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Review Article

Flavonoids as Antioxidants: A Review on Tempuyung Plant (Sonchus Arvensis)

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ABSTRACT

Flavonoids are prevalent in plants, fruits, and seeds; they are responsible for the colour, aroma, and flavour of things. Changes in the environment dramatically boost the antioxidant capacity and enzyme activity of flavonoid production. Yet, the significance of *in vivo* antioxidant function has recently come under question. Sonchus arvensis is a traditional herbal plant that can be found in Asia. This plant has many active compounds with many positive biological activities. Researchers worldwide have studied this plant's potential as medicine in recent years. It shows that this species has a high amount of flavonoid content which can act as an antioxidant. Hence, the aim of this article was to review the specific information about active compounds in Sonchus arvensis, especially the flavonoid content and its role as an antioxidant. This article was library research on the flavonoids contained in herbal plants, especially tempuyung (Sonchus arvensis). This article showed that Sonchus arvensis was considered herbal medicine with significant antioxidant activity. Therefore, Sonchus arvensis could be used as a potential raw material for medicine that would benefit human health. This plant should be further researched to understand the extraction and its effect as a medicine.

GRAPHICAL ABSTRACT

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Introduction

Indonesia is a nation with a rich biodiversity. It has a wide variety of medicinal and culinary plants and herbs. It is well-known that Indonesia is home to 9606 different species of medicinal plants [1]. 3-4% of them are used commercially as medicine [2] among which is Tempuyung plant (Sonchus ravenous) that can be used as herbal medicine [3]. It can be found easily in Indonesia. This plant attracts enormous attention from many researchers around the world because of various active compounds in it. This plant is classified into the Sonchus genus and belongs to the Asteraceae family. Several names, including water radish and Jombang clay, are known. It has strong roots, is upright physically, and contains sap. Tempuyung grows wild in places exposed to the sun or slightly sheltered and easily lives in Java [4]. The tempting plant is generally utilized as animal feed, fresh vegetables, and herbal medicine. This plant is believed can reduce urine acid levels, dissolve kidney stones, cure inflammation, prevent hypertension, treat burns, and can be used to minimize hearing loss. According to many researchers who studied about tempuyung plant, explain that this plant has a high content of active compounds such as flavonoid (Luteolin-7-O-glucoside, apigenin 7-O-glucoside), mineral ions (Silica, potassium, magnesium, and sodium), coumarin (Skepoletin), taraxasterol, inositol, and phenolic acid. Due to these compounds, the tempuyung plant or Sonchus arvensis has become an alternative medicine used by many people, mainly Indonesian.

Flavonoids are a sizable category of prokaryotic and plant secondary metabolites categorized as phenolic chemicals [5]. Flavonoids are prevalent in plants, fruits, and seeds. They are responsible for the colour, aroma, and flavour of things. Flavonoids play a variety of roles in plants, including controlling cell growth, luring insect pollinators, and defending against biotic and abiotic stressors [6]. Several flavonoids are essential components of herbal medicine and are used to regulate inflammation and prevent cancer since they are widely present in the human diet [7]. These substances' bioactive qualities, including as anti-inflammatory, anti-cancer, anti-ageing, cardioprotective, neuroleptic, immunomodulatory, anti-diabetic, anti-bacterial, anti-parasitic, and antiviral effects are linked to a variety of health advantages in humans. However, the chemical structure of flavonoids, especially the presence of hydroxy groups, affects bioavailability and bioactivity in humans. Flavonoids possess a basic 15-carbon flavone framework, C6 C3-C6, with two benzene rings (A and B) linked by a three-carbon pyran ring (C). The position of the catechol B ring on the C pyran ring and the number and place of hydroxy groups on the B ring catechol group affect the antioxidant capacity of flavonoids. Functional hydroxy groups of flavonoids can donate electrons by resonance to stabilize free radicals and provide antioxidant protection [8]. Flavonoids have several subtypes, including chalcones, flavones, flavonols, and isoflavones. These subgroups have unique primary sources. For example, onions and tea are the primary dietary sources of flavonols and flavones [9].

The flavonoids bioactivities that promote health are numerous. They still stand out among them because of their ability to act as antioxidants [10]. As phytochemicals, flavonoids cannot be synthesized by humans or animals. Thus, animal flavonoids are of plant origin rather than being biosynthesized *in situ*. The most prevalent flavonoid in foods are flavanols. Flavonoids, which give foods their colour and flavour, prevent fat from oxidizing, and protect vitamins and enzymes from harm [11]. Isoflavones, flavanols, and flavones from soy make up the majority of flavonoids included in the typical human diet. Catechin concentrations range from 4.5 to 610 mg/kg, despite the fact that most fruits and some legumes contain catechins. Depending on the technique used, cooking, processing, and eating can lower flavonoid levels. For instance, a recent study found that cloud concentrations of 206-644 mg/L were higher than those of 81-200 mg/L in orange juice, showing that flavanones were concentrated in the cloud during the processing and storage. Given the diverse diversity of flavonoids that are accessible, their extensive distribution in various plants, and their varying consumption in humans, it is challenging to estimate the typical dietary intake of flavonoids [12]. An appealing objective that satisfies the nutritional needs of a rising and increasingly demanding global population is increasing flavonoid content [13]. Flavonoids are thought to have lowering effects on people for a very long time. Changes in environmental circumstances have been shown to considerably boost the enzymes activity involved in flavonoid production and their antioxidant capability in numerous food species [14-16].

Humans experience intracellular metabolism of flavonoids, such as conjugation to glutathione and frequent O-methylation or glucuronidation of cyclic flavonoids. These structural alterations lessen the hydrogen atom-donating capacity of flavonoids. In the aqueous environment of cells, flavonoids are not very soluble (for example, flavonoids in plant cells are often glycosylated to improve their solubility in aqueous media cell medium), and flavonoid concentrations in plasma or most tissues ranged from high nanomoles (nM) to low micromoles (μM) [17].

Evidence-based epidemiological and pharmacological data have shown that flavonoids are essential in preventing and managing modern diseases. Total flavonoid content and antioxidant capacity are the focus of research on pharmaceutical and food applications of natural phytochemicals [18]. Flavonoids are abundant in plant-based foods and beverages, such as fruits, vegetables, tea, cocoa, and wine [19]. Hence, they are called dietary flavonoids.

Many studies about the tempuyung plant have been explored to find out the content of active compound and how to use it optimally as herbal medicine. One of the most important active substances in this plant is a flavonoid compound. The main functional groups in this chemical's structure are two benzenes, cyclohexane, and ether. It is a type of phenolic compound with 15 carbon atoms. Generally speaking, these substances can be divided into flavonols, flavones, and anthocyanins. Flavonoids can be found, extracted in several parts of the plant, and they are extensively found in vegetables and fruits. Not only for human medicine, but flavonoid also has a crucial role in biological activities in plants and animals. Due to its phenolic structure, its common flavonoid has essential responsibilities as a floral fragrance that help plant germination. For animals, a flavonoid also significantly affects their health, which can be an alternative to disease therapy. The high antioxidant ability makes flavonoids essential in treating diseases such as Alzheimer's, cancer, and atherosclerosis. Therefore, because of the flavonoids importance, this article will explain the flavonoid content in the tempuyung plant (Sonchus arvensis) and its function as an antioxidant.

Active compound content in the Tempuyung plant

According to many studies that have been conducted, the tempuyung plant is herbal medicine that has many active compound contents. Kartini *et al.* studied many potential Indonesian plant species for antioxidants, including Sonchus arvensis. They extracted dried leaves from tempting plant using ethanol as a solvent by reflux method, and then extracted compounds were determined using the Folin-Ciocalteu and colourimetric methods. The study shows that the tempuyung plant has a flavonoid content of about 3.78 ± 0.09 g of quercetin equivalents (QE) per 100 g thick extract [20]. Another study was also reported by Khan *et al.* [21], who analysed the total amount of phenolic compound and extraction yield in various fractions of Sonchus arvensis. The phenolic compounds in the Sonchus arvensis are extracted by multiple solvents, including methanol, chloroform, ethyl acetate, and *n*-hexane. The study shows that methanol extract has the most significant value of phenolic compound and the highest extraction yield, which is 420 ± 6.9 mg gallic acid equivalent (GAE mg/g extract) with a gain of 7.2%. After that, chloroform fraction can extract the compounds about 5.2% with total phenolic compounds is 315 ± 9.3 GAE mg/g extract.

Meanwhile, ethyl acetate and n-hexane have a total amount of phenolic compounds of about 292±3.0 and 131±2.3 GAE (Gallic Acid Equivalent) mg/g extract, respectively. The sample's phenolic compounds include rutin, myricetin, hyper side, catechin, orientation, kaempferol, and quercetin. Khan also reported quantitatively analysing flavonoid compounds in various fractions of Sonchus arvensis. Total flavonoid compounds in the methanol extract have also a higher value of 23.4±1.2 mg/g dry extract with 1.9±0.05 [21]. Moreover, research on active compound content in the tempuyung plant is also studied [22]. Table 1 presents Sonchus species extracts' extraction yields, phenolic contents, and flavonoid contents. It shows that Sonchus arvensis has a high yield of about 107.2±9.5 with the highest total phenolic content among the Sonchus species, is 417.3±38.3 mg/g (rutin per gram dry extract), and total flavonoid is 131.2±11.8 mg/g. The highest flavonoid extracted is owned by Sonchus oleraceus, 148.5±13.6 mg/g, slightly higher than Sonchus arvensis. Meanwhile, the highest extraction yield obtained by Sonchus brachyurous is 121.5±1.8 [22].

The total amount of active compounds in the tempuyung plant is influenced by many factors, including solvent selection, extraction method, conditions, and the tempuyung plants themselves. Tempuyung plants in each region will have different amounts of active compounds according to environmental influences. Besides flavonoid and phenolic compounds, this plant has many volatile compounds that can be utilized as anti-bacterial, antioxidant, anti-diarrhoeal, inhibits phagocytosis, and anti-cancer. Deylan (2016) reported that Sonchus arvensis has about 42 volatile compounds from the GC-MS analysis method. These compounds are mainly aliphatic hydrocarbon, aldehyde, ester, fatty alcohol, and a fatty acid group. The highest quantity is pentacosane, about 75 mg/kg. 9-Tricosene, Z-Tricosan about 23 mg/kg, Phytol 21.13 mg/kg, heneicosene about 18 mg/kg, and 1,2-benzene dicarboxylic acid, bis (2-methyl propyl) ester about 17.53 mg/kg. Higher hydrocarbons like pentacosane, heneicosene, and tetracosane have tremendous anti-bacterial activity. Higher fatty acid heptadecanoic acid can be an anti-inflammatory and anti-bacterial compound. Furthermore, the aldehyde compounds such as decanal, tetradecane, and 2,4-decadienal are highly recommended for antidiarrhoeal. In contrast, the ester compounds; namely, 1,2-benzene dicarboxylic acid, bis (2-methyl propyl), and 9,12,15-octadecadienoic acid, ethyl ester, have a significant effect to inhibits phagocytosis [23]. The summary of volatile compounds from the tempuyung plant and chromatogram from GC-MS analysis are given in Table 2 and Figure 1.

Flavonoid content and its antioxidant effect

One of the essential compounds in the tempuyung plant is a flavonoid. This compound is one of the most abundant components in tempuyung extract, which has excellent biological properties as an antioxidant. Among their groups, flavones and catechins are two flavonoid compounds with the most potent antioxidants. Flavonoids have high additive effects on endogenous scavenger compounds, which can protect the body against reactive oxygen species [9]. Flavonoids can be extracted in polar and semi-polar fractions with a total amount of 5.21 mgQ/g and 84.69 mgQ/g, respectively [24]. Many kinds of research have been conducted with many different quantitative analysis methods to determine the antioxidant activities of tempuyung plant.

Table 1: Total extraction, phenolic, and flavonoid contents of *Sonchus* species extracts

Extract	Extraction yield (mg extract/g dry material)	Total phenolic (mg gallic acid/g dry extract)	Total flavonoid (mg of rutin/g dry extract)
S. oleraceus	102.6 ± 9.2	388.4 ± 35.7	148.5 ± 13.6
S. arvensis	107.2 ± 9.5	417.3 ± 38.3	131.2 ± 11.8
S. asper	96.5 ± 8.7	302.6 ± 27.1	116.5 ± 10.2
S. uliginosus	100.3 ± 9.1	278.7 ± 24.4	89.7 ± 8.2
S. brachyotus	121.5 ± 1.8	343.6 ± 31.6	82.3 ±7.9
S. lingianus	98.7 ± 8.6	326.8 ± 29.7	133.7 ± 12.4

Source: Data analysed.

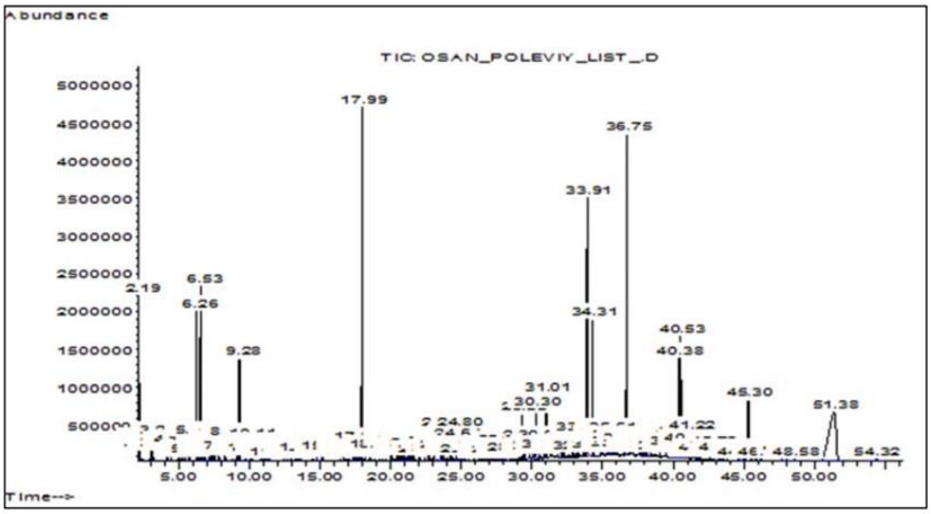

Figure 1: Chromatogram of volatile compounds of *Sonchus arvensis (*Source: Data analysed)

Table 2: Volatile compounds of *Sonchus arvensis* with their biological activities

S. No.	R/T	Name of the Compound	Compound Nature	Activity
1	14.78	Decanal	Aldehyde	Anti-diarrhoeal
2	18.57	2,4-Decadienal	Aldehyde	Anti-diarrhoeal
3	21.22	Tetradecane	Aliphatic hydrocarbon	Antibacterial, antioxidant
4	24.35	Pentadecane	Aliphatic hydrocarbon	Antibacterial, antioxidant
5	27.30	Hexadecane	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
6	30.15	Benzoic acid, 2-ethylhexyl ester	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
7	30.28	3-Tetradecene	Ester	Inhibit phagocytosis
8	31.00	Tetradecanoic acid	Aliphatic hydrocarbon	Anti-inflammatory, cancer preventive, anti-bacterial, anti-coronary
9	31.87	Octadecene	Fatty acid	Anti-bacterial
10	32.85	Tetradecanal	Aliphatic hydrocarbon	Anti-diarrhoeal
11	33.25	1,2-benzenedicarboxylic acid, bis(2-methylpropyl)ester	Aldehyde	Inhibit phagocytosis
12	34.30	1-Hexadecanol	Ester	Antibacterial
13	34.90	Nonadecane	Fatty alcohols	Antibacterial, antioxidant
14	35.40	Hexadecanoic acid, ethyl ester	Aliphatic hydrocarbon	Inhibit phagocytosis
15	37.70	Eicosane	Ester	Antibacterial, antioxidant
16	37.90	10-Heneicosene	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
17	40.05	Heneicosene	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
18	40.35	Phytol	Aliphatic hydrocarbon	Antimicrobial, anti-cancer, cancer preventive
19	40.55	9, 12, 15-octadecatrienoic acid, ethyl ester	Diterpene	Inhibit phagocytosis
20	41.85	Dokozan	Ester	Antibacterial, antioxidant
21	42.76	9-Tricosene, Z	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
22	44.70	Triclosan	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
23	45.30	Tetracosane	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
24	47.80	Pentacosane	Aliphatic hydrocarbon	Anti-bacterial, antioxidant
25	50.7	Hexacosane	Aliphatic hydrocarbon	Anti-bacterial, antioxidant

Source: Data analysed.

Sri *et al.* [25] predicted the antioxidant effect of the tempuyung plant by peroxide value. The tempuyung plant has a lower peroxide value (865.60) than α-tocopherol (1142.77). It indicates that tempuyung has a more excellent antioxidant activity than α-tocopherol. The lower peroxide indicates higher antioxidant activity [25]. The antioxidant activity of this plant is also studied by Xia *et al.* and they compared six Sonchus species and determined the reducing power of each species. The reducing power correlates well with the Sonchus species' antioxidant activity. The order of reducing power Sonchus species is as follows: Sonchus arvensis (A700 = 0.80) > Sonchus oleraceus (A700 = 0.78) > Sonchus brachyurous (A700 = 0.74) > Sonchus ligands (A700 = 0.68) > Sonchus asper (A700 = 0.61) > Sonchus uliginous (A700 = 0.52). Accordingly, the Sonchus arvensis or tempuyung plant has a higher antioxidant activity due to the extract's high flavonoid and phenolic compounds [22]. Figure 2 depicts the correlation between concentration and the reducing power of the six Sonchus species.

Various elements also determine antioxidant activity. It exhibits that methanolic fraction is more effective in extracting the active compounds of Sonchus arvensis and results in the highest value of antioxidant activity compared with other fractions; namely, chloroform, ethyl acetate, and n-hexane. Furthermore, the solvent concentration influences the antioxidant activity level. Rafi *et al.* have been studying the effect of solvent concentration on the antioxidant level in Sonchus arvensis. It reported that higher solvent concentration extracted higher antioxidant compounds, which resulted in higher antioxidant activity levels [26]. The total antioxidant activity is also correlated with flavonoid and phenolic compounds. It shows that phenolic compounds have a higher antioxidant effect compared with flavonoids. Another study was further reported by Istikharah [27], who determined the antioxidant level with vitamin C as a positive control. This analysis uses DPPH and ABTS methods. The quantitative analysis method using DPPH as a free radical source shows that ethanol fraction from Sonchus arvensis could be scavenging 50% DPPH radical in concentration 64.97 µm/ml while to scavenge 50% ABTS, it needs 138.26 µm/ml. These findings indicate that ethanol extract from Sonchus arvensis leaves has significant antioxidant activity on DPPH radicals and ABTS [27].

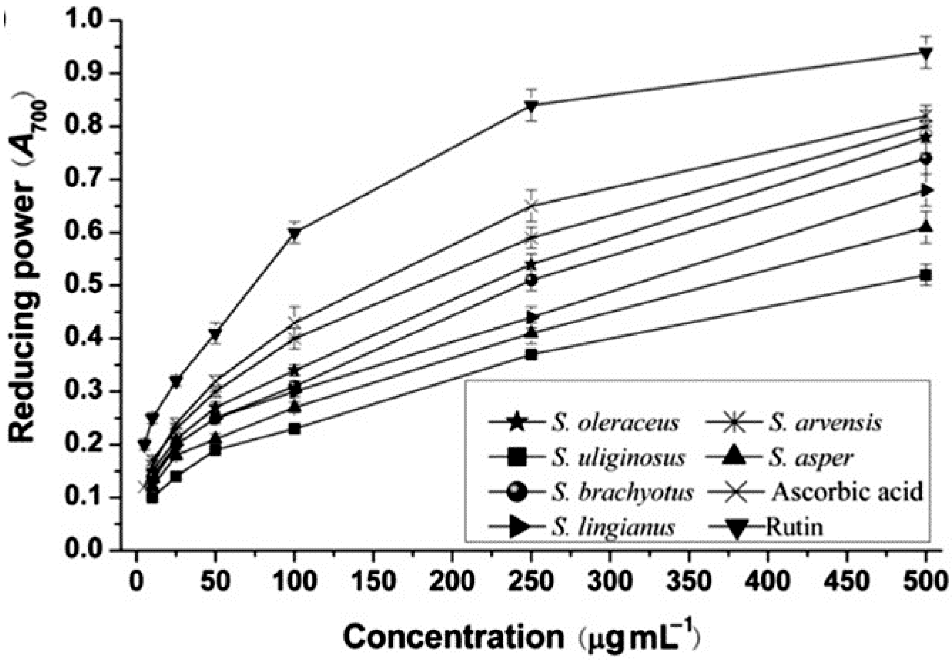

Figure 2: Analysis of reducing power on *Sonchus* species (Source: Data analysed)

Conclusion

The Tempuyung plant, also known as Sonchus arvensis, has a number of medicinal chemicals that could be used as herbal remedy. The biological activity that is affected by these active chemicals has a big impact on human health. The number of phenolic and flavonoid chemicals in this plant is significant, and these compounds have a lot of antioxidant activity. Sonchus arvensis extract contains various quantities of antioxidant activity. The antioxidant value cannot be determined with precision. It results from the varying concentrations of phenolic and flavonoid components as well as the extraction solvent. In addition, Sonchus arvensis is regarded as herbal remedy with strong antioxidant properties. Sonchus arvensis should therefore be considered as a potential source of raw materials for drugs that might be beneficial to human health. To comprehend the extraction and impact of this plant as a medicine, further research is required.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the article and agreed to be responsible for all the aspects of this work.

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