Trop J Nat Prod Res, February 2023; 7(2):2293-2304 ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Review Article

Benefits of Total Phenolic and Flavonoid Content of *Portulaca oleracea* as Antioxidant and Antidiabetic: A Review

Raihan P. Putra[1], Syarifah I. Aisyah[2], Waras Nurcholis[1,3]*

[1]*Department of Biochemistry, Faculty of Mathematics and Natural Sciences, IPB University, Jl. Tanjung Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia*
[2]*Department of Agronomy and Horticulture, IPB University, Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia*
[3]*Tropical Biopharmaca Research Center, IPB University, Jl. Taman Kencana, Kampus IPB Taman Kencana, Bogor 16128, West Java, Indonesia.*

ARTICLE INFO

Article history:
Received 25 August 2022
Revised 04 October 2022
Accepted 10 February 2023
Published online 01 March 2023

ABSTRACT

Degenerative disease is a disease that causes damage or destruction to tissues or organs of the body. This damaging process can be caused by age, unhealthy lifestyle, and environmental pollution, which causes a decrease in the production of antioxidant compounds. One of the plants that have the potential as a source of natural antioxidants is *Portulaca oleracea*. This study aims to determine the phenolic and flavonoid content of *P. oleracea* and their pharmacological activities. This study uses several databases indexed by Scopus, Pubmed, and Google Scholar. Several studies related to pharmacological activities such as antioxidants and antidiabetics have been reported in this review, where the compounds that play a role in the pharmacological activity of *P. oleracea* are phenolic and flavonoid compounds. The compound of phenolic and flavonoid compounds and antioxidant activity are influenced by several factors such as growth stages, the solvent used, extraction temperature, and the target metabolite. The antioxidant activity of this plant has been investigated using the DPPH, FRAP, and ABTS assays. As antidiabetic, kaempferol and quercetin are compounds that have the highest activity in this plant.

Keywords: *Portulaca oleracea*, pharmacological effects, degenerative disease, phenolic compound, and flavonoid compound.

Introduction

Degenerative diseases are diseases that cause damage or destruction to tissues or organs of the body. Damage or destruction of these tissues or organs can be caused by an imbalance in the levels of free radicals and antioxidants, resulting in oxidative stress.[1] Factors that cause tissue or organ damage are increasing age and an unhealthy lifestyle. These degenerative diseases include kidney, cholesterol, hypertension, heart disease, stroke, diabetes mellitus, and gout. The surprising fact is that global epidemics are worse in many low- and middle-income countries, where 80% of deaths from degenerative diseases occur in some of these countries. An unhealthy lifestyle is one of the leading causes of degenerative diseases.[2] In addition, environmental pollution can also cause degenerative diseases because it can reduce the production of bodyguard compounds or antioxidants.[3]

One of the plants that can be used as a source of natural antioxidants is purslane (*Portulaca oleracea*). *Portulaca oleracea* L., family Portulacaceae, commonly known as purslane, is a common weed found in grass areas as well as in field crops.[4] Although considered a weed, in some places, this plant is used as a vegetable to be consumed by eating it raw, made into salads, or cooked into soup.[5]

The characteristic of purslane is that it has a purplish-brown round stem, single leaf, grows upright, thick fleshy stems and leaves are oval with dark green leaves and dark red underside, the tips of the leaves are round and curved inward with a long stalk short.[6]

*Corresponding author. E mail: wnurcholis@apps.ipb.ac.id
Tel: +62-8179825145

Citation: Putra RP, Aisyah SI, Nurcholis W. Benefits of Total Phenolic and Flavonoid Content of *Portulaca oleracea* as Antioxidant and Antidiabetic: A Review. Trop J Nat Prod Res. 2023; 7(2):2293-2304 http://.www.doi.org/10.26538/tjnpr/v7i2.1

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria.

Purslane is an herbal remedy in Central Europe, Asia, and the Mediterranean region.[7] *Portulaca oleracea* has been used as a traditional medicine in many countries, acting as a febrifuge, antiseptic, and vermifuge.[8] Purslane exhibits various pharmacological effects, including antibacterial, antiulcerogenic, anti-inflammatory, antioxidant[9], and wound healing.[10] Purslane is also referred to as an important source of omega-3 fatty acids.[11] Purslane is listed by the World Health Organization (WHO) as one of the most widely used medicinal plants and has been given the term "Global Panacea".[12]

According to Husein *et al.*[5], *Portulaca oleracea* contains phenolic compounds in the form of caffeic acid, p-coumaric acid, scopoletin, ferulic acid, and chlorogenic acid. Phenolic compounds are one of the secondary metabolites of plants that can act as antioxidant agents. These compounds can be identified using liquid chromatography such as HPLC, UPLC, and LC/MS. In addition, this type of purslane also contains flavonoid compounds such as quercetin, myricetin, apigenin, and kaempferol. The presence of phenolic and flavonoid content provides many benefits in the development of natural medicines, especially as antioxidants.[13]

Methods

This review article uses several databases indexed by Scopus, Pubmed, and Google Scholar. This review uses keywords such as *Portulaca oleracea*, pharmacological effects, degenerative disease, phenolic compound, and flavonoid compound. These databases were identified and analyzed based on their relevance to the topic. The inclusion criteria use journals containing total phenolic, total flavonoid, and pharmacological effects such as antioxidant and alpha-glucosidase inhibitor of *P. oleracea*.

Results and Discussion

Several studies on the activity of the bioactive components of *Portulaca oleracea* have been presented in Table 1, along with the solvents and

extraction methods used. Based on Table 1, most studies use the maceration method for extraction because maceration is an extraction method by immersing the material with a solvent suitable for the active compound to be taken with low heating or without a heating process. The main advantage of the maceration extraction method is that the procedures and equipment used are simple, not heated, so natural materials do not decompose and directly extract polyphenols from plants.[14]

In addition, Fernandez *et al*.[15] and Guo *et al*.[16] used the Ultrasound-assisted extraction (UAE) technique to examine total phenolics, total flavonoids, and antioxidant activity in *Portulaca oleracea*. UAE is a new extraction technique that has proven to be a simple, inexpensive, and environmentally friendly process for extracting natural products.[17,18] Ultrasound can break cell walls and increase the mass transfer rate, which leads to higher extraction rates. In addition, cavitation can cause collisions on the surface of the extracted material resulting in surface peeling and erosion.[19-21] Therefore, UAE is a technique for extracting bioactive compounds from plant materials that can increase yields and efficiency.

The pharmacological activity of *P. oleracea* has been reported in several studies listed in Table 1, such as antioxidant and antidiabetic. Phenolics and flavonoids compounds were identified in *P. oleracea* presented in Table 2.

Tabel 1: Several pharmacological studies of *Portulaca oleracea*

Sample	Extraction method	Solvent	Method	Properties	Result / finding	Ref.
Whole plant of *P. oleracea* from Xiachang Dist., Taipei City, Taiwan	Maceration	n-hexane, chloroform, dichloromethane, ethyl acetate, acetone, methanol, ethanol	TPC, TFC, DPPH, $ABTS^{\cdot}$ scavenging assays, Alpha-glucosidase inhibitory assay	TPC, TFC, Antioxidant, Antidiabetic	Ethanol extract has TPC (219.27 ±4.13 mg/g), and TFC (437.38 ± 13.14 mg/g) higher than other solvents *P. oleracea* has seven compounds that affect as an alpha-glucosidase inhibitor which kaempferol and quercetin showed the highest IC_{50} Ethanol extract has antioxidant activity higher than other solvents via DPPH and hydroxyl radical scavenging assays Ethyl acetate extract has antioxidant activity higher than other solvents via ABTS radical scavenging assays	22
Aerial parts of *P. oleracea* from Andujar (southeast of Spain)	Ultrasonic Assisted Extraction (UAE)	Methanol	TPC, HPLC Analysis, ABTS and DPPH scavenging assays	TPC, Antioxidant	DPPH assays value of the raw and steamed extract were 260 µmol TE / g DE and 160 µmol TE / g DE ABTS assays value of the raw and steamed extract were 390 µmol TE/ g DE and 200 µmol TE / g DE HPLC-MS results, raw extract (57 mg GAE/g DE) has phenolic content higher than steamed extract (33 mg GAE/g DE) Steamed extract (30 mg/100 g DE) has flavonoid content	15

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

					higher than raw extract (28 mg/ 100 g DE) *P. oleracea* contains phenolic compound such as caffeoylglucaric acid, caffeic acid glucuronide isomers, ferulic acid-O-hexoside, ferulic acid derivative, caffeic acid-O-hexoside, and sinapoyl hexoside *P. oleracea* contains flavonoid compound such as catechin, epicatechin, quercetin-O-hexoside isomers, kaempferol-O-hexoside, and isorhamnetin-O-hexoside	
Aerial of *P. oleracea* at different plant growth stages	Maceration	Methanol, ethanol, aquadest	TPC, TFC, DPPH and FRAP scavenging assays	TPC, TFC, Antioxidant	The methanol extract (360,3 mg GAE/100 g DW) has TPC higher than other solvents (Ethanol 276.8; water 142.8 mg GAE/100 g DW) The flavonoid contents were also markedly higher in the methanolic extract (49.18 mg rutin equivalent/g DW) compared to the ethanol extract (41.30 mg rutin equivalent/g DW) and water extract (28.7 mg rutin equivalent/g DW) The values of TPC and FRAP at 15 days were significantly lower than those at 30, 45, and 60 days The values of TPC at 15, 30, 45, 60 days were 174.5 mg GAE/100 g, 276.8 mg GAE/100 g, 300.5 mg GAE/100 g, 348.5 mg GAE/100 g respectively The values of FRAP at 14, 30, 45, and 60 days were 1.8 mg GAE/g, 2.8 mg GAE/g,	23

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

							3.6 mg GAE/g, 4.3 mg GAE/g respectively The values of DPPH showed by ascorbic acid equivalent antioxidant activity (AEAC) at 15, 30, 45, adn 60 days were 229.5 mg AA/100 g, 263.8 mg AA/100 g, 293.0 mg AA/100 g, 319.3 mg AA/100 g respectively	
Aerial parts of *P. oleracea* from Alappuzha, Kerala State, India	Maceration (stiring with aqueous acetone)	Aqueous acetone (70:30)	TPC, TFC, DPPH, FRAP, and ABTS	TPC, TFC, Antioxidant			The values of TPC of *P. Oleracea* raw, *P. oleracea* boiled, and *P. oleracea* blanched were 22.94 mg GAE/g extract, 19.25 mg GAE/g extract, 10.02 mg GAE/g extract, respectively The values of TFC of *P. Oleracea* raw, *P. oleracea* boiled, and *P. oleracea* blanched were 64.99 mg rutin equivalent/ g extract, 85.14 mg rutin equivalent/ g extract, 81.57 mg rutin equivalent/ g extract DPPH assay values of the *P. oleracea* raw, boiled, and blanched were 11 440.39 mmol TEA/g extract, 3 561.92 mmol TEA/g extract, 11 452.15 mmol TEA/g extract. ABTS assay values of the *P. oleracea* raw, boiled, and blanched were 51 041.34 mmol TEA/g extract, 53 818.25 mmol TEA/g extract, 53 037.68 mmol TEA/g extract FRAP assay value of the *P. oleracea* raw, boiled, and blanched were 5 474.42 mmol Fe (II)/g extract, 5 971.68 mmol Fe (II)/g extract, 5 499.16 mmol Fe (II)/g extract	25

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Whole plant of *P. oleracea* from six casual locations in Turkey	Maceration	Methanol	DPPH, ABTS scavenging assays	Antioxidant	The crude extract has an antioxidant activity value 511.8 µgram/mL via ABTS radical scavenging assays Fraction 3 has the highest absorption in the selected wavelength range (200-400 nm) among all fractions and crude extract Fraction 3 appears to have the lowest IC_{50} and the highest TEAC values among the fractions and crude extract, indicating its higher antioxidant activity. Crude extract's IC_{50} value was found to be 511.8 µgram/mL whereas fraction 3 was detected to have IC_{50} values of 154.1 µgram/mL. ABTS (TEAC values) of fraction 3 (1.9 mM Trolox) was found to be almost four times higher than that of the crude extract (0.5 mM Trolox)	34
The seeds, leaf, and stem of *P. oleracea* from Dire Dawa, Ethiopia	Soxhlet	Ethanol (DPPH), Methanol (Hydrogen peroxide)	DPPH and Hydrogen peroxide scavenging assays	Antioxidant	The highest DPPH activity was obtained for leaf oil (12.55%), followed by seed oil (2.05%) and stem oil (0.35%) The peroxide scavenging was indicated to be the highest for stem oil (0.70%), followed by seed oil (0.45%), and leaf oil (0.35%)	35
The whole plant of *P. oleracea*	Maceration	n-hexane, dichloromethane, chloroform, ethylacetate, methanol	TPC, DPPH radical scavenging assays	TPC, Antioxidant	The highest total phenolic content was shown in methanol extract (22.8 mg GAE/g extract) The total phenolic content in n-hexane, dichloromethane, chloroform, and ethylacetate solvents was 9.3 mg GAE/g extract, 6.6	29

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

				mg GAE/g extract, 9.5 mg GAE/g extract, and 20.3 mg GAE/g The highest IC_{50} of *P. oleracea* extract via DPPH radical scavenging showed in ethyl acetate extract (62.9 g/mL) IC_{50} values for n-hexane, dichloromethane, chloroform, and methanol via DPPH radical scavenging were 63.5 g/mL, 91.0 g/mL, 86.0 g/mL, and 85.7 g/mL, respectively. The IC_{50} of α-glucosidase inhibition was lower than that of α-amylase. But, in all *P. oleracea* extracts obtained the IC_{50} of α-glucosidase inhibition was higher	
Seed oil of *P. oleracea* from Xinjiang Yuansen Agriculture Science and Technology Development	Ultrasound assisted and soxhlet extraction method	Ethanol, aquabidest	DPPH and hydroxyl radical scavenging activity assays	Antioxidant	The IC_{50} value of purslane seed oil (PSO) with the hydroxyl free radical method is 1.388 mg/mL The IC_{50} value of PSO is higher than TBHQ (2.193 mg/mL), almond oil (2.53 mg/mL), and grape seed oil (6.66 mg/mL) The higher content of linolenic acid influences the high antioxidant power of PSO The IC_{50} value of purslane seed oil (PSO) with the DPPH radical scavenging method is 11.16 mg/mL This IC_{50} value is lower than TBHQ, which is 0.07886 mg/mL IC_{50} PSO value is higher than walnut oil (147.0 mg/mL) but lower than flaxseed oil (3.31 mg/mL)	16

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

	The stronger DPPH radical scavenging ability is influenced by the higher content of omega-3 linolenic fatty acids.

Total Phenolic Compound (TPC)

Research conducted by Chen *et al*.[22] stated that the ethanolic extract of *P. oleracea* had the highest TPC compared to n-hexane, chloroform, dichloromethane, ethyl acetate, acetone, and methanol. Fernandez *et al*.[15] stated that the total phenolic content of raw *P. oleracea* was higher than that of steamed *P. oleracea*. The TPC value in *P. oleracea* was influenced by growth stages. Research conducted by Uddin *et al*.[23] stated that TPC in mature plants (60 days growth stages) was higher than in developing plants (15 days growth stages). This increase in TPC is because species exclusivity, vegetation period, and growing conditions (climate factors, altitude, and soil properties) affect the biosynthesis and accumulation of secondary metabolites in plants, including phenolic compounds.[24] HPLC analysis of aerial parts of *P.oleracea* showed that *P. oleracea* has phenolic compounds such as caffeolyglucaric acid, caffeic acid glucuronide isomers, ferulic acid-O-hexoside, ferulic acid derivative, caffeic acid-O-hexoside, and sinapoyl hexoside.[15]

Total Flavonoid Compound (TFC)

Research conducted by Nagarani *et al*.[25] stated that raw *P. oleracea* had the lowest TFC value compared to boiled and blanched *P. oleracea*, where boiled *P. oleracea* had the highest TFC value. This is due to the polyphenol oxidase enzyme's inactivation, which causes polyphenol degradation inhibition.[26] In addition, heating can trigger the Maillard reaction, which decomposes phenolic compounds and produces new products with higher antioxidants.[27] HPLC analysis of aerial parts of *P. oleracea* showed that *P. oleracea* has flavonoid compounds such as catechin, epicatechin, quercetin-O-hexoside isomers, kaempferol-O-hexoside, and isorhamnetin-O-hexoside.[15]

Antioxidant Activity

The difference in antioxidant activity is related to the type of antioxidant present in each extract. Phenols and flavonoids are antioxidant components, and these compounds can affect the antioxidant activity found in plants. DPPH, ABTS, and FRAP assay are several methods for determining antioxidant activity. DPPH and ABTS assays have been commonly used to determine antioxidant activity based on the principle of the ability to donate hydrogen atoms of the target compound. FRAP is a method used to measure the antioxidant content of a sample by reducing Fe^{3+} ions to Fe^{2+} ions. The antioxidant power is indicated by the ability to reduce the Fe^{3+} ion.[28]

DPPH assay

The results of a study by Salehi *et al*.[29] showed that the ethyl acetate extract had the highest antioxidant activity of the whole plant of *P. oleracea*, described as IC_{50} value. However, in the study by Chen *et al*.[22], ethanol extract had the highest antioxidant activity compared to n-hexane, chloroform, dichloromethane, ethyl acetate, acetone, and methanol. This can occur due to several factors in the natural product extraction process, such as the solvent used, the extraction temperature, and the target metabolite. Changes in solvent polarity cause significant differences in phytochemical composition and biological activity.[22]

ABTS assay

Ethyl acetate extract has the highest antioxidant activity compared to n-hexane, chloroform, dichloromethane, acetone, methanol, and ethanol.[22] Raw extract from aerial parts of *P. oleracea* has higher antioxidant activity than steamed extract.[15] The decrease in antioxidant activity due to steam follows research conducted by Haw *et al*.[30], where *Hibiscus cannabinus* samples treated with steam blanched at 80˚C and 120˚C experienced a decrease in antioxidant activity compared to the crude extract.

FRAP assay

The antioxidant activity of *P. oleracea* in the FRAP method increased as the growth stages progressed, where the highest antioxidant activity was found on day 60.[23] In addition, a study conducted by Nagarani *et al*.[25] showed that the highest FRAP value was found in boiled extract compared to blanched extract and raw extract. Gorinstein *et al*.[31] found that thermal treatment maintained their bioactive components (polyphenols, flavonoids, flavanols, and tannins) and total antioxidant capacity in samples processed by the FRAP assay. The production of redox-active secondary metabolites (Maillard reaction and Amadori rearrangement products) and the breakdown of complex phenolic compounds by heat treatment, which softens or damages plant cell walls, account for the increase in reducing activity in the prepared samples observed in this study.

Inhibitor alpha-glucosidase

In addition to antioxidant activity, *P. oleracea* has a pharmacological effect as an antidiabetic. According to Chen *et al*.[22] seven *P. oleracea* ingredients have pharmacological effects as alpha-glucosidase inhibitors, whereas kaempferol and quercetin have the highest IC_{50} values. This follows a study by Salehi *et al*.[29], where *P. oleracea* has a high IC_{50} value of alpha-glucosidase inhibition. In previous research by Sharma *et al*,[32] 50% ethanol extract of *P. oleracea* had antidiabetic activity against STZ mice. This follows the study of Li *et al*,[33] which showed that polysaccharide extract from *P. oleracea* could significantly reduce fasting blood glucose (FBG), total cholesterol (TC), and triglyceride (TG) concentrations in diabetic rats.

Conclusion

Portulaca oleracea has a pharmacological effect as an antioxidant. The antioxidant activity of this plant is influenced by several factors such as growth stages, the solvent used, extraction temperature, and the target metabolite. Besides antioxidants, the content of kaempferol and quercetin from *P. oleracea* has potential as antidiabetics by inhibiting alpha-glucosidase activity.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

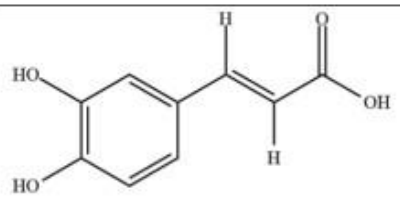
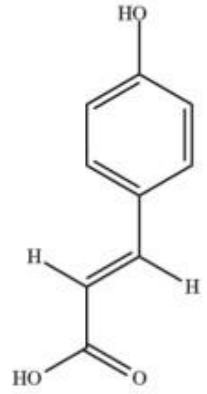
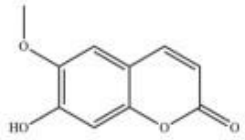
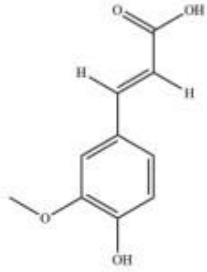
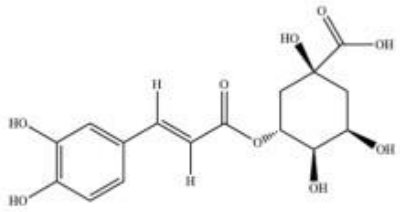
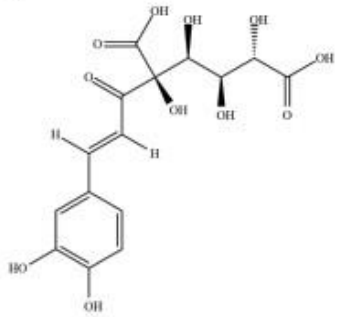
The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgments

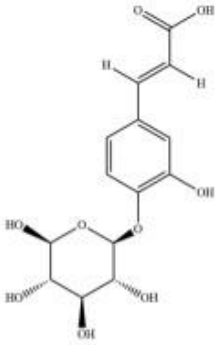
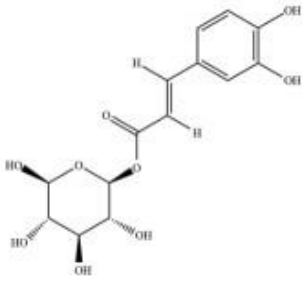
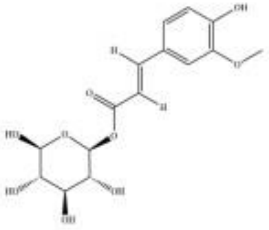
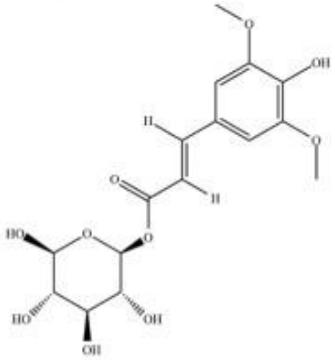
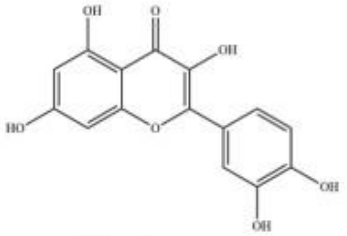
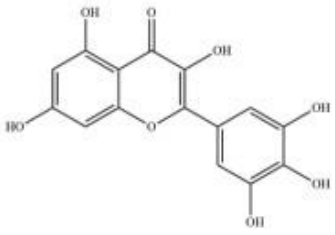
This research was fully funded by PDUPT research program from the Ministry of Research, Technology and Higher Education of the Republic of Indonesia with contract number 3555/IT3.L1/PT.01.03/P/B/2022.

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

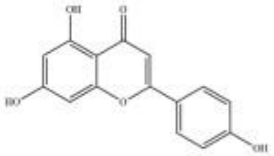
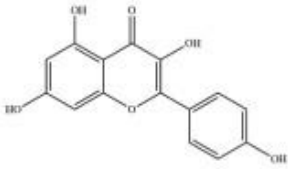
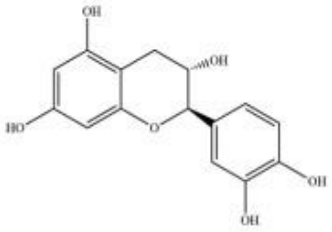
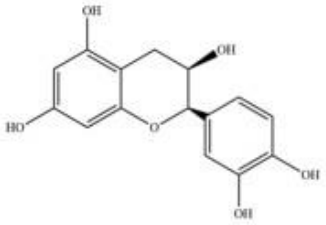
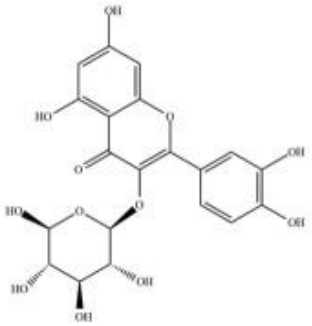
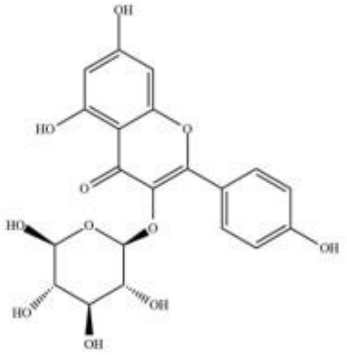
Table 2: Phenolic and Flavonoid compounds in *Portulaca oleracea*

Type	Compound	Structure	Ref.
Phenolic	Caffeic acid		5
	p-coumaric acid		5
	Scopoletin		5
	Ferulic acid		5
	Chlorogenic acid		5
	Caffeoylglucaric acid		15

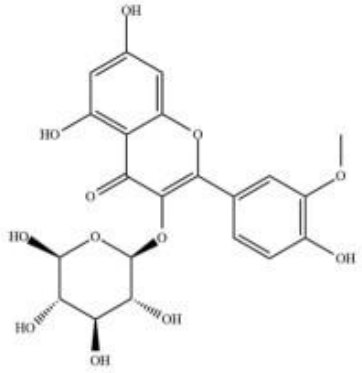
ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

	Caffeic acid glucoronide isomer		15
	Caffeic acid-O-hexoside		15
	Ferulic acid-O-hexoside		15
	Sinapoyl-*O*-hexoside		15
Flavonoid	Quercetin		5
	Myricetin		5

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Apigenin		5
Kaempferol		5
Catechin		15
Epicatechin		15
Quercetin-O-hexoside isomers		15
Kaempferol-*O*-hexoside		15

Isorhamnetin-O-hexoside 15



References

1. Barbaza MYU, Castro-Cruz KAD, Ramos JLT, Hsieh CL, Tsai PW. Synergistic antidiabetic activity of extracts of *Asystasia gangetica* and *Morus alba*. Trop J of Nat Prod Res. 2021; 5(2):242-247.
2. Handajani A, Roosihermiatie B, Maryani H. Faktor-faktor yang berhubungan dengan pola kematian pada penyakit degeneratif di Indonesia. Bul. Penelit. Sist. Kesehat. 2010; 13(1):42–53.
3. Arnanda QP, Nurwarda RF. Penggunaan radiofarmaka teknesium-99M dari senyawa glutation dan senyawa flavonoid sebagai deteksi dini radikal bebas pemicu kanker. J Farmaka. 2019; 17(2):236–243.
4. Silva R, Carvalho IS. In vitro antioxidant activity, phenolic compounds and protective effect against DNA damage provided by leaves, stems and flowers of *Portulaca oleracea* (purslane). Nat Prod Commun. 2013; 9(1): 45-50.
5. Husein SG, Sundalian M, Husna N. Review: analisis komponen senyawa kimia krokot (*Portulaca oleracea* L. dan *Portulaca grandiflora* Hook.). J. Sains Kes. 2021; 3(2): 317-327.
6. Yuniastri R, Hanafi I, Sumitro EA. 2020. Potensi antioksidan pada krokot (*Portulaca oleracea*) sebagai pangan fungsional. J Keteknikan Pertanian Tropis dan Biosistem. 2020; 8(3): 284-290.
7. Iranshahy M, Javadi B, Iranshahi M, Jahanbakhsh SP, Mahyari S, Hassani FV. A review of traditional uses, phytochemistry, and pharmacology of *Portulaca oleracea* L. J. Ethnopharmacol. 2017; 205 :158-7.
8. Lee AS, Kim JS, Lee YJ, Kang DG, Lee HS. Anti-TNF-alpha activity of *Portulaca oleracea* in vascular endothelial cells. Int. J. Mol. Sci. 2012; 13(5):5628-44.
9. Chen B, Zhou H, Zhao W, Zhou W, Yuan Q, Yang G. Effects of aqueous extract of Portulaca oleracea L. on oxidative stress and liver, spleen leptin, PARα and FAS mRNA expression in high-fat diet induced mice. Mol Biol Reports. 2012; 39(8): 7981–7988.
10. Zhou Y-X, Xin H-L, Rahman K, Wang S-J, Peng C, Zhang H. Portulaca oleracea L.: a review of phytochemistry and pharmacological effects. BioMed Res. Int. 2015; 2015: 1-11.
11. Uddin MK, Juraimi AS, Hossain MS, Nahar MAU, Ali ME, Rahman MM. Purslane weed (*Portulaca oleracea*): a prospective plant source of nutrition, omega-3 fatty acid, and antioxidant attributes. The Sci World J. 2014; 2014: 1-6.
12. Xu X, Yu L, Chen G. Determination of flavonoids in *Portulaca oleracea* L. by capillary electrophoresis with electrochemical detection. J. Pharm. Biomed. Anal. 2006; 41(2):493-9.
13. Nur S, Sami FJ, Wilda R, Awaluddin A, Afsari MIA. Korelasi antara kadar total flavonoid dan fenolik dari ekstrak dan fraksi daun jati putih (*Gmelina arborea* Roxb) terhadap aktivitas antioksidan. Jurnal Farmasi Galenika. 2019 5(1): 33-42.
14. Jovanović AA, Đorđević VB, Zdunić GM, Pljevljakušić DS, Šavikin KP, Gođevac DM, Bugarski BM. Optimization of the extraction process of polyphenols from *Thymus serpyllum* L. herb using maceration, heat- and ultrasoundassisted techniques. Sep Purif Technol. 2017; 179:369-80.
15. Fernandez-Poyatos MdP, Liorent-Martinez EJ, Ruiz-Medina A. Phytochemical composition and antioxidant activity of *Portulaca oleracea*: influence of the steaming cooking process. Foods. 2021; 10(94): 1-14.
16. Guo G, Yue L, Fan S, Jing S, Yan L-J. Antioxidant and antiproliferative activities of purslane seed oil. J of Hypertension. 2016; 5(2): 1-6.
17. Altemimi, A., Lakhssassi, N., Baharlouei, A., Watson, D.G., Lightfoot, D. Phytochemicals: extraction, isolation, and identification of bioactive compounds from plant extracts. Plants. 2017; 6(4): 42.
18. Rombout N, Tixier AS, Bily A, Chemat F. Green extraction process of natural products as tools for biorefinery. Biofuel Bioproducts and Biorefining. 2014; 8(4):530-544.
19. Shirsath SR, Sable SS, Gaikwad SG, Sonawe SH, Saini DR, Gogate PR. Intensification of extraction of curcumin from *Curcuma amada* using ultrasound assisted approach: effect of different operating parameters. Ultrason. Sonochem. 2017; 38: 437-445.
20. Toma M, Vinatoru M, Paniwnyk L, Mason TJ. Investigation of the effects of ultrasound on vegetal tissues during solvent extraction. Ultrasonics Sonochemistry. 2001; 8(2): 137-142.
21. Vilkhu K, Mawson R, Lioyd S, Bates D. Applications and opportunities for ultrasound assisted extraction in the food industry. Innovative Food Sci & Emerging Tech. 2008; 9(2): 161-169.
22. Chen W-C, Wang S-W, Li C-H, Lin H-R, Yang C-S, Chu Y-C, Lee T-H, Chen J-J. Comparison of various solvent extracts and major bioactive components from *Portulaca oleracea* for antioxidant, anti-tyrosinase, and anti- α-glucosidase activities. Antioxidants. 2022; 11(398): 1-17.
23. Uddin MK, Juraimi AS, Ali ME, Ismail MR. Evaluation of antioxidant properties and mineral composition of purslane (*Portulaca oleracea* L.) at different growth stages. Int. J. Mol. Sci. 2012; 13: 10257-10267.
24. Chepel V, Lisun V, Skrypnik L. Changes in the content of some group of phenolic compounds and biological activity of extracts of various parts of heather (*Calluna vulgaris* (L) Hull) at different growth stages. Plants. 2020; 9 (926): 1-19.
25. Nagarani G, Abirami A, Nikitha P, Siddhuraju P. Effect of hydrothermal processing on total polyphenolics and antioxidant potential of underutilized leafy vegetables, *Boerhaavia diffusa* and *Portulaca oleracea*. Asian Pac. J. Trop. Biomed. 2014; 4(1): 5468-5477.
26. Shaimaa GA, Mahmoud MS, Mohamed MR, Emam AA. Effect of heat treatment on phenolic and flavonoid compounds and antioxidant activities of some Egyptian

sweet and chilli pepper. Nat Prod Chem and Res. 2016; 4(3):1-6.
27. Shamsul M, Zahrah MASF. Boiling increase antioxidant activity, total phenolic content and total flavonoid content in *Plectranthus amboinicus* leaves. GSC Biol and Pharmaceutical Sci. 2019; 6(3):24-30.
28. Aryal S, Baniya MK, Danekhu K, Kunwar P, Gurung R, Koirala N. Total phenolic content, flavonoid content and antioxidant potential of wild vegetables from western nepal. Plants. 2019; 8(96): 1-12.
29. Salehi P, Asghari B, Esmaeili MA, Dehghan H, Ghazi I. Alpha-glucosidase and alpha-amylase inhibitory effect and antioxidant actibity of ten plant extracts traditionally used in Iran for diabetes. J of Med Plants Res. 2013; 7(6): 257-266.
30. Haw YT, Sim YY, Nyam KL. Effect of steam blaching and high temperature drying on the physicochemical properties, antioxidant activities and consumer acceptability of *Hibiscus cannabinus* leaves tea. J Food Sci Technol. 2020; 57(12): 4588-4598.
31. Gorinstein S, Jastrzebski Z, Leontowicz H, Leontowicz M, Namiesnik J, Najman K, Park YS, Heo BG, Cho JY, Bae JH. Comparative control of the bioactivity of some frequently consumed vegetables subjected to different processing condition. Food Control. 2009; 20(4): 407-413.
32. Sharma A, Vijayakumar M, Rao ChV, Unnikrishnan MK, Reddy GD. Action of *Portulaca oleracea* against streptozotocin-induced oxidative stress in experimental diabetic rats. J. Complement. Integr. Med. 2009; 6(1): 1-10.
33. Li F, Li Q, Gao D, Peng Y, Feng C. Preparation and antidiabetic activity of polysaccharide from *Portulaca oleracea* L. Afr. J. Biotechnol. 2009; 8: 569-573.
34. Erkan N. 2012. Antioxidant actibity and phenolic compounds of fractions from *Portulaca oleracea* L. Food Chemistry. 2012; 133(2012): 775-781.
35. Desta M, Molla A, Yusuf Z. Characterization of physico-chemical properties and antioxidant activity of oil from seed, leaf and stem of purslane (*Portulaca oleracea* L.). Biotech Reports. 2020; 27(2020): 1-5.