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REVIEW ARTICLE

Potential of Polyphenolic Compounds in Rosella Flowers on Reducing Oxidative Stress and Inflammation After Exercise: A Systematic Review

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Abstract

Study purpose. This study aims to analyze and highlight the potential of rosella flowers in reducing oxidative stress and inflammation after physical activity.

Materials and methods. The study used a systematic review method by searching various journal databases such as Scopus, Web of Science, Pubmed and Embase. The inclusion criteria in this study were articles published in the last 5 years and articles discussing Rosella Flowers, Oxidative Stress, Free Radicals, Inflammation, and Exercise. The exclusion criteria in this research were articles published in disreputable journals. A total of 357 articles from the Scopus, Web of Science Pubmed and Embase databases were identified. A total of 8 articles that met the inclusion criteria were selected and analyzed for this systematic review. For standard operations, this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) assessment.

Results. The results of this systematic review research report that the flavonoid content found in rosella flowers has anti-oxidant and anti-inflammatory properties which have the potential to reduce oxidative stress and uncontrolled inflammation caused by physical activity and intense exercise.

Conclusions. Rosella flowers show their ability as an anti-oxidative by donating hydrogen atoms to free radicals through phenolic compounds, thus breaking the cycle of ROS formation. The natural active ingredients in rosella flowers are able to reduce MDA and increase GSH which contributes to reducing oxidative stress and decreasing TNF-α which provides an anti-inflammatory effect in athletes after exercise.

Keywords: rosella flower, oxidative stress, free radicals, inflammation, exercise.

Introduction

Recently, most people have adopted a healthy lifestyle through regular exercise, thus preventing the onset of various diseases (diabetes, cancer, Alzheimer's, cardiovascular and dementia) as well as improving physical fitness and health. Regular exercise can also reduce peroxidants, increase antioxidant capacity and activate antioxidant enzymes, all of which help in protecting cells from the harmful effects of oxidative stress and stopping cell damage (Taherkhani, Suzuki & Castell, 2020; Daniela et al., 2022; Amiri et al., 2023). However, intense and irregular sports training actually causes athletes to experience inflammation, oxidative stress, muscle damage and injury, and chronic fatigue, which are associated with the toxic effects of free radicals. Increased oxidative stress can be assessed through

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malondialdehyde (MDA) and advanced oxidation rate of protein products (AOPP), which are biomarkers of oxidative damage. Meanwhile, reducing oxidative stress can be seen from increasing levels of antioxidants, such as superoxide dismutase (SOD) and glutathione peroxidase (GXP) (Souissi et al., 2020). Oxidative stress is an imbalance between antioxidants and oxidant processes that causes molecular damage and disruption of redox signals and control. Excessive production of reactive oxygen species (ROS) and reactive nitrogen species (RNS) causes disruption of the redox balance, causing inflammatory effects (Kruk et al., 2022). Increases in inflammatory mediators, such as tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), NF-kB, and C-reactive protein (CRP), correlate with an imbalance in ROS production (Merrigan & Jones, 2021). This causes chronic inflammation, which then triggers oxidative stress and chronic inflammation (El Assar et al., 2022).

Oxidative stress occurs after exercise-induced muscle damage (EIMD) with increased reactive oxygen species (ROS) (Bindu, Mazumder & Bandyopadhyay, 2020). EIMD can cause pain or muscle loss during the first 12-72 hours after exercise (Ayubi et al., 2023). The inflammatory response due to EIMD triggers a decrease in muscle strength, decreased range of motion (ROM), delayed muscle soreness (DOMS), local swelling, and an increase in muscle proteins in the blood (creatine kinase (CK), lactate dehydrogenase (LDH), and myoglobin (Mb) (Jamurtas, 2018; Fern & Mielgo-ayuso, 2020). Researchers have focused on using pharmaceutical, nutritional, and physical methods to reduce the inflammatory response in muscle damage caused by eccentric exercise. Free radicals and ROS caused by oxidative stress during exercise can be stabilized using antioxidants found in plants. Antioxidant supplementation in research conducted by (Canals-Garzón et al., 2022) reported that antioxidant properties were able to reduce oxidative stress by attenuating the lipid peroxidation response and reducing malondialdehyde (MDA) directly. Excessive ROS production in the body can be protected and reduced through antioxidant enzyme systems such as superoxide dismutase (SOD) and catalase (CAT). Apart from that, antioxidants have also been proven to be able to ward off free radicals and prevent destructive effects by limiting ROS damage mechanisms by reducing oxidative stress and inflammation (Amiri et al., 2023).

Supplements containing high levels of phenolic compounds derived from plants, for example, polyphenols (PC) have antioxidant and anti-inflammatory properties that can reduce oxidative stress, thus helping athletes to recover after exercise (Mason et al., 2020; Rojano-Ortega, 2021). Polyphenols are a group of phytochemicals in plants that are classified into four main classes, namely stilbenes, lignin, phenolic acids and flavonoids (Zhang et al., 2022). There are several factors for the use of polyphenols in improving post-exercise recovery, namely signaling activity that increases endogenous antioxidant responses, protective effects on red blood cells, and improved blood vessel function (Rudrapal et al., 2022). The structural components in polyphenols function as RONS scavengers and their antioxidant activity also has an indirect effect (Rudrapal et al., 2022). This is proven by the presence of a phenolic group and 2-3 double bonds as well as a 4-keto group in ring C which is able to capture free radicals and chelate metals so that this compound can significantly fight and protect against the effects of oxidative stress (Platzer et al., 2021). Most studies report that reducing inflammation and oxidative stress can be achieved by consuming polyphenols for at least 3 consecutive days before and after vigorous exercise sessions to improve muscle injury repair (Kruk et al., 2022; O'Connor, Mündel and Barnes, 2022).

One natural product that can be used, with potential anti-inflammatory and antioxidant effects, is the rosella flower. Hibiscus sabdariffa L. or known as Rosella contains vitamins, minerals and bioactive components, such as polyphenols (anthocyanins, flavonoids, phenolic acids, tannins), polysaccharides, pectins, non-phenolic organic acids, carotenoids, caffeic acid, chlorogenic acid, acid ascorbate, and quercetin, which makes it a powerful antioxidant (Singh et al., 2021). One of the polyphenols which are classified as flavonoids which have strong antioxidant properties is anthocyanin (Jin et al., 2022). This compound is a powerful free radical scavenger with inhibiting glycation and scavenging activity against DPPH and superoxide anions thereby increasing antioxidant activity or reducing ROS to detoxify oxidative damage (Jin et al., 2022). Roselle can also be further studied as a pharmacological treatment to reduce risk factors for cardiovascular disease because it has been proven to have antihyperlipidemic, antihyperglycemic, antioxidant, anti-inflammatory, antihypertensive, and antifibrosis properties (Ratna et al., 2018; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022; Khongrum et al., 2022; Sapian et al., 2023). Therefore, we want to relate and discuss in depth the potential use of Rosella in reducing oxidative stress and inflammation after physical activity through a systematic review.

This study aims to analyze and highlight the potential of Rosella in reducing oxidative stress and inflammation after physical activity.

Materials and methods

Study Design

This research uses a systematic review method by searching various journal databases such as Scopus, Web of Science, and Pubmed. It is considered a premier platform worldwide as it brings together publications that have scientific impact and relevance.

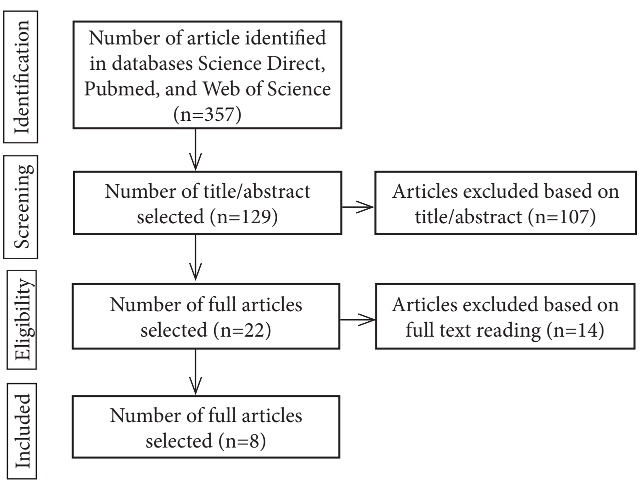


Fig 1. PRISMA flowchart of the article selection process

Eligibility criteria

The inclusion criteria in this study were articles published in the last 5 years and articles discussing Rosella, Oxidative Stress, Free Radicals, and physical exercise. The exclusion criteria in this study were articles published in disreputable journals.

Procedure

Titles, abstracts and full texts of articles were screened then verified and stored in Mendeley software. In the first stage, 357 articles from the Science Direct, Web of Science, and Pubmed databases were identified. Next, in the second stage, 129 articles were screened based on the suitability of the title and abstract. In the third stage, 22 articles were ordered for further processing. At this stage, we filter based on the overall suitability of the article. Then in the final stage 8 articles were selected that met the inclusion criteria and analyzed for this systematic observation. For standard operations, this study follows the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) assessment.

Results

Table 1. Results of a review of the effects of rosella on oxidative stress and free radicals

Author	Sample Characteristics	Study Design	Intervention	Results
Khongrum et al. (2022)	Rosella flowers were collected and dried at 50°C for 24 hours. Then it is ground and extracted to obtain a thick extract. Rosella extract was given to 43 adults suffering from dyslipidemia and grouped based on exclusion criteria into 2 groups, namely the RP jelly drink group and the placebo group.	Experimental	Subjects in the treatment group were given 300 mL rosella supplements once a day for 8 weeks. Then, subjects were asked to do physical activities such as moderate exercise, vigorous activity, walking, and sitting. Then the serum lipid profile, inflammation parameters, and oxidative stress status were analyzed.	Rosella supplementation given to subjects showed a significant reduction in LDL-C and TG. This can be proven by decreasing tumor necrosis factor-α (TNF-α) and malondialdehyde (MDA), as well as increasing glutathione (GSH), resulting in reduced inflammation and improved oxidative stress.
Singh et al. (2021)	Rosella samples were dried and made into powder. Rosella powder is extracted with water, methanol and ethanol and the mixture is centrifuged, filtered, evaporated to obtain a dry extract.	Laboratory experiments	Rosella samples were made into powder by drying. Then it is extracted using several solvents. The concentrated extract is filtered and evaporated to obtain a dry extract. Sample extracts were tested for total phenolic content, flavonoid content, DPPH radical scavenger test, and antioxidant activity test.	Rosella extract is reported to contain many polyphenolic and flavonoid compounds which contribute to antioxidant activity.
Ratna et al. (2018)	25 Male rats weighing 150-180 g were grouped into 5 groups, namely negative control rat group (standard feed without rosella extract), positive group (hot feed without rosella extract), treatment group 1 rosella extract 200 mg.kg/BW (R1), treatment group 2 rosella extract 300 mg.kg/BW (R2), and treatment group 3 rosella extract 400 mg.kg/BW (R3).	Experimental	Subjects were given rosella supplements orally for 4 weeks according to the dosage. Next, the subject's internal organs were taken for further analysis such as measuring serum CML, measuring IL-6 and amyloid.	Giving rosella supplements to subjects can increase serum CML levels, reduce IL-6 levels significantly, and reduce amyloid levels significantly. So this supplement has the potential to reduce oxidative damage and increase antioxidant performance.
Ujianti et al. (2023)	Rosella extract samples were given to subjects orally, where 30 male Sprague-Dawley rats were grouped into 6 groups and given the following treatment: (1) normal control group, (2) vitamin B12 restricted diet group without rosella extract, and (3) group limited diet vitamin B12 + rosella extract.	Experimental	Subjects were given rosella extract supplementation at a dose of 400 mg/kg/weight/day for 8 and 16 weeks. After that, the subjects' organs and blood samples were taken for histological and biochemical analysis.	The results of phytochemical analysis show that rosella extract contains bioactive compounds such as flavonoids, saponins, tannins, triterpenoids and quinones. Rosella extract supplementation can significantly reduce levels of pro-inflammatory cytokines and increase anti-inflammatory cytokines, reduce levels of TNF-α and IL-6, and increase levels of IL-10 and Nuclear-erythroid-2 Associated Factor 2 (NRF2). So it can be concluded that rosella extract is able to reduce inflammation and reduce oxidative stress.

Table 1. Continued

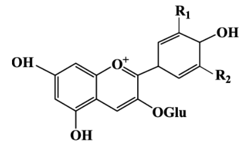
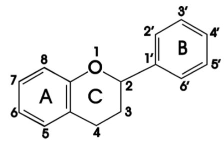
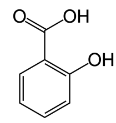
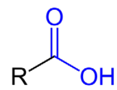
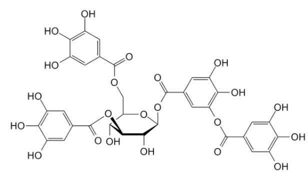
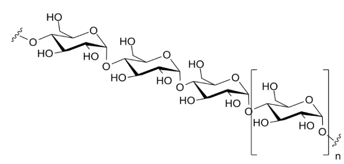
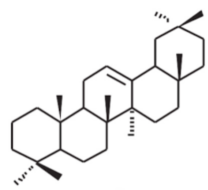
Author	Sample Characteristics	Study Design	Intervention	Results
Marhuenda et al. (2020)	84 sedentary and healthy subjects were given rosella extract supplements and a placebo for 84 days. Subjects were divided into 2 groups, namely the placebo group and the rosella extract group.	Experimental	Samples of rosella extract and placebo were given orally to subjects according to the dosage for 84 days. Then the subjects were asked to do physical exercise and blood samples were taken for analysis processes such as measuring LDL, HDL, triglycerides and total cholesterol.	It was reported that rosella extract caused a decrease in LDL and cholesterol after consumption by the subjects. Rosella extract as a source of bioactive compounds has a high polyphenol content so it has the potential for antioxidant and anti-inflammatory activity. In addition, this compound has been proven to be able to reduce oxidative stress and inhibit the increase in triglycerides and inflammatory adipokines.
Santoso et al., (2019)	Rosella extract was given orally to subjects at a dose of 500 mg/kg BW 5 times a week for 11 weeks. Subjects were 25 male Wistar rats weighing 200-250 g, divided into 5 groups, namely: control group (C), control + rosella extract (C+HSL), excessive training (OT), excessive training + rosella extract (OT+HSL), and aerobic (A).	Experimental	Rosella extract supplementation at a dose of 500 mg/kg was given to subjects for 11 weeks according to group division. Subjects did physical exercise and then samples of the subject's organs were taken to measure IL-6 and TNF-α levels.	The results of this study report that rosella extract can reduce levels of TNF-α and IL-6 significantly. This is due to the presence of bioactive compounds such as quercetin and anthocyanins which have the potential to act as antioxidants and anti-inflammatory.
Anel, Subapriya & Singh (2019)	Rosella petals are washed, dried, and ground into powder. Then it was made into a drink supplement which was given to 30 athletes aged 15-19 years (20 boys and 10 girls). Subjects were divided into 2 groups, namely the experimental group and the placebo group.	Experimental	Rosella supplementation was given to athletes orally at a dose of 240 mL before and after physical exercise for 90 days. Fitness parameters (vertical jumps, sit ups, long jumps) and blood samples were taken to analyze antioxidant levels.	Rosella extract supplementation can increase the subject's blood hemoglobin by significantly reducing serum Malondialdehyde (MDA) levels. So this extract has the potential to reduce oxidative stress and has antioxidant activity.
Mohamed et al. (2022)	Rosella flowers are dried and ground into powder, then extracted. Rosella extract was administered orally to 15 male Sprague-Dawley rats.	Experimental	Rosella extract supplementation was given to subjects orally. Then the extract was tested for antioxidant activity (lipid peroxidation, GSH, SOD, catalase activity), phenolic content, spectrophotometric analysis, and antidiabetic activity test.	Rosella extract contains high levels of polyphenolic compounds. This compound has strong potential as an antioxidant that can capture free radicals (DPPH), inhibit nitric oxide (NO) radicals, and increase iron ion-reducing power (FRAP). This extract can also increase SOD levels and reduce MDA levels, thereby reducing oxidative stress.

Discussion

The main research objective of this systematic review is to analyze and highlight the potential of rosella in reducing oxidative stress and inflammation after physical exercise. Rosella flower with the Latin name "Hibiscus sabdariffa L." is a plant that is found in tropical countries such as Brazil, the Philippines, Hawaii, the Caribbean, and Australia, as well as places such as India, Malaysia, Thailand, Indonesia, and China. Rosella belongs to the Malvaceae family and more than 300 species of rosella have been identified. The morphology of this plant is that it has a maximum height of 2.5 m, the stem is dark red and cylindrical in shape, the leaves are deeply lobed, 3-5 alternate with a length of 8-15 cm, and the edges of the leaves have teeth. The flowers are 8-12 cm in diameter, found singly in the terminals or axils of the leaves, white to pale yellow with a dark red spot at the base of each petal, and have sturdy fleshy petals at the base, 1-2 cm wide, expanding to 3-3.5 cm , fleshy and bright red when the fruit is ripe (Figure 1) (Riaz & Chopra, 2018; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022; Wang et al., 2022; Sapian et al., 2023).

Rosella flower petals have the potential to treat various diseases such as cardiovascular disease, diabetes, obesity, coughs, hypercholesterolemia, hypertension, kidney and skin diseases, and digestive disorders. Rosella flower petals are known for their therapeutic potential which is rich in protein (5.5-9.14%), carbohydrates (7.4-12.3%), and fat (0.47-1.32%) (Singh et al., 2021; Mohamed et al., 2022). Apart from being rich in dietary fiber, rosella is known to contain various bioactive compounds such as polyphenols (flavonoids, phenolic acids, anthocyanins, and tannins), pectin, polysaccharides, carotenoids, and non-phenolic organic acids, which are responsible for various biological and pharmacological functions such as anti-hyperglycemic, anti-hyperlipidemia, anti-hypertension, antioxidant, anti-inflammatory, anti-fibrosis, antimicrobial, anticarcinogenic, hepatoprotective and antidiabetic, which can be seen in full

Table 2. Active chemical compounds in Hibiscus sabdariffa

Chemical Groups	Active Compounds	Structure
Anthocyanins	delphinidin-3-sambubioside cyanidin-3-sambubioside delphinidin-3-glycoside cyanidin-3-glycoside	
Flavonoids	quercetin, hibiscetin (hibiscetin-3-glucoside), sabdaritrin, gossypitrin, and other gossypetin glycosides, luteolin, rutin	
Phenolic acids	chlorogenic acid, protocatechuic acid, caffeic acid, gallic acid	
Non-phenolic organic acids	hibiscus acid, hydroxy citric acid, malic acid, ascorbic acid, oxalic acid, succinic acid, tartaric acid, arachidic acid, citric acid, pelargonic acid	
Tannins	no specific name indicated	
Polysaccharides (Sugars)	galactose, galacturonic acid, rhamnose, arabinose, glucose, mannose, xylose, pectins	
Triterpenoids	α-amyrin, lupeol	 1
Others	calcium, magnesium, iron, trace elements, vitamins, and polyphenols	-

in Table 2 and Figure 3 (Frank et al., 2012; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022; Sapian et al., 2023)

It has been found that the phytochemical components in rosella have strong antioxidant qualities which have the ability to prevent the negative effects of oxidative stress. Antioxidants are responsible for scavenging free radicals thereby preventing oxidation. Antioxidant activity can be attributed to the presence of phenolic acids and flavonoids (Hossain, Dave & Shahidi, 2022). Based on research by (Sapian et al., 2023) reported that rosella extract given to obese mice was able to reduce oxidative stress by increasing superoxide dismutase (SOD) enzyme activity and glutathione (GSH) concentrations, as well as downregulating NOX2 and 8-isoprostane gene expression. This is because phenolic acid, anthocyanin and flavonoid compounds can capture free

Fig. 2. Roselle plant (Riaz & Chopra, 2018; Sapian et al., 2023)

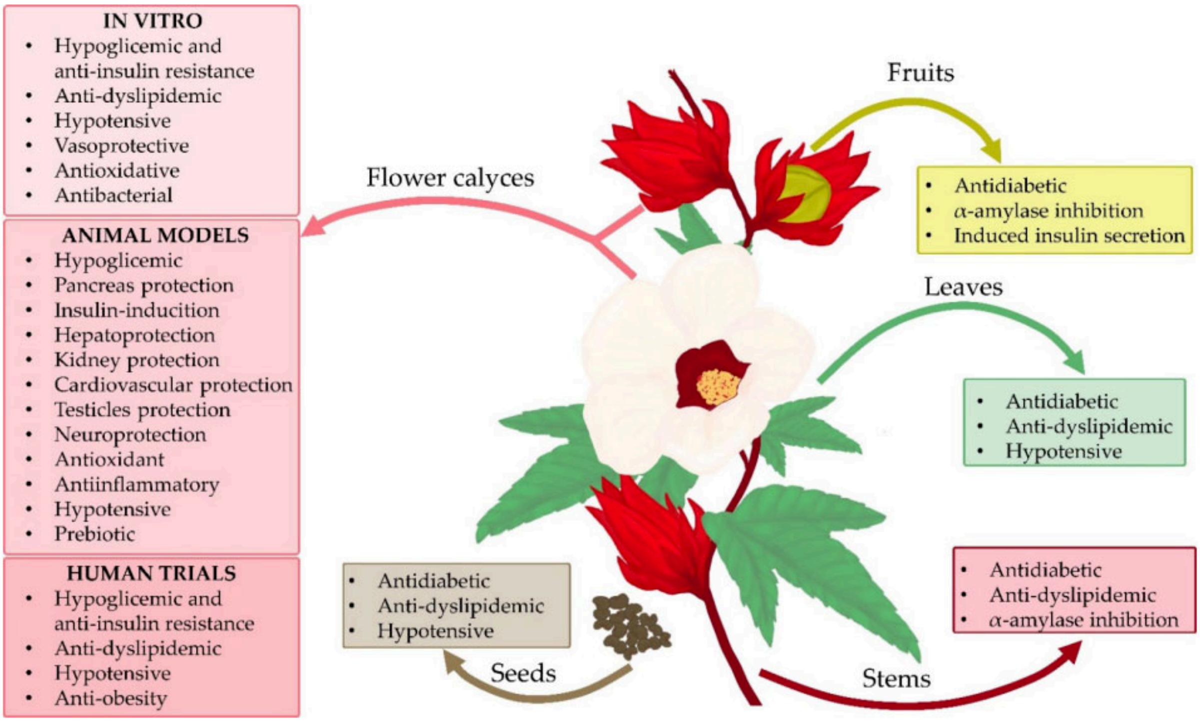


Fig. 3. Beneficial effects of different parts of roselle (Jamrozik, Borymska and Kaczmarczyk-Żebrowska, 2022)

radicals such as reactive nitrogen species (RNS) and ROS, thereby inhibiting oxidative stress.

Hibiscus acid, hydroxycitric acid, malic acid, ascorbic acid, oxalic acid, succinic acid, tartaric acid, arachidic acid, and citric acid are the most significant organic acids in roselle. This compound can reduce oxidation and encourage the production of the anti-inflammatory cytokine IL10, which in turn inhibits pro-inflammatory cytokines such as IL-6 and TNF-α. Therefore, roselle has strong antioxidant properties that can reduce cardiovascular inflammation and have cardioprotective effects (Sapian et al., 2023). In addition, polyphenols are also responsible for the antioxidant effects of Rosella. Delphinidin-3-sambubioside and cyanidin-3-sambubioside are the two most significant anthocyanins found in roselle. The most significant flavonoids that have been extracted from roselle are luteolin, gossypitrin and various glycosides gossypetin, sabdaritrin, quercetin, and hibiscetin (hibiscetin-3-glucoside). Along with many other phytochemicals, there are phenolic acids such as caffeic acid, protocatechuic acid, and chlorogenic acid. Glucose, mannose, xylose, rhamnose, arabinose, galactose and galacturonic acid make up the majority of sugars in roselle flower petals. Some authors also imply that in the petals there are triterpenoids such as α-amyrin and lupeol (Riaz & Chopra, 2018; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022).

Polyphenols have a benzene ring with one or more hydroxyl groups (-H2O) attached to it. According to their chemical structure, phenolic compounds are divided into five main classes, namely phenolic acids, flavonoids, stilbenes, lignin and condensed tannins. The class of polyphenols that accounts for 80% of all polyphenol chemicals are flavonoids. The framework of this class of polyphenols consists of two aromatic rings (rings A and B) which are connected by three carbon atoms to form a heterocyclic ring C which has an oxygen atom. Flavonoids are divided into six subclasses, namely flavones, isoflavones, flavonols, flavanols, flavanones, and anthocyanidins which can be seen in Figure 3. Polyphenols act in preventing and reducing the impact of oxidative stress originating from the presence of phenolic groups, 2-3 double bonds, and 4 groups. -keto on the C ring, which allows free radical capture and metal chelation (Kruk et al., 2022). A study reported that phenolic compounds are able to inhibit oxidation, mediate anti-inflammatory actions by blocking the MAPK signaling pathway, inhibit the synthesis of pro-inflammatory cytokines, especially nitric oxide synthase (iNOS), nitric acid (NO), TNF-α, interleukin-1β (IL-1β), and prostaglandin E2 (PGE2) (Hossain, Dave & Shahidi, 2022).

Regular physical activity practice has been proven to be able to maintain health by increasing immunity, reducing the risk of various diseases such as diabetes, osteoporosis, cancer, Alzheimer's, cardiovascular disease, and so on. However, intense and irregular exercise actually causes inflammation, oxidative stress, muscle damage and injury, which are associated with the toxic effects of free radicals (FR) (Souissi et al., 2020; Taherkhani, Suzuki & Castell, 2020; Daniela et al., 2022). Reactive oxygen species (ROS) are produced in large amounts during exercise. This species plays a significant physiological function in exercise adaptation. However, these ROS will increase in large amounts if physical exercise is carried out for a long period of time and excessively, causing an imbalance in antioxidant defenses, which ultimately results in oxidative stress (Martins et al., 2020). Oxidative stress occurs due to an imbalance between the production of free radicals in the body and the body's capacity to detoxify free radicals by neutralizing

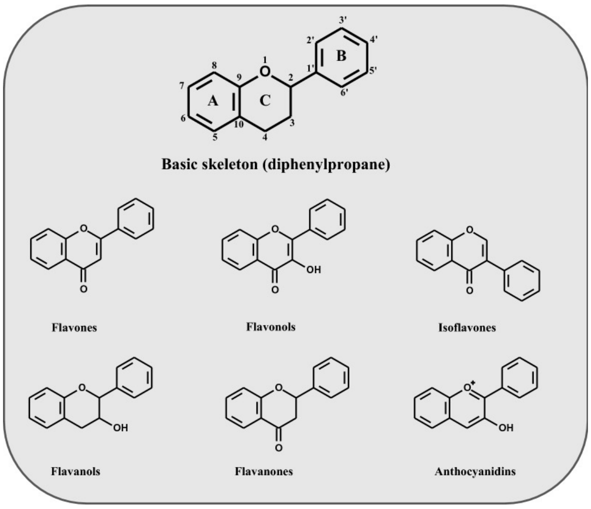


Fig. 4. Chemical structure of flavonoids and their main subclasses

their damaging effects through antioxidant mechanisms. Malondialdehyde (MDA), a major marker of lipid oxidation, is one of the end products of the oxidation process that can be used to identify this phenomenon. Numerous studies report that oxidative stress can cause a number of problems for athletes, including fatigue, inflammation, and muscle injury (Hadi et al., 2017).

Microtrauma/muscle injury can be healed adaptively through an inflammatory process. However, continuous intense exercise causes chronic inflammation. This inflammatory process can interfere with an athlete's recovery by developing muscle pain during physical exercise. Therefore, an important strategy for post-exercise recovery is needed, where muscle fibers produce and release pro-inflammatory myokines such as IL-6 when physically active. In inflammatory situations, other myokines such as TNF-α and IL-10 are also expressed (Santoso et al., 2019; Porto et al., 2023; Volpe-Fix et al., 2023). TNF-α is one part of the pro-inflammatory cytokines that trigger muscle pain (Fernández-Lázaro et al., 2020; Ayubi et al., 2022; Nanavati et al., 2022). TNF-α produced by heart cells is responsible for the inflammatory response to stress (Santoso et al., 2019). Nuclear factor E2 (NRF2)-mediated signaling pathway controls the inhibition of oxidative stress. NRF2 is an important transcription factor that controls the expression of several antioxidant enzymes, ultimately increasing the body's capacity to defend against free radicals (Wang et al., 2021).

Various diseases related to oxidative stress, such as heart disease, neurological disease, cancer, diabetes mellitus, and uncontrolled inflammatory processes due to intense exercise can be prevented or treated with chemicals containing phenolic compounds. This compound is believed to have the capacity to scavenge free radicals and function as an antioxidant and anti-inflammatory which can reduce oxidative stress, thus helping athletes in the post-exercise recovery process (Mason et al., 2020; Rojano-Ortega, 2021). Phenolic compounds can inhibit enzymes that cause ROS to become highly oxidized and reduce the amount of ROS produced (Aatab et al., 2023). In addition, the production of IL-6 and TNF-α can be suppressed through the use of quecetin and anthocyanin compounds. IL-6 production can be inhibited by quercetin through the regulatory effect of p38-mitogen-activated protein kinase (p38-MAPK). The expression of TNF-α can also be suppressed by this compound through reducing NF-kβ gene expression and decreasing Iκβα and Iκββ phosphorylation so that quercetin can reduce NF-κβ activation. Anthocyanin compounds can also inhibit the production of nitric oxide, rostaglandin E2, TNF-α, and IL-6. Anthocyanins have been reported to reduce the formation of reactive oxygen species, which in turn reduces MAPK activation and inflammatory cytokine production. Anthocyanins reduce the synthesis of proinflammatory mediators such as IL-6 and TNF-α by blocking the translocation of NF-κβ from the cytosol to the nucleus and preventing the phosphorylation of Iκβ (Santoso et al., 2019). One natural product that contains this bioactive is rosella. Rosella has antioxidant and anti-inflammatory properties and can be an intervention strategy in reducing oxidative stress and controlling uncontrolled inflammatory processes due to intense exercise.

The idea that rosella contains antioxidant properties and reduces oxidative stress is supported by a study by (Khongrum et al., 2022) who reported that rosella extract contains many polyphenols, anthocyanins, quercetin and gallic acid which contribute to lowering lipids and inhibiting LDL-C oxidation through antioxidant activity. Oxidative stress can be inhibited by using polyphenolic compounds. In this study, the natural active ingredients in rosella supplementation were able to reduce maloddialdehyde (MDA) and increase glutathione (GSH) which contributed to reducing oxidative stress and reducing tumor necrosis factor-α (TNF-α) which provided an anti-inflammatory effect. This research is also strengthened by a laboratory study which reports that rosella extract has potential for antioxidant activity. This observation is supported by the high levels of polyphenols and flavonoids contained in rosella. The main polyphenolic compounds from this extract are delphinidin 3-O-sambubioside chloride and cyanidin 3-O-sambubioside chloride which are classified as anthocyanin compounds. In addition, antioxidant activity can be seen from the significant increase in DPPH values through scavenging free radicals thereby inhibiting oxidative stress (Singh et al., 2021).

Furthermore, the results of other research show that rosella extract has strong antioxidant properties due to the presence of active compounds such as flavonoids, alkaloids, anthocyanins, bsitosterol, and ascorbic acid. Delphinidin 3-sambubioside (DP3-Sam), an anthocyanin compound, has a higher antioxidant effect than other antioxidants because it is able to inhibit the expression of inflammatory mediators. The compounds contained in rosella extract are able to reduce iNOS, IL-6, NO, MCP-1, and TNF-α by downregulating the NF-kB and MEK1/2 – ERK1/2 signal pathways and by inhibiting free radicals. Antiocyanins are also able to reduce Aβ levels through scavenging free radicals and reducing ROS, thereby detoxifying oxidative damage and strengthening antioxidant action (Ratna et al., 2018). Research by (Ujianti et al., 2023) reported that rosella extract can inhibit the formation of homocysteine which causes oxidative stress. This is caused by rosella extract which contains several bioactive compounds such as flavonoids, quinones, tannins, triterpenoids and saponins. This compound is believed to have antioxidant and anti-inflammatory activity by capturing ROS and free radicals, reducing reactive O_2, and preventing the formation of free radicals. Rosella extract supplementation is responsible for increasing antioxidant defense and reducing lipid peroxidation against oxidative stress through the NRF2 signaling pathway. This extract can reduce pro-inflammatory cytokines such as TNF-α and IL-6 by inhibiting the development of NAFLD and increasing anti-inflammatory cytokines such as IL-10.

Additionally, research studies by (Marhuenda et al., 2020) revealed that rosella extract contains polyphenolic compounds, namely quercetin-3-O-β-D-glucuronide and aglycone, which are responsible for inhibiting the increase in triglycerides, inflammatory adipokines, and free radicals that cause oxidative stress. Quercetin can inhibit TNF-α gene expression by modulating NF-κβ. So this extract has the potential for antioxidant and anti-inflammatory activity. This research is strengthened by (Santoso et al., 2019) who reported that rosella extract has antioxidant and anti-inflammatory properties because it contains polyphenolic compounds such as quercetin and anthocyanin. This compound can reduce pro-inflammatory mediators by inhibiting IL-6 production and reducing TNF-α expression by reducing NF-κβ activation. Anthocyanins also play a role in reducing ROS production thereby reducing the production of inflammatory cytokines. So it was concluded that rosella extract supplementation had a protective effect against chronic inflammation.

Other research by (Anel, Subapriya and Singh, 2019) strengthens reports that rosella extract supplements contain phytochemicals such as flavonoids, tannins, alkaloids, saponins and anthraquinones which have the potential to act as antioxidants. This antioxidant property can reduce serum MDA levels so that it can reduce oxidative stress in athletes after physical exercise. In addition, research by (Mohamed et al., 2022) shows that rosella extract supplementation has high antioxidant and antidiabetic potential due to its high polyphenol content. This antioxidant property plays a role in inhibiting oxidative stress damage through the donation of hydrogen atoms by phenolic compounds to free radicals thereby breaking the cycle of ROS formation. The increase in GSH levels which acts as a defense against free radicals after administration of rosella extract shows its anti-oxidative ability. In addition, rosella extract is able to increase SOD activity, thereby showing anti-oxidative ability and reducing oxidative stress. With increasing levels of SOD, GSH, and catalase activity, MDA levels decrease due to the antioxidant properties of this rosella extract.

So, the polyphenol content (phenolic acids, flavonoids and anthocyanins) contained in rosella has antioxidant and anti-inflammatory properties which have the potential to reduce oxidative stress and inflammation due to intense exercise. Furthermore, for more details regarding the benefits of rosella in reducing oxidative stress and inflammation, see Figure 5.

Conclusions

The polydenol compounds such as flavonoids, phenolic acids and anthocyanins found in rosella have anti-oxidant properties which can reduce oxidative stress. In this case, rosella extract shows its ability as an anti-oxidative through donating hydrogen atoms by phenolic compounds to free radicals thereby breaking the cycle of ROS formation. The natural active ingredients in rosella flowers are able to reduce MDA and increase GSH which contributes to reducing oxidative stress and reducing TNF-α which provides an anti-inflammatory effect in athletes after physical exercise. The compounds contained in rosella extract are able to reduce iNOS, IL-6, NO, MCP-1, and TNF-α by downregulating the NF-kB and MEK1/2 – ERK1/2 signal pathways and by inhibiting free radicals. Antiocyanins are also able to reduce Aβ levels through scavenging free radicals and reducing ROS, thereby detoxifying oxidative damage and strengthening antioxidant work. We recommend that rosella can be used in individuals to reduce oxidative stress and inflammation caused by physical activity and intense exercise.

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Conflicts of Interest

The authors declare no conflict of interest.

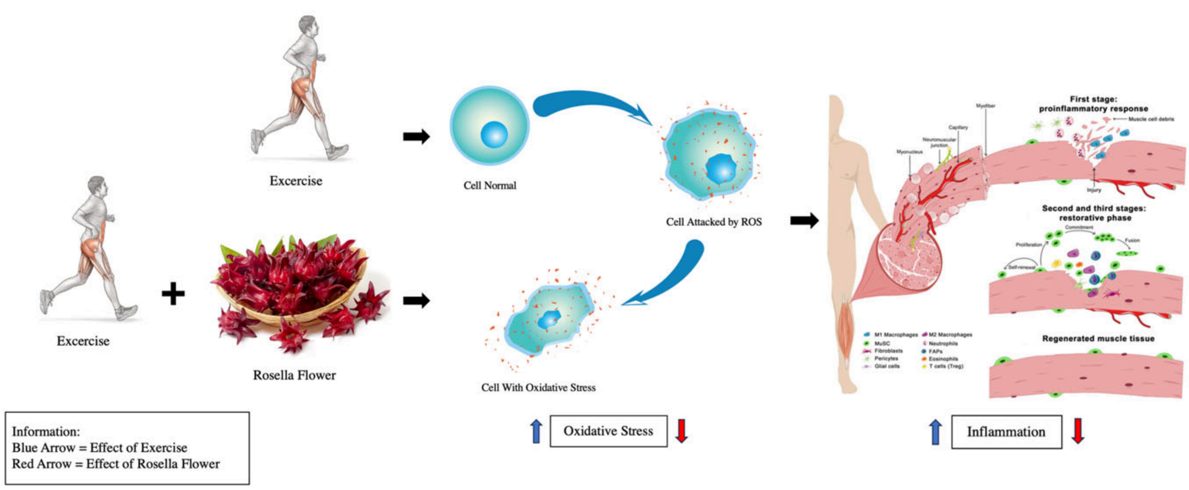

Fig. 5. Mechanism of Action of Rosella Flowers to Reduce Oxidative Stress and Inflammation

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Потенціал впливу поліфенольних сполук квітів розелли на зменшення оксидативного стресу та запалення після проведення фізичних вправ: систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 2 табл., 5 рис., 42 джерела.

Мета дослідження. Метою даного дослідження є аналіз та визначення потенціалу впливу квіток розелли на зменшення оксидативного стресу та запалення після фізичної активності.

Матеріали та методи. У дослідженні використовувався метод систематичного огляду шляхом пошуку в різних наукометричних базах даних журналів, таких як Scopus, Web of Science, Pubmed та Embase. Критеріями включення до даного дослідження були статті, опубліковані за останні 5 років, а також статті, в яких розглядалися такі питання, як квіти розелли, оксидативний стрес, вільні радикали, запалення та фізичні вправи. Критеріями виключення в дослідженні були статті, опубліковані в недоброчесних журналах. Загалом було знайдено 357 статей з науковометричних баз даних Scopus, Web of Science Pubmed та Embase. Для даного систематичного огляду було відібрано та проаналізовано загалом 8 статей, які відповідали критеріям включення. Що стосується стандартних операцій, дане дослідження проводилося відповідно до оцінки «Переважні елементи звітності для систематичних оглядів і мета-аналізів» (PRISMA).

Результати. Результати даного систематичного оглядового дослідження свідчать, що вміст флавоноїдів у квітках розелли має антиоксидантні та протизапальні властивості, які потенційно сприяють зниженню оксидативного стресу та неконтрольованого запалення, спричиненого фізичною активністю та інтенсивним тренуванням.

Висновки. Квіти розелли володіють антиоксидантною дією, оскільки через фенольні сполуки передають атоми водню вільним радикалам, розриваючи таким чином цикл утворення АФК. Природні активні компоненти квітів розелли мають здатність зменшувати рівень МДА та підвищувати вміст GSH (глутатіону), що сприяє зменшенню оксидативного стресу та зниженню рівня TNF-α, який забезпечує протизапальний ефект у спортсменів після виконання фізичних навантажень.

Ключові слова: квітка розелли, оксидативний стрес, вільні радикали, запалення, фізичні вправи.

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