined the best method that produces the highest yield in extracting soursop leaves.

2. Methods
The extraction process that will be discussed in this review is presented in Figure 2.

Figure 2 explains the general scheme for extracting active compounds from soursop leaves. Soursop leaves that have been taken from the tree first pass the pre-treatment stage before the extraction process is carried out. Pre-treatment is a special preparation stage for a raw material before it will be further processed. Pre-treatment that is done generally includes washing raw materials to remove impurities that stick to soursop leaves, drying soursop leaves using sunlight, or using an oven to reduce water content. In addition, pre-treatment can also convert soursop leaves into powder form by grinding or mashing to a certain particle size, which aims to expand the contact area with the solvent so that the extraction efficiency increases [10, 11]. After the pre-treatment stage is completed, then the selection of the soursop leaf extraction method is done. The extraction technique is a crucial stage because it will
determine how the extract is obtained. Extraction techniques are divided into two techniques namely conventional and non-conventional.

2.1 Conventional extraction techniques
Conventional extraction techniques are classic extraction techniques and extraction techniques that have long been found and are still used today which are based on extraction methods that use solvents or mixing and with the addition of heat. The conventional extraction techniques discussed in this review are the maceration method and the soxhletation method.

2.1.1 Maceration method. Maceration is one of the conventional methods of extraction that is very simple and the cheapest because it only requires a simple container as the place for extraction, but this method requires a long time for the extraction process [12]. The maceration method can be done anywhere and this method is most often used in extracting active compounds in soursop leaves. The container for the maceration method can be seen in Figure 3. The number of raw materials, the selection of solvents, and the correct extraction time are things that affect the effectiveness of this method. The extraction process by the maceration method is done by immersing the sample in the extracting solvent [13]. Table 1 shows some common solvents used in soursop leaf extraction by maceration methods, including methanol, ethanol, ethyl acetate, and distilled water. Some other solvents such as hexane, chloroform, butanol, propanol and others can also be used by considering the toxicity and price of the solvent.

![Figure 3. Simple container for maceration extraction method.](image_url)

2.1.2 Soxhletation methods. A soxhlet is a tool used in this extraction process. This tool consists of several parts including a heat source, round bottom flask, soxhlet extractor, and condenser which can be seen in Figure 4. At the laboratory scale, these tools are combined to extract soursop leaves. The sample is placed in a soxhlet extractor that has been wrapped in a thimble, and the solvent is poured into a distillation flask. The use of condenser devices in this extraction method aims to condense the evaporated solvent so that it can be reused. In table 2, there are several solvents such as methanol and water which have been used in soursop leaf extraction by the soxhletation method. Some other solvents that can potentially be used by considering the boiling point of the solvent are hexane, chloroform, butanol, propanol, and others. This method when compared with other methods, one of the advantages of this method does not require the separation of the extraction results [14].
2.2. Non-conventional extraction techniques
The unconventional extraction technique is the latest extraction technique with the advantage offered is a short extraction time. The conventional extraction technique discussed in this review is Microwave-Assisted Extraction (MAE).

2.2.1 Microwave-assisted extraction. Microwave-Assisted Extraction is an extraction technique using electromagnetic waves [15]. Microwaves are often used on a laboratory scale because they are small in size and easy to operate. A microwave that works by assisting electromagnetic waves makes the extraction time faster, only a few minutes. This is because all electromagnetic waves generated are converted directly into heat [11]. Microwave-assisted extraction schemes can be seen in Figure 5. Comparison of the amount of raw material, choice of solvent, microwave power, and extraction time is very influential on this extraction method. Table 3 shows that the ethanol solvent has been used as a soursop leaf extraction solvent using MAE. Based on these results, solvents such as acetone, acetonitrile, hexane, 2-propanol, and ethyl acetate can be studied as substitutes for ethanol. The choice of solvent in MAE is influenced by the dielectric constant which will affect the dissipation factor and microwave power [11].
3. Results and discussion

Table 1, Table 2, and Table 3 show the results of the work of several researchers who extracted soursop leaves by the maceration method, soxhletation method, and MAE.

**Table 1. Results of soursop leaf extraction by maceration method**

| Weight (g) | Solvent             | Immersion Time (days) | Yield (%) | Active Compound     | Reference |
|------------|---------------------|-----------------------|-----------|---------------------|-----------|
| 5,000      | Methanol            | 1                     | 10        | Acetogenins         | [7]       |
| 500        | Methanol            | 2                     | 7.26      | Alkaloid and sterols| [16]      |
| 6.5        | Methanol            | 5                     | 6.6       | Alkaloid and Acetogenins | [6] |
| 1,000      | Ethanol 98%         | 3                     | 12.5      | Phenolics and Flavonoid | [17] |
| 1,981      | Ethyl Acetate       | 4                     | 4.1       | Terpenoid           | [18]      |
| 1,190      | Distilled water     | 1                     | 32.96     | Alkaloid            | [19]      |
| 1,000      | Distilled water     | 2                     | 3.62      | Tannins and Polyphenolic | [20] |

**Table 2. Results of soursop leaf extraction by soxhletation method**

| Weight (g) | Solvent       | Extraction Time (h) | Yield (%) | Active Compound   | Reference |
|------------|---------------|---------------------|-----------|-------------------|-----------|
| 60         | Methanol      | 72                  | 29.13     | Phenolic and Flavonoid | [21] |
| 201        | Methanol      | 6                   | 24.9      | Flavonoid         | [22]      |
| 0.03       | Water         | 16                  | 4         | Flavonoid         | [5]       |

**Table 3. Results of soursop leaf extraction by MAE**

| Weight (g) | Solvent          | Microwave Power (W) | Extraction Time (minutes) | Yield   | Active Compound                    | Reference |
|------------|------------------|---------------------|---------------------------|---------|------------------------------------|-----------|
| 20         | Ethanol 70%      | 600                 | 10                        | 33.98%  | Phenolic                           | [23]      |
| unknown    | Ethanol          | 850                 | 5                         | 20 g    | Unspecified / whole extract content | [24]      |

The maceration method is a method that is easy to do, simple, and cheap so it is often used by researchers. The soxhletation method is a method that is often used as a comparison method to study the use of other methods [14]. The soxhletation method requires a faster extraction time in just a few hours compared to the maceration method which extracts for days.

Table 1 shows the results of soursop leaf extraction research data obtained on the maceration method with the highest yield of 32.96% by using distilled water solvent, and 12.5% by using 98% ethanol solvent. Table 2 shows the results of soursop leaf extraction research data using the soxhletation method with the highest yield of 29.13% by using methanol as the solvent. Table 3 shows the results of research data on soursop leaf extraction using MAE with the highest yield of 33.98% by using 70% ethanol solvent. Various kinds of solvents used by the researchers are methanol, ethanol, ethyl acetate, and distilled water. Besides the price, the selection of the solvent is also based on the level of polarity. These solvents offer a certain level of solubility for each solvent which is useful for optimizing
extraction yields [25]. Organic solvents are often used because they are easily obtained, however, at present the use of water as a solvent is preferred because it is cheaper and environmentally friendly. Based on the research results in Table 1, Table 2, and Table 3 it can be seen that the maceration method is the easiest method to do and uses cheaper equipment, but requires a long extraction time. Soxhletation method is a method that is generally carried out on a laboratory scale because it uses tools that are usually found in a laboratory. Both of these methods are conventional methods that need to be developed. One of the new methods is MAE which offers a shorter extraction time because it uses electromagnetic waves. This MAE method is a modification of the soxhletation extraction method which obtains a heat source from electromagnetic waves by using a microwave. Based on the yield obtained by the three methods, the highest yield is obtained by MAE with a yield of 33.98%. MAE offers faster extraction times and also produces high yields. Nevertheless, the publication of research results that use MAE in extracting soursop leaves is still small. Therefore this MAE has the potential to be developed by researchers in extracting soursop leaves.

4. Conclusion
Soursop leaves have the potential to be further investigated because they contain many active compounds that are efficacious in the health sector such as alkaloids, terpenoids, flavonoids, tannins, saponins, acetogenins, and others. There are three methods that can be used to extract active compounds from soursop leaves, namely the maceration method with solvent immersion, soxhletation with a solid-liquid extraction system, and microwave with electromagnetic waves. Each of these extraction methods offers various conveniences and drawbacks. The best method for extracting active compounds from soursop leaves is the MAE method with a yield of 33.98%.

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