INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
24–0339/2025/33:330203
http://www.fspublishers.org

Full Length Article

Evaluation of Phytochemical and Biological Studies of Ultrasound-Assisted Extraction of *Eugenia uniflora* Seed Extract for Antioxidant and Anti-Tyrosinase Activity

Desy Muliana Wenas[1,2], Berna Elya[1*], Sutriyo[3] and Heri Setiawan[4]
[1]*Pharmacognosy and Phytochemistry Department, Faculty of Pharmacy, Universitas Indonesia, Depok, Indonesia*
[2]*Department of Biology Pharmacy, Faculty of Pharmacy, National Science and Technology Institute, South Jakarta, Indonesia*
[3]*Pharmaceutical Department, Faculty of Pharmacy, Universitas Indonesia, Depok, Indonesia*
[4]*Pharmacology Department, Faculty of Pharmacy, Universitas Indonesia, Depok, Indonesia*
[*]For correspondence: berna.elya@farmasi.ui.ac.id
Received 05 August 2024; Accepted 01 October 2024; Published online 08 December 2024

Editor: Abdul Wahid

Abstract

Suriname cherry (*Eugenia uniflora* L.) is believed to have anti-aging properties due to its main constituents, myristicin and quercetin. This study examines the anti-tyrosinase and antioxidant properties of the seed of unripe fruit extract of Suriname Cherry. The extraction process used an ultrasound-assisted extraction (UAE) method with 70% ethanol. Total phenolic and flavonoid contents were measured. Antioxidants including 2, 2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), 2, 2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) and anti-tyrosinase activities were evaluated for the bioactivities. The antioxidant activities of *E. uniflora* seed extract had substantial IC_{50} values for DPPH 5.75 µg/mL, then FRAP values were 5197.7 µM/g. In conclusion, the Suriname Cherry seed extract has anti-tyrosinase and antioxidant properties. Furthermore, the ethanolic seed extract had anti-tyrosinase and antioxidant characteristics, suggested that the Suriname cherry plant could be a promising anti-aging agent.

Keywords: Antityrosinase; Antioxidant; *Eugenia uniflora*; Seed; Ultrasound-assisted extraction

Introduction

Hyperpigmentation, as one of the features of skin aging, can occur earlier with external factors like air pollution and ultraviolet exposure from sunlight. The main enzyme that responsible for hyperpigmentation is tyrosinase, which involves in melanogenesis in melanin skin pigment synthesis. One of the antiaging mechanisms is to use a tyrosinase inhibitor. Tyrosinase inhibitor is a substance that can reduce the tyrosinase enzymatic activity in melanin synthesis. Therefore, tyrosinase inhibitors are important in depigmentation substances for cosmetics development (Zolghadri *et al.* 2019) . Tyrosinase has two important roles in catalyzing the melanin biosynthesis process. The processes are L-tyrosine, o-hydroxylation and L-DOPA oxidation. Then, L-tyrosine converts into dopaquinone. This step in melanogenesis is significantly rate-limiting (Fan *et al*. 2021). Limited commercial market substances that are qualified for clinical inhibitors and skin-lightening.

With increasing demand for tyrosinase inhibitors in industry, it is important to find effective tyrosinase inhibitors. Inhibiting tyrosinase contributes to the reduction of skin hyperpigmentation. The most widely used tyrosinase inhibitors, such as hydroquinone and kojic acid, have major adverse effects including erythema and dermatitis. Tyrosinase inhibitors have drawn significant interest in the cosmeceutical industries for their potential to prevent skin aging and hyperpigmentation disorder (Şöhretoğlu *et al.* 2018). Therefore, the hazards of tyrosinase inhibitors have resulted in severe restrictions on the use of such products in many countries, increasing the pursuit of them from natural sources with minimal side effects and maximum efficacy (Meriç *et al.* 2024). One of the natural sources is Myrtaceae plants.

Myrtaceae family plants are aromatic dicotyledonous plants consisting of shrubs and tree species (Farias *et al.* 2020). The biological diversity of Myrtaceae plants has unique characteristics due to the countless adaptive mechanisms to environmental nuances in tropical, and also subtropical areas. One of the species of Myrtaceae is Suriname cherry (*Eugenia uniflora* L.). The miniature pumpkin-shaped fruit is edible, tastes sweet and sour, and has a hint of aroma of

To cite this paper: Wenas DM, B Elya, Sutriyo, H Setiawan (2025). Evaluation of phytochemical and biological studies of ultrasound-assisted extraction of *Eugenia uniflora* seed extract for antioxidant and anti-tyrosinase activity. *Intl J Agric Biol* 33:330203. https://doi.org/10.17957/IJAB/15.2263

red chili pepper. The plants have ethnopharmacology properties that are used to treat various illnesses like stomach, hypertension, inflammation, diabetes, rheumatism, and wound infection (Souza *et al.* 2012). The leaf is known in pharmacology as antidiabetic, antihypertension, antimicrobial and antiinflammation (Bezerra *et al.* 2019). Suriname cherry has been used for cosmetics in Brazil, especially essential oils. Suriname cherry was explored first for industrial cosmetic purposes of its essential oil. The aroma of essential oil has an exotic, citric, fresh, and green note in perfume production (Gallucci *et al.* 2010).

However, seed is known for greater potential bioactivities that have not been explored. It has been investigated that the antioxidant of *E. uniflora* seed is greater than its fruit extract (Celli *et al.* 2011). It is also been proven that seed has greater antioxidants than the fruit of other species in the Myrtaceae family (Girardelo *et al*. 2020). The ethanolic extract of *E. uniflora* seed has a great potential for antioxidants due to its high phenolic concentration (Santos *et al.* 2015). High phenolic compounds on Suriname Cherry's seed may have the tyrosinase inhibitors properties that allow it to have potential for skin whitening agents and help treat hyperpigmentation skin conditions (Wenas *et al.* 2024). The chemical structure of phenolic substances of extract enable it to attach to the tyrosinase active site (Şöhretoğlu *et al.* 2018). Therefore, it is required to investigate Suriname cherry seeds' ability to suppress tyrosinase enzyme. The objective of this study is to explore the quantitative phytochemical analysis, bioactivities for free radical inhibition, and antiaging assay activity of seed extract especially its capacity to inhibit tyrosinase, thereby contributing to skin aging and hyperpigmentation.

Materials and Methods

Sample preparation and ultrasound-assisted extraction (UAE)

The unripe fruits of Suriname cherry at the age of 3-4 weeks after the flowering stage, were gathered from Depok City in Indonesia. The seeds were collected by cutting the fruit in cross-sections and removing the seeds from unripe fruits in the range color of green to yellow (Fig. 1). The seeds were left to dry naturally for seven days in the air.

A 10 g of seed powder was added to 100 mL of 70% ethanol. Seed powder was extracted with UAE method in a Q2000 Sonicator with direct probe type immersed in 70% ethanol solvent medium at room temperature, frequency of 20 kHz, and extraction time of 15 min. The crude extract was filtered and evaporated with a rotary evaporator to obtain seed extract as residue. Seed extract yield was calculated by comparing the extract weight with the initial seed powder weight.

Phytochemical screening

Phytochemical screening in the seed extract was performed following the protocol of Wenas *et al.* (2020). The secondary metabolites were identified from change in reaction color and precipitating for terpenoids, flavonoids, alkaloids, saponins, and tannins.

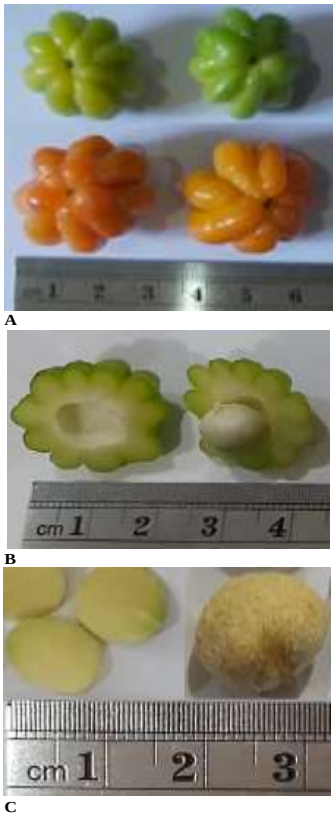

Fig 1: Unripe fruits (A), cross-section of fruit (B) and seeds from unripe fruit (C) of Suriname cherry

TPC assay: The total phenolic content of the seed extract was determined using a reagent of Folin-ciocalteu. A mixture of 1 mL extract and 5 mL 7.5% Folin-ciocalteu diluted solution was prepared, shaken for 1 min, and left to stand still for 8 min. Then added 4 mL solution of 1% NaOH, then the mixture was incubated at 25°C for 1 h in the dark. A wavelength of 730 nm was used to measure the absorbance value (Jehan *et al.* 2023). Gallic acid as a control was used to prepared calibration curve from a series of gallic acid concentrations. The amount of phenolic of each extract was determined in triplicate by comparing with the calibration curve. The total phenol content of the extract was quantified as mg gallic acid equivalent per gram of the extract (mg GAE/g).

TFC assay: A reaction was conducted with a volume of 500 µL of seed extract solution in combination with 100 µL $AlCl_3$ (10%), 100 µL sodium carbonate (1 M), and 1.5 mL ethanol P. The yellow color in the mixture indicated the possible presence of flavonoids. After being vortexed, the mixtures were placed in an incubator in the darkness at ambient temperature for 30 min. The absorption was taken using a UV-Vis spectroscopy (T80+) at 437 nm. All

measurements were made in triplicate. A standard curve was generated using a series (5–100 mg/L) of quercetin standards. The total flavonoid content was determined by using the standard curve equation, and the resulting values were expressed in milligrams of QE per gram extract (Sulistyowati *et al*. 2023).

DPPH antioxidant assay: Seed extract series concentration solutions were prepared in 2.4, 3.6, 4.8, 6 and 7.2 ppm. The seed extract series concentration solutions as much as 12, 18, 24, 30 and 36 µL, respectively was added to 1 mL methanolic DPPH (0.4 mM), and the methanol solvent (3988, 3982, 3976, 3970 and 3964 µL) was added to the mixture to make a total amount of 5 mL. After that, the solution was left out in dark at 25°C for 30 min and incubated. Spectrophotometer was used to detect the absorbance at 517 nm. The test was performed three times. The determination of the extract antioxidant bioactivity gave the IC_{50} (it is the amount of the sample that can prevent 50% DPPH radical activity). The percent inhibition was obtained based on DPPH radical scavenging, with the following formula (Rizki *et al.* 2022):

$$\%\ Inhibition = \frac{(control\ absorbance - extract\ absorbance)}{control\ absorbance}\ x\ 100\%$$

Where y = a + bx equation is determined by making a curve of linear regression with x representing the extract concentration in g/mL unit, while y representing the inhibition percent (%). The following formula is used to calculate IC_{50} value.

$$IC_{50} = \frac{(50 - a)}{b}$$

The experiment was held out 3 times. The IC_{50} of DPPH is calculated for mean and standard deviation.

ABTS antioxidant assay: The method of ABTS antioxidant assay in this research is modified using free radical ABTS substance. ABTS stock solution is prepared and twelve hours incubated without light. A diluted ABTS solution is prepared by making the ratio of 1:10 ABTS stock solution with 96% ethanol. Seed extract stock solution and positive control were prepared respectively into several series of concentration solutions. One mL ABTS (1:10), then adding ethanol up to 5 mL volume. The samples were kept for 30 min at 25°C without light. The sample's absorbance was then measured at 753 nm using a uv-vis spectrophotometer (Wiliantari *et al.* 2022). The experiment was held out 3 times. The IC_{50} of ABTS is calculated for mean and standard deviation.

FRAP assay: $FeSO_4.7H_2O$ solution of 1 mM was used to make as a standard series solution in 10, 75, 100, 125 and 150 µM to obtain the calibration curve. FRAP I solution is made with adding acetate buffer, TPTZ or 2,4,6-Tris(2-pyridyl)-s-triazine 10 mM and aquades in ratio of 10: 1: 1 The solution was made of 2 mL FRAP I solution, (50, 75, 100, 125 and 150 µL) FeSO4, added aquades until volume reach 5 mL. The same procedure was carried out for the standard (quercetin). FRAP II solution is made with adding acetate buffer, TPTZ and $FeCl_3$ in ratio of 10: 1: 1. Quercetin was prepared in seri concentration as 2, 4, 6, 8, 10 and 12 µM. The solution was made of 2 mL FRAP II reagent, (3, 6, 8, 12, 15 and 18 µL) quercetin, added aquades until volume reach 5 mL. The seed extract solution is made in 5 ppm. The mixture solution was placed in the closed dark compartment for 30 min. UV-Vis spectrophotometer was used to measure the absorbance of the sample at 596 nm. The percentage Fe^{3+} to Fe^{2+} reduction by the sample in the presence of $FeSO_4$ in µM/g of dried extract is taken as the FRAP value, which was calculated using the equation (de Barros *et al.* 2024):

$$SC = \frac{\Delta A - a}{b}$$

$$\text{FRAP value } (\mu M/g) = \frac{SC\ x\ V\ x\ DF}{w}$$

Where SC is the sample concentration (µM), V is the sample volume (mL), DF is dilution factor and w is sample weight (mg). The experiment is held out for 3 times. The FRAP value is calculated for its mean and standard deviation.

Anti-tyrosinase assay: Using color-changing observation, the UAE extract of *E. uniflora* were evaluated for their antiaging properties. The ability to inhibit tyrosinase of *E. uniflora* seed extract was determined colorimetrically. Phosphate buffered solution 50 mM was prepared by add 19.8 mg KH_2PO_4 into 50 mL aquades, then adjust the acidity level to 6.5 and add aquades until volume 100 mL aquades. A 96-well microplate (Iwaki Pyrex) consisting of 80 µL of phosphate buffered saline, 40 µL of extract solution (1–500 µg/mL), 40 µL of L-DOPA solution in 4 mM concentration, and 40 µL of mushroom tyrosinase solution (75 U/mL). The microplate was kept in a microplate reader, shaken for 1 min, and incubated at 25°C for 30 min. The absorption was measured at 490 nm using a microplate reader (GloMax® Discover). Quercetin was used as positive control. Following formula was used to present the ability to inhibit tyrosinase activity of each concentration and expressed as inhibition percentage (Desmiaty *et al.* 2020):

$$\%\ Inhibition = \frac{A_0 - A_1}{A_0} \times 100\ \%$$

Where A_0 is blank absorbance is deducted by the blank control absorbance and A_1 is sample absorbance deducted by sample control absorbance. The inhibition percentage from the concentration series of sample solutions and positive controls were used to produce a linear regression curve of anti-tyrosinase enzyme activity. The sample concentration is represented by *x* and the inhibition percentage is represented by *y* axis to get equation of y = a + bx. The formula of the IC_{50} value calculation is presented below.

$$IC_{50} = \frac{50 - a}{b}$$

The tyrosinase inhibitory activity of the extract was quantified as the IC_{50} value. The experiment is held for 3

times. The value of IC_{50} is calculated for the average and standard deviation.

Statistical analysis

The total phenol, total flavonoid, inhibition percentage of DPPH, ABTS, and antityrosinase assay and FRAP value are expressed as mean±SD in triplicates. Linear regression was performed using Microsoft Excel's Statistical software edition 2018.

Results

TPC and TFC assay

Determination of TPC of seed extract using gallic acid calibration curve from the equation y=0.0706x-0.0145 with squared R-value as 0.9971. TPC of seed extract was 11.618 ± 2.457 mg GAE/g extract. TFC results were measured using the quercetin standard with the equation y = 0.0823x –0.0402 (R^2 = 0.9997). The TFC of seed extract was obtained at 2.735 ± 0.05 mg QE/g extract (Table 1).

Antioxidant activities

The relationship between inhibition percentage and concentration of extract is presented in linear regression equations. The equation of seed extract is y = 7.4736x+7.6436 (R^2 = 0.99) and quercetin is y = 12.197x-8.0387 (R^2 = 0.9953) (Fig. 2). The DPPH radical scavenging ability of Suriname cherry ethanolic seed extract for IC_{50} value was 5.75 μg/mL (Table 2). The seed extract had a strong DPPH radical scavenging ability, even though it was lower than the positive control (quercetin) which was 4.75 μg/mL (Table 2). The seed extract of DPPH antioxidant activity was considered as strong, even though it was lower than the standard.

The FRAP value of seed extract was 5197.7 µM/g, which was significantly higher than quercetin (1177.99 µM/g). Greater amount of FRAP presents more ability to scavenge radicals. ABTS antioxidant assay showed that the *E. uniflora* seed extract has an IC_{50} value of 3.381 µg/mL (Table 2). For ABTS, linear regression equations of Quercetin obtained was y = 24.73x + 0.665 with R^2 = 0.994. The IC_{50} value of this assay of the *E. uniflora* seed extract is 3.381 (Table 2), while Quercetin is 1.995 µg/mL (Table 2).

Anti-tyrosinase activity

Suriname cherry seed extract had tyrosinase inhibition ability in IC_{50} value of 111.01 µg/mL. Quercetin showed a higher tyrosinase inhibition activity with an IC_{50} value of 5.30 µg/mL (Table 2).

Discussion

The UAE of Surinam cherry seed yields 32.4 %. Similar to previous studies in other species in the *Eugenia* genus, that ultrasound-assisted extraction gave higher yield (40 %) of the seed extract as compared to conventional extraction method (Albuquerque *et al.* 2024). Ultrasonic wave frequency provides the acoustic cavitation that disrupts the seed's cell wall and allows the ethanol solvent to dissolve the secondary metabolite compound (Shen *et al.* 2023).

The results of TPC and TFC indicated that Suriname cherry seed extract contained relatively high polyphenol and flavonoid components, which can have a significant role as a tyrosinase inhibitor. The activity of DPPH free radical scavenging of *E. uniflora* seeds extract in IC_{50} was 5.75 µg/mL compared to IC_{50} as 4.75 µg/mL of Quercetin. The antioxidant activity further confirms its in vitro antioxidant activity, which might be useful for preventing aging. Suriname cherry seed extract was able to donate H^+ that reacted with DPPH radical substance. The reduction in DPPH to hydrazine leads to a reduction in the absorbance of the reaction as measured at 517 nm spectrophotometer (Baliyan *et al*. 2022). This result aligns with the antioxidant from previous research, *E. involucrata* seed extract in DPPH antioxidant as IC_{50} as 33.6 ug/mL (Girardelo *et al*. 2020). The suriname cherry seed extract has higher DPPH antioxidants than *E. involucrata* seed extract. The DPPH method measures the scavenging ability of antioxidants by using DPPH.

In the ABTS method, the 2,2-azino-bis-3-ethylbenzothiazoline-6-sulphonic acid is used to generate a radical solution. When a sample containing antioxidants is added to a solution containing ABTS radical cation, the absorption decreases as the ABTS radical cation is terminated. The ABTS antioxidant of Suriname cherry seed extract is 3.38 µg/mL, while Quercetin is 1.97 µg/mL. Spectrophotometric measurement of the production of $ABTS^{4+}$ is inhibited by the presence of an antioxidant of seed extract. The potential of the antioxidant of seed extract increases with decreasing test solution absorption at 734 nm. The seed extract was able to donate hydrogen or electrons in order to scavenge the ABTS radical cation, as opposed to trolox (Kumar *et al.* 2018). The ABTS of Suriname cherry seed extract is considered as high antioxidant category, but still lower than the quercetin as positive control. ABTS is used for estimating the total antioxidant capacity of extracts, especially flavonoid and polyphenol compounds (Dong *et al.* 2015; Dorsey and Jones 2017).

The antioxidant potency of Suriname cherry seed extract in FRAP assay is determined by its capacity to transfer electrons to the FRAP reagent. The salt of ferric tripyridyl triazine will follow the reduction chemical reaction and change into a form of ferrous ion at acidic buffer solution. This confirms the existence of the antioxidant ability of the extract (Amalia *et al.* 2023). The result of FRAP value of seed extract is 5197.7 µM $FeSO_4$/g which is higher than the quercetin (1177.9 µM $FeSO_4$/g). This means the *E. uniflora* seed extract is able to catalyze the transformation of the Fe^{2+} or ferrous form into the

Table 1: Determination of TPC and TFC of seed extract of Suriname cherry

Phytochemistry Quantitative	Replication			% w/w Average ± SD
	1	2	3	
Total phenolic (mg GAE/g extract)	9.694	14.386	10.774	11.618 ± 2.46
Total flavonoid (mg QE/g extract)	2.770	2.684	2.751	2.735 ± 0.05

Table 2: Antioxidant and anti-tyrosinase of seed extract of Suriname cherry

Sample	DPPH (IC_{50})	ABTS (IC_{50})	FRAP (Mean ± SD)*	Anti-tyrosinase IC_{50})
Extract	5.75 ± 0.58	3.38 ± 0.04	5197.70 ± 12.76	595.74 ± 1.02
†Control	4.75 ± 0.03	1.97 ± 0.02	1177.99 ± 39.11	27.54 ± 1.09

*Mean and Standard Deviation µM $FeSO_4$/g extract; †quercetin equivalent; ‡kojic acid

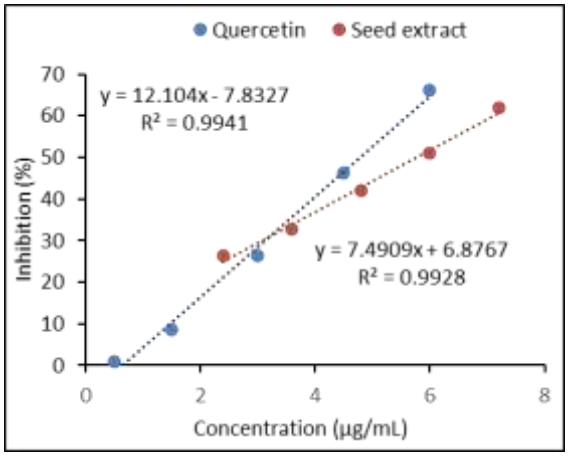

Fig. 2: The DPPH antioxidant activity of Suriname cherry seed extract and quercetin as control

Fe^{3+}/ferric cyanide complex better than the positive control. The FRAP value of this suriname cherry seed extract (5197 µM $FeSO_4$/g) is higher compared to FRAP value of Suriname cherry leaf extract (2493 µM $FeSO_4$/g extract) (Kurniawati *et al.* 2017). This result shows that suriname cherry seed has greater FRAP antioxidant activity.

The UAE using the polar solvent can improve extraction. It was proven that the DPPH, ABTS and FRAP antioxidant assay of Surinam cherry seed extract is higher than the other part of the plant. This also supported by the previous experiment from other species of *Eugenia* genus, that seed extract of the *E. involucrata* had higher antioxidant activities in DPPH and ABTS methods in comparison to the fruit extract (pericarps and pulps) (Nicácio *et al.* 2017). The antioxidant activity of Surinam cherry seed extract in this study is possibly associated with the high phenolic and flavonoid compounds present in the seed. The phytochemical compounds in *E. uniflora* seed extract are dominated with phenolic and flavonoids according to the high TPC and TFC. The antioxidant activities of seed extract may also correlated to the secondary metabolite compounds (Girardelo *et al*. 2020).

The Suriname cherry seed extract is considered as low category of tyrosinase inhibiting ability, because it was higher than 500 µg/mL, while quercetin has IC_{50} of 5.3 µg/mL, which considered as very strong category of anti-tyrosinase. The ability to inhibit tyrosinase of *E. uniflora* seed extract might be due to the phenolic compounds and flavonoids that could inhibit the action of the tyrosinase enzyme. The quantity of phenolic hydroxyl on 1, 2-diphenylethene derivatives can significantly reduce tyrosinase activity. Tyrosinase activity inhibition is markedly increased by adding two phenol hydroxyls as opposed to one hydroxyl and by replacing methoxyl with phenol hydroxyl (Pillaiyar *et al.* 2017). The mechanism by which phenol hydroxyl compounds block tyrosinase was examined. Tyrosine and dopamine's hydroxyls are the only sources of H^+ and epoxy double oxygen bond because tyrosinase's action center is hydrophobic (Zolghadri *et al*. 2019). Similar to tyrosine and dopamine, phenol hydroxyl compounds can suppress tyrosinase activity (Zuo *et al*. 2018). It is possible that polar active substances with antioxidant and antityrosinase activity, such as flavonoids, terpenoids, and phenolics such as gallic acid, ellagic acid, and myricitrin are present in the seed extract of Surinam cherry (Almeida *et al*. 2023). Therefore, the *E. uniflora* seed extract may need to be explored for other pharmaceutical purposes, such as elastase inhibition, antiacne or antiinflammation activity.

Conclusion

Total phenolic content was significantly associated to the antioxidant capacity as measured by the DPPH, FRAP, ABTS assays of the ethanolic seed extract from unripe fruit of Suriname cherry. Seeds of Suriname cherry fruit extract had potent antioxidant and anti-tyrosinase properties. Thus, Suriname cherry seeds can be developed as an anti-aging pharmaceutical product.

Acknowledgments

This research is funded by the Ministry of Education and Culture Republic of Indonesia for Dissertation Completion Scholarship (BPI No. 202307120136).

Author Contributions

BE conceived and designed the experiments, contributed

materials and analysis instruments; DMW performed the experiment and analyzed the data; BE, S, HS and DMW wrote the draft and the corrections of the manuscript.

Conflicts of Interest

The authors do not have any conflicts of interest.

Data Availability

Data contained in this work will be made available upon a reasonable request to the corresponding author.

Ethics Approval

Outside the scope of this paper.

Funding Source

Funding Source: Dissertation Completion Scholarship (BPI No. 202307120136) from Ministry of Education and Culture Republic of Indonesia

References

Albuquerque BR, J Pinela, C Pereira, F Mandim, S Heleno, MBPP Oliveira, L Barros (2024). Recovery of anthocyanins from *Eugenia* spp. fruit peels: A comparison between heat- and ultrasound-assisted extraction. *Sustain Food Technol* 2:189–201

Almeida LF, ECF Santos, JCB Machado, AM Oliveira, TH Napoleão, MRA Ferreira, LAL Soares (2023). Phytochemical profile, *In vitro* activities, and toxicity of optimized *Eugenia uniflora* extracts. *Boletin Latinoamericano y Del Caribe de Plant Med Aromat* 22:130–144

Amalia A, MFL Nugraha, S Sukenda, B Elya (2023). In vitro phytochemical, antioxidant, and antibacterial evaluations of various extracts of *Eleocharis dulcis* (Burm. f.) Trin. ex Hensch. *Trop J Nat Prod Res* 7:2911–2918

Baliyan S, R Mukherjee, A Priyadarshini, A Vibhuti, A Gupta, RP Pandey, CM Chang (2022). Determination of antioxidants by DPPH radical scavenging activity and quantitative phytochemical analysis of *Ficus religiosa*. *Molecules* 27:1326

Bezerra ICF, RTDM Ramos, MRA Ferreira, LAL Soares (2019). Optimization strategy for extraction of active polyphenols from leaves of *Eugenia uniflora* Linn. *Food Anal Meth* 13:735–750

Celli GB, AB Pereira-Netto, T Beta (2011). Comparative analysis of total phenolic content, antioxidant activity, and flavonoids profile of fruits from two varieties of Brazilian cherry (*Eugenia uniflora* L.) throughout the fruit developmental stages. *Food Res Intl* 44:2442–2451

de Barros GL, A Tuhanioglu, S Kaur, L Nora, A Ubeyitogullari (2024). Extraction of anthocyanins from purple sweet potato using supercritical carbon dioxide and conventional approaches. *Appl Food Res* 4:1–13

Desmiaty Y, FC Saputri, M Hanafi, R Prastiwi, B Elya (2020). Anti-elastase, anti-tyrosinase, and anti-oxidant of *Rubus fraxinifolius* stem methanolic extract. *Pharmacogn J* 12:271–275

Dong JW, L Cai, Y Xing, J Yu, ZT Ding (2015). Re-evaluation of ABTS·G+ assay for total antioxidant capacity of natural products. *Nat Prod Commun* 10:2169–2172

Dorsey BM, MA Jones (2017). Healthy components of coffee processing by-products. In: *Handbook of Coffee Processing By-Products*, pp:27–62. Galanakis CM (Ed.). Academic Press, London

Fan YF, SX Zhu, F-B Hou, D-F Zhao, Q-S Pan, Y-W Xiang, X-K Qian, G-B, Ge, P Wang (2021). Spectrophotometric assays for sensing tyrosinase activity and their applications. *Biosensors* 11:290

Farias D de P, IA Neri-Numa, FF de Araújo, GM Pastore (2020). A critical review of some fruit trees from the Myrtaceae family as promising sources for food applications with functional claims. *Food Chem* 306:125630

Gallucci S, AP Neto, C Porto, D Barbizan, I Costa, K Marques, P Benevides, R Figueiredo (2010). Essential oil of *Eugenia uniflora* L.: An industrial perfumery approach. *J Essen Oil Res* 22:176–179

Girardelo JR, EL Munari, JCS Dallorsoleta, G Cechinel, ALF Goetten, LR Sales, FH Reginatto, VC Chaves, FA Smaniotto, S Somacal, T Emanuelli, JC Benech, C Soldi, E Winter, GMM Conterato (2020). Bioactive compounds, antioxidant capacity and antitumoral activity of ethanolic extracts from fruits and seeds of *Eugenia involucrata* DC. *Food Res Intl* 137:109615

Jehan NN, T Sunarni, D Marlina (2023). Characterization of microencapsulated saga leaves extract (*Abrus precatorius* L.) and analgetic activity tests in male mice (*Mus musculus*). *Pharm Pharm Sci J* 10:280–289

Kumar S, RK Chaitanya, VR Preedy (2018). Chapter 20 - Assessment of antioxidant potential of dietary components. In: *HIV/AIDS: Oxidative Stress and Dietary Antioxidants*, pp. 239–253. Preedy VR, RR Watson (Eds.). Academic Press, London

Kurniawati P, IR Maulida, Muhaimin (2017). The determination of antioxidant activity of Brazil-cherry (*Eugenia uniflora* L.) leaves extract using FRAP method. *AIP Conf Proc* 1911:020019

Meriç Zİ, EÖ Nath, A Doğan, L Bitiş (2024). Antioxidant, anti-tyrosinase activities and characterization of phenolic compounds for some plants from the Marmara Region, Türkiye. *J Res Pharm* 28:396–408

Nicácio AE, EM Rotta, JS Boeing, EO Barizão, E Kimura, JV Visentainer, L Maldaner (2017). Antioxidant activity and determination of phenolic compounds from *Eugenia involucrata* DC. fruits by UHPLC-MS/MS. *Food Anal Meth* 10:2718–2728

Pillaiyar T, M Manickam, V Namasivayam (2017). Skin whitening agents: Medicinal chemistry perspective of tyrosinase inhibitors. *J Enzyme Inhibit Med Chem* 32:403–425

Rizki MI, AK Sari, D Kartika, A Khairunnisa, Normaidah (2022). Determination of total phenolic content and antioxidant assay fraction of ethanolic cempedak leaf extract (*Artocarpus integer*) with DPPH method. *Media Pharm Indo* 4:168–178

Santos DNE, LL de Souza, NJ Ferreira, AL de Oliveira (2015). Study of supercritical extraction from Brazilian cherry seeds (*Eugenia uniflora* L.) with bioactive compounds. *Food Bioprod Proc* 94:365–374

Shen L, S Pang, M Zhong, Y Sun, A Qayum, Y Liu, X Ren (2023). A comprehensive review of ultrasonic assisted extraction (UAE) for bioactive components: Principles, advantages, equipment, and combined technologies. *Ultrasonics Sonochem* 101:106646–106651

Şöhretoğlu D, S Sari, B Barut, A Özel (2018). Tyrosinase inhibition by some flavonoids: Inhibitory activity, mechanism by *In vitro* and *In silico* studies. *Bioorg Chem* 81:168–174

Souza PM, ST Elias, LA Simeoni, JE de Paula, SM Gomes, ENS Guerra, PO Magalhães (2012). Plants from Brazilian cerrado with potent tyrosinase inhibitory activity. *PLoS One* 7:e48589

Sulistyowati, B Elya, R Iswandana, S Nur (2023). Phytocompounds and *In vitro* antiaging activity of ethanolic extract and fractions of *Rubus fraxinifolius* Poir. leaves. *J Pharm Pharm Res* 11:595–610

Wenas DM, LS Aliya, WM Anjani (2020). Formula of yellow kepok banana (*Musa acuminata x Musa balbisiana*) corm extracts as antiinflamation. *Buletin Penelitian Tanaman Rempah Dan Obat* 30:100–110

Wenas DM, B Elya, Sutriyo, H Setiawan (2024). Antioxidant and tyrosinase inhibitory activities of unripe and ripe fruit and seed extracts of *Eugenia uniflora*. *Trop J Nat Prod Res* 8:7734–7739

Wiliantari S, R Iswandana, B Elya (2022). Total polyphenols, total flavonoids, antioxidant activity and inhibition of tyrosinase enzymes from extract and fraction of *Passiflora ligularis* Juss. *Pharmacog J* 14:660–671

Zolghadri S, A Bahrami, M Tareq, H Khan, AA Saboury (2019). A comprehensive review on tyrosinase inhibitors. *J Enzyme Inhibit Med Chem* 34:279–309

Zuo AR, HH Dong, YY Yu, QL Shu, LX Zheng, XY Yu, SW Cao (2018). The antityrosinase and antioxidant activities of flavonoids dominated by the number and location of phenolic hydroxyl groups. *Chin Med* 13:51