Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

REVIEW ARTICLE

ANTIOXIDANT AND ANTI-INFLAMMATORY PROPERTIES OF BEE PRODUCTS POTENTIALLY REDUCE OXIDATIVE STRESS AND INFLAMMATION AFTER PHYSICAL ACTIVITY/EXERCISE: A SYSTEMATIC REVIEW

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: December 16, 2023
Published: December 22, 2023

DOI: 10.17309/tmfv.2023.6.19

Abstract

Study purpose. This research aims to analyze and highlight the potential of bee products in reducing oxidative stress and inflammation after physical activity/exercise.

Materials and methods. This research uses 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 bee products, honey, oxidative stress, inflammation, physical activity, and exercise. The exclusion criteria in this study were articles published in disreputable journals. Titles, abstracts, and full texts of articles were screened then verified and stored in Mendeley software. A total of 7,124 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.

Results. Bee products that have anti-oxidant properties can reduce oxidative stress and the anti-inflammatory properties of bee products can reduce uncontrolled inflammation due to exercise.

Conclusions. Bee products contain flavonoids which have anti-oxidant properties which can reduce oxidative stress. In addition, the anti-inflammatory properties of bee products can reduce uncontrolled inflammation due to physical activity/exercise. In this case, honey works by inhibiting inflammation through NF-κB signals and reducing inflammation by suppressing the secretion of pro-inflammatory cytokines such as TNF-α and inflammatory markers such as CRP. Reducing inflammation can reduce the intensity of muscle pain. It is recommended that bee products be used in individuals to reduce oxidative stress and inflammation after physical activity/exercise.

Keywords: bee products, oxidative stress, inflammation, physical training, healthy lifestyle.

Introduction

Regular physical activity/exercise can improve health and fitness (Ruegsegger & Booth, 2018). However, on the other hand, intense physical activity/exercise will trigger uncontrolled oxidative stress due to an imbalance between reactive oxygen species (ROS) and antioxidants (Thirupathi et al., 2021). Increased ROS can cause degenerative diseases such as cancer, cell damage and type 1 diabetes (Darenskaya et al., 2021). In addition, physical activity/exercise at high intensity, especially with eccentric movements, causes metabolic stress in the form of energy deficiency and muscle damage (Harty et al., 2019). Muscle damage caused by exercise is characterized by the onset of muscle pain (Casanova et al., 2018). Thus, the resulting muscle pain

can limit performance after a training session (Owens et al., 2019; Romero-Parra et al., 2021; Viribay et al., 2020; Xin & Eshaghi, 2021). Several studies explain that pain occurs due to an uncontrolled inflammatory process due to increased levels of Tumor Necrosis Factor-Alpha (TNF-a) and Interleukin 6 (IL-6) levels during exercise-induced muscle damage (Dupuy et al., 2018). Meanwhile, Creatine Kinase (CK) is believed to be a biomarker for muscle damage (Esteves-Lima et al., 2020; Oosthuyse & Bosch, 2017).

In most cases, inflammation peaks 1 to 2 days after an exercise session (Chang et al., 2021; Hung et al., 2021; Muljadi et al., 2021). The current phenomenon is that around 30 million people worldwide who experience pain are usually treated with non-steroidal anti-inflammatory drugs (NSAIDs) (Ayubi & Sastika Putri, 2021; Kyriakidou et al., 2021). Giving NSAIDs after exercise is a wrong alternative for managing pain, this is because NSAIDs have a disruptive effect on the muscle growth response which has an impact on hypertrophy and muscle strength. As a result, giving NSAIDs will actually negate the results of the exercise carried out (Schoenfeld, 2012).

Alternative solutions need to be sought to overcome this problem. One of the natural products produced by bees is honey. Apart from honey, bees also produce many by-products such as pollen, propolis and royal jelly (Ali & Kunugi, 2020). Several studies report that bee product has anti-inflammatory properties (Esa et al., 2022; Eteraf-Oskouei et al., 2020). In this regard, anti-inflammatory cytokines such as interleukin 10 (IL-10) play an important role in controlling the inflammatory response. (Srivastava et al., 2017). Apart from that, bee products is also famous for its anti-oxidants (Cianciosi et al., 2018). On the other hand, honey plays a role in suppressing pro-oxidant activity by increasing the heme oxygenase 1 (HO-1) and glutathione peroxidase (GPx) genes. (Iova et al., 2021). Bee products has also been used in the world of medicine and health to speed up wound healing (Cianciosi et al., 2018). In this case, the many benefits of bee products give us the opportunity to relate and discuss in depth the effects of bee products in reducing oxidative stress and uncontrolled inflammation after physical activity/exercise through a systematic review.

This research aims to analyze and highlight the potential of bee products in reducing oxidative stress and inflammation after physical activity/exercise.

Materials and methods

Studi design

This research uses a systematic review method by searching various journal databases such as Scopus, Web of Science, Pubmed and Embase.

Eligibility criteria

The inclusion criteria in this study were articles published within the last 5 years. The next article discusses bee products, honey, oxidative stress, inflammation, physical activity, and exercise. The exclusion criteria in this study were articles published in national and non-reputable journals.

Procedure

Titles, abstracts and full texts of articles were screened then verified and stored in Mendeley software. In the first stage, 7,124 articles from the Scopus, Web of Science Pubmed and Embase databases were identified. Next, in the second stage, 55 articles were screened based on the suitability of the title and abstract. In the third stage, 31 articles were verified for further processing. At this stage we filter based on the suitability of the full article. Next, in the final stage, 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.

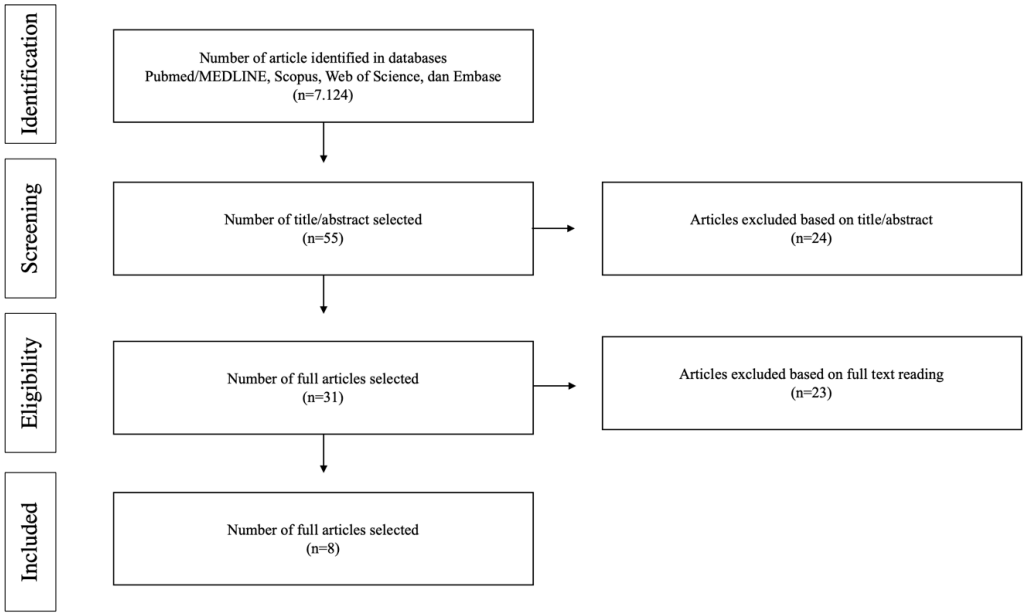

Fig. 1. PRISMA flowchart of the article selection process

Results

Table 1. Results of a review of the effects of bee products on oxidative stress and inflammation

Author	Sample Characteristics	Study Design	Intervention	Results
(Kheirdeh et al., 2022)	56 female mice aged 8-10 weeks, weighing 200-220 g, were divided into 8 groups, namely healthy control group, experimental autoimmune encephalomyelitis group, sham group, royal jelly group with a honey base dose of 50mg/kg, royal jelly group with a base ingredient honey dose 100mg/kg, sports training group + royal jelly with a honey-based ingredient dose 50mg/kg and sports training group + royal jelly with a honey-based ingredient dose 100mg/kg.	Experimental	Providing royal jelly intervention with honey as the base ingredient. Intervention was carried out every day for 5 weeks. Training consists of tretmill training every session of 5 to 25 minutes at a speed of 6m/s 5 times a week.	Royal jelly consumed at a dose of 50 mg/kg and 100 mg/kg together with aerobic exercise has benefits on pain threshold.
(Petelin et al., 2019)	A total of 72 overweight people aged 25 years were divided randomly into 2 groups, namely the control group and the treatment group with bee product in the form of royal jelly.	Experimental	Bee product in the form of royal jelly with a dose of 333 mg/capsule	Providing bee product interventions such as royal jelly has the potential to provide benefits on lipid profiles, inflammation, oxidative stress, mood and satiety in overweight people.
(Ali et al., 2021)	8 relevant studies on honey, fatigue, physical performance, inflammation and exercise during COVID-19	Literature Review	Giving bee products such as royal jelly, propolis and bee pollen.	This literature study reports that bee products such as royal jelly, propolis and bee pollen have the potential to improve physical performance, speed recovery and reduce the inflammatory response during COVID-19.
(Ranneh et al., 2021)	42 rats weighing 250-270 g received 4.6 and 9.2 g/kg bee honey for 7 days followed by lipopolysaccharide induction and blood samples were taken 6 hours later.	Experimental	Bee honey is given at doses of 4.6 and 9.2 g/kg	Bee honey is able to reduce the production of reactive oxygen species (ROS), lipid peroxidation, reduce NF-kB signals and pro-inflammatory cytokines.
(Tavafzadeh et al., 2023)	48 young women aged 19-25 years were divided into 4 groups, namely the 16 weeks sedentary activity group, the 8 weeks exercise group followed by 8 weeks sedentary activities, the 8 weeks honey supplementation group followed by 8 weeks sedentary activities group, and the 8 weeks combination exercise and honey supplementation group. followed by 8 weeks of sedentary activity.	Experimental	Honey supplementation was given in a dose of 20 g and dissolved in 300 mL water. The aerobic exercise used is dance training.	The combination of honey supplementation and dance training can effectively maintain bone health and antioxidant status triggered by exercise
(Stavropoulou et al., 2022)	Eight-week-old female C57BL/6 mice were lipopolysaccharide induced and monitored for 4 hours.	Experimental	Honey intervention was given 30 minutes before lipopolysaccharide injection.	The anti-inflammatory properties of honey are able to strongly suppress serum TNF-a levels in mice that experience inflammation due to lipopolysaccharide induction.

Table 1 (continued)

Author	Sample Characteristics	Study Design	Intervention	Results
(Ovchinnikov et al., 2022)	20 healthy swimmers with an average age of 19 years and male were divided into 2 groups, namely the placebo group and the group given bee products supplementation in the form of royal jelly.	Experimental	Bee products intervention in the form of royal jelly supplementation was given at a dose of 400 mg once a day for 10 days. Before being given intervention, swimmers did HIIE training, which was done in 4 sets over a distance of 50 meters with maximum speed and recovery between sets for 45 seconds.	Bee products intervention in the form of royal jelly for 10 days has the potential to speed up recovery from muscle damage and reduce oxidative stress.
(Noura et al., n.d.)	24 mice aged an average of 8 weeks were injected with 8 mg/kg trimethyltin. Next, the mice were divided into 4 groups, namely the resistance training group, the resistance training group + royal jelly group, the royal jelly group, and the control group.	Experimental	Endurance training in the form of treatmill training at a speed of 15-20m/ minute, 5 sessions per week for 8 weeks. Royal jelly is given at a dose of 100 mg/kg every day.	Endurance training and royal jelly were able to significantly reduce the expression of inflammatory markers such as the biomarker CRP in mouse muscle tissue.

Discussions

The main research objective of this systematic review is to analyze and highlight the potential of bee products in reducing inflammation and oxidative stress after physical activity/exercise. Bee products contain flavonoids which have antioxidant properties. The chemical structure of bee products can be seen in Figure 2 (Silva et al., 2021). It is known that physical activity increases the production of Reactive Protein Species (ROS) (Thirupathi et al., 2021). Excessive increase in ROS production can cause damage to muscle fibers which will later lead to fatigue (Wang et al., 2021). On the other hand, the presence of a small stimulus from a low increase in ROS production can express endogenous antioxidants (Eddaikra & Eddaikra, 2021; Simioni et al., 2018). However, if physical activity is carried out intensely, it will cause an imbalance between excessive ROS production and the oxidant defense system, called oxidative stress (Hajam et al., 2022).

The idea that bee products contain antioxidant properties is supported by a study conducted on mice reporting that honey intervention at doses of 4.6 and 9.2 g/kg for 7 days followed by lipopolysaccharide induction had the potential to reduce the production of reactive oxygen species (ROS) (Ranneh et al., 2021). In addition, a study conducted on young women reported that honey supplementation given at a dose of 20 g and dissolved in 300 mL water during aerobic exercise was effectively able to maintain bone health

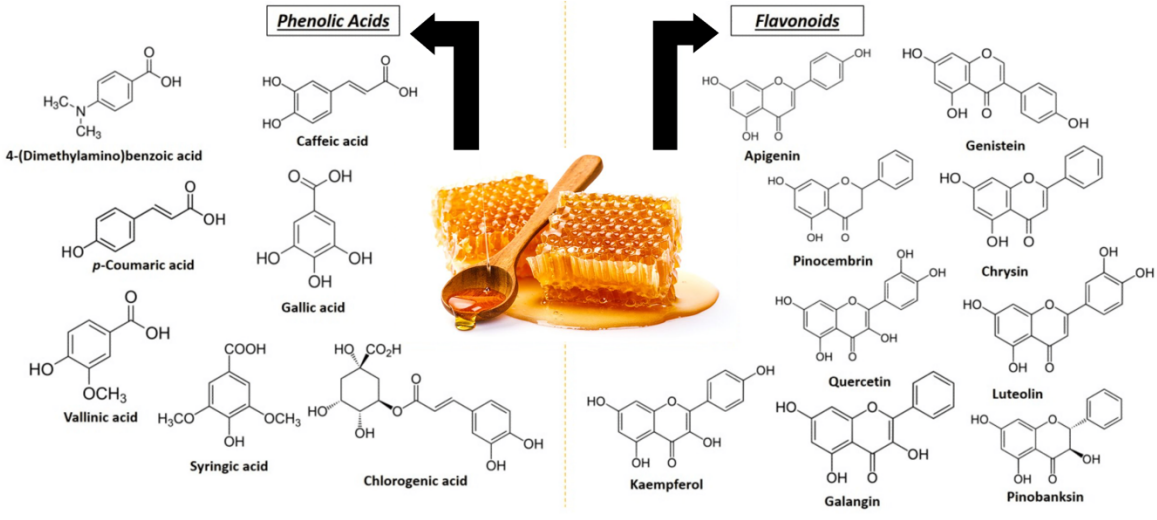

Fig. 2. Chemical structure of bee products

and antioxidant status triggered by exercise (Tavafzadeh et al., 2023). Furthermore, the results of this study were strengthened by research which reported that swimmers who were given bee product intervention in the form of royal jelly supplementation at a dose of 400 mg for 10 days had the potential to reduce oxidative stress and speed up recovery after training (Ovchinnikov et al., 2022). Physiologically, an interesting thing is that the flavonoids contained in honey work by increasing mitochondrial calcium ions (Ca2+) in cells, causing hyperpolarization of cell membranes. So increasing mitochondrial Ca2+ has the potential to reduce oxidative stress (Overdevest et al., 2018).

Furthermore, one of the main sources of oxidative stress is the immune system, and inflammation is the main reaction of the immune system to restore cells damaged by intense exercise back to normal (Simioni et al., 2018). Indeed, when the cells of an organ are damaged, the immune system becomes active (Marshall et al., 2018). The cells will stimulate magrophages to increase the production of pro-inflammatory and anti-inflammatory cytokines (Ayubi et al., 2022). It has been reported that TNF-a is one of the pro-inflammatory cytokines that trigger muscle pain (Fernández-Lázaro et al., 2020; Nanavati et al., 2022). In this regard, bee products, which has anti-inflammatory properties, can be an intervention strategy in controlling uncontrolled inflammatory processes due to exercise. A study conducted on mice reported that Royal jelly consumed at a dose of 50 mg/kg and 100 mg/kg along with aerobic exercise had benefits on pain threshold (Kheirdeh et al., 2022). The results of this research were reinforced by a study which reported that the anti-inflammatory properties of bee products were able to strongly suppress serum TNF-a levels in mice experiencing inflammation due to lipopolysaccharide induction (Stavropoulou et al., 2022). In this regard, a study on mice also reported that resistance training in the form of treadmill training for 15-20 minutes, 5 sessions/week carried out for 8 weeks and administration of royal jelly was able to significantly reduce the expression of inflammatory markers such as the biomarker CRP in mouse muscle tissue (Noura et al., n.d.). Furthermore, a study in mice also reported that bee honey intervention given at doses of 4.6 and 9.2 g/kg to mice induced by lipopolysaccharide was able to reduce NF-kB signals and pro-inflammatory cytokines (Ranneh et al., 2021). Regarding NF-kB signaling, NF-kB is initially active when tissue damage occurs and then plays an important role in mediating inflammation, especially the secretion of pro-inflammatory cytokines such as TNF-a (Acar et al., 2018). So if NF-kB signaling is inhibited using bee products, it will also affect pro-inflammatory cytokines and reduce muscle pain. Recent literature studies during COVID-19 report that bee products and exercise have the potential to improve physical performance, speed recovery and reduce the inflammatory response during COVID-19 (Ali et al., 2021). Furthermore, a study on overweight people reported that providing bee products supplementation interventions in the form of royal jelly had the potential to benefit lipid profiles, inflammation, oxidative stress, mood and satiety in overweight people (Petelin et al., 2019).

So, bee products which has anti-oxidant properties can reduce oxidative stress and the anti-inflammatory properties of honey can reduce uncontrolled inflammation due to exercise. Furthermore, for more details regarding the benefits of honey in reducing oxidative stress and inflammation, see Figure 3.

Conclusions

Bee products contain flavonoids which have anti-oxidant properties which can reduce oxidative stress. In addition, the anti-inflammatory properties of bee products can reduce uncontrolled inflammation due to physical activity/exercise. In this case, honey works by inhibiting inflammation through NF-kB signals and reducing inflammation by suppressing the secretion of pro-inflammatory cytokines such as TNF-a and inflammatory markers such as CRP. Reducing inflammation can reduce the intensity of muscle pain. It is recommended

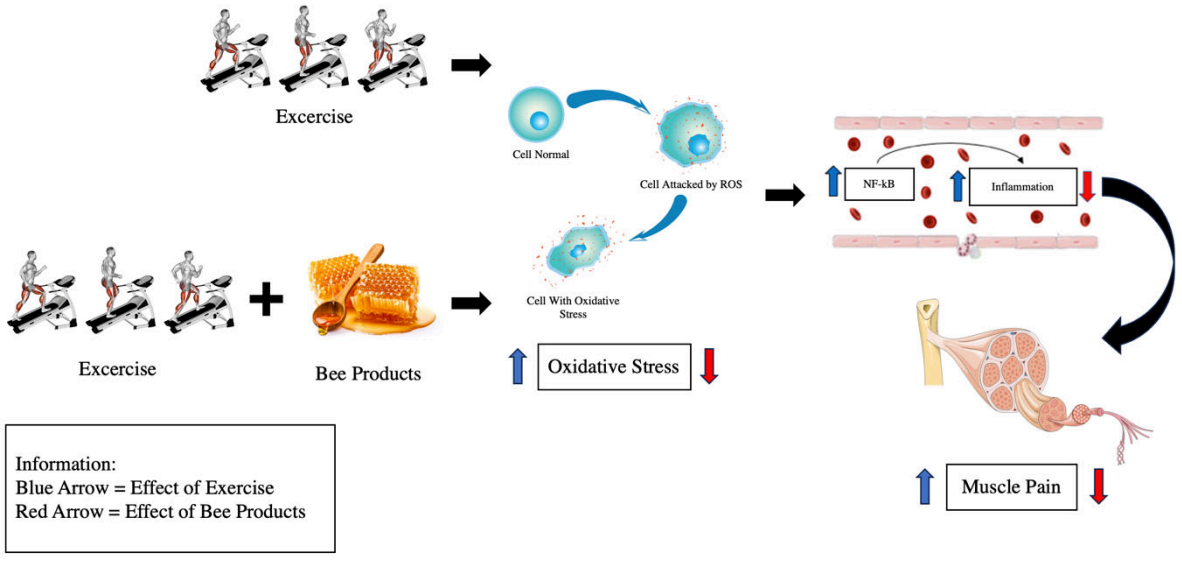

Fig. 3. Mechanism of action of bee products to reduce oxidative stress and inflammation

that bee products be used in individuals to reduce oxidative stress and inflammation after physical activity/exercise

Funding

This research received no external funding

Acknowledgments

The authors would like to thank the support from Universitas Negeri Surabaya, and Universitas Negeri Padang

Conflicts of Interest

The authors declare no conflict of interest

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АНТИОКСИДАНТНІ ТА ПРОТИЗАПАЛЬНІ ВЛАСТИВОСТІ ПРОДУКТІВ БДЖІЛЬНИЦТВА ПОТЕНЦІЙНО ЗМЕНШУЮТЬ ОКСИДАТИВНИЙ СТРЕС І ЗАПАЛЕННЯ ПІСЛЯ ФІЗИЧНОЇ АКТИВНОСТІ/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: 9 с., 1 табл., 3 рис., 43 джерела.

Мета дослідження. Метою цього дослідження було проаналізувати та підкреслити потенціал продуктів бджільництва до зменшення оксидативного стресу та запалення після фізичної активності/вправ.

Матеріали та методи. У цьому дослідженні використовують метод систематичного огляду шляхом пошуку в різних базах даних журналів, таких як Scopus, Web of Science, PubMed та Embase. Критеріями включення в цьому дослідження були статті, опубліковані за останні 5 років, і статті, у яких обговорювали продукти бджільництва, мед, оксидативний стрес, запалення, фізичну активність і вправи. Критеріями виключення в цьому дослідженні були статті, опубліковані в журналах із сумнівною репутацією. Назви, анотації та повні тексти статей ретельно відбирали, перевіряли та зберігали в програмному забезпеченні Mendeley. Загалом було визначено 7124 статті з баз даних Scopus, Web of Science, PubMed та Embase. Загалом для цього систематичного огляду було відібрано та проаналізовано 8 статей, які відповідали критеріям включення.

Результати. Продукти бджільництва, які мають антиоксидантні властивості, можуть зменшувати оксидативний стрес, а протизапальні властивості продуктів бджільництва можуть зменшувати неконтрольоване запалення, спричинене виконанням фізичних вправ.

Висновки. Продукти бджільництва містять флавоноїди, які мають антиоксидантні властивості, що можуть зменшувати оксидативний стрес. Крім того, протизапальні властивості продуктів бджільництва можуть зменшувати неконтрольоване запалення, спричинене фізичною активністю/вправами. У цьому разі мед діє, інгібуючи запалення шляхом активації сигнального шляху NF-κB (ядерний фактор «каппа-бі») і зменшуючи запалення шляхом пригнічення секреції прозапальних цитокінів, таких як TNF-α (фактор некрозу пухлини альфа, ФНП-альфа), і маркерів запалення, таких як CRP (С-реактивний білок). Зменшення запалення може зменшити інтенсивність м'язового болю. Рекомендується використовувати продукти бджільництва для зменшення оксидативного стресу та запалення після фізичної активності/вправ.

Ключові слова: продукти бджільництва, оксидативний стрес, запалення, фізична підготовка, здоровий спосіб життя.

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Cite this article as: Kusuma, D.A., Naharudin, M.N.B., Callixte, C., Aljunaid, M., Firmansyah, A., Mario, D.T., Ilham, Komaini, A., & Ayubi, N. (2023). Antioxidant and Anti-Inflammatory Properties of Bee Products Potentially Reduce Oxidative Stress and Inflammation After Physical Activity/Exercise: A Systematic Review. *Physical Education Theory and Methodology, 23*(6), 954-962. https://doi.org/10.17309/tmfv.2023.6.19

Received: 15.10.2023. Accepted: 16.12.2023. Published: 22.12.2023