Sports Medicine and Health Science 3 (2021) 177–180

Contents lists available at ScienceDirect

Sports Medicine and Health Science

journal homepage: www.keaipublishing.com/en/journals/sports-medicine-and-health-science/

Commentary

Bee honey and exercise for improving physical performance, reducing fatigue, and promoting an active lifestyle during COVID-19

A R T I C L E I N F O

Keywords
Bee honey
Physical activity
Fatigue
Skeletal muscle
Coronavirus disease 2019/COVID-19
Non-compliance
Aging

A B S T R A C T

An active lifestyle has enormous health benefits. However, physical activity has globally decreased since the beginning of the current coronavirus disease 2019 (COVID-19) outbreak because of social distancing measures. Older adults and people with age-related diseases (e.g., diabetes, obesity, cancer, cardiovascular disorders, etc.) are widely affected by COVID-19 and its grave adverse effects because of their baseline poor immune function. Although they are in intense need for the therapeutic benefits of exercise, they may express a low capacity for exercising due to skeletal muscle dysfunction and low motivation. Honey is a natural energy-rich, low glycemic index food with a variety of biological activities. It is reported to correct muscle pathology in diseased conditions. Because skeletal muscle is the key structure involved in the exercise, we explored the literature for the exercise-promoting potential of natural honey. Bee honey improves physical performance at moderate levels of activity, and it reduces the production of inflammatory cytokines and biomarkers of fatigue following strenuous exercise among athletes. Supplementing ischemic heart disease patients with honey combined with floral pollen improved patients' tolerance for physical loads and corrected metabolic dysfunctions. Therefore, the therapeutic use of honey may have implications for increasing the capacity for exercise in aged and diseased individuals. Soundly designed studies are needed to evaluate such possibilities.

Background

Because social distance has been the most agreed upon preventive measure against coronavirus disease 2019 (COVID-19), there has been a global tendency toward staying at home, which is associated with a considerable reduction in physical activity levels.[1–6] Substantial declines in physical activity are widely noticed in older adults,[1–3] and they are associated with increased prevalence of frailty, falls, and fractures.[1] Longitudinal data show a considerable decline in the activity level among older adults who engaged in moderate or strenuous physical activity at the beginning of the outbreak while negative emotions have increased secondary to physical inactivity.[2] Low physical activity induces metabolic resistance, inflammation, oxidative stress, gut microbiome dysfunction, skeletal muscle wasting, especially among the elderly[4,7–9]—who represent the highest majority of COVID-19 victims because of their high immune and nutritional vulnerabilities.[10–12]

Old age is associated with decreased energy expenditure, poor metabolism, increased production of free radicals and inflammatory cytokines, which increase the development of age-related disorders such as type 2 diabetes mellitus and cardiovascular diseases.[13–15] Anabolic resistance is high in old age and age-related disease while exercise is the most favorable intervention for enhancing anabolism.[4,7] In fact, physical activity and dietary modifications are major lifestyle interventions for improving metabolism and preventing age-related metabolic disorders such as type 2 diabetes mellitus.[16] However, the compliance of older adults with a planned regular physical activity is generally poor for a plethora of reasons: low back pain, knee pain, muscle strains, easy fatiguability, decreased social interaction, and low motivation due to psychological and mental diseases.[17–20] Even more, some effective exercise activities designed for older adults may be associated with a high risk for injury.[20]

Muscle contraction is an energy-consuming activity,[7] and proper dietary intake (e.g., high-energy containing food) is necessary to fuel moderate to high levels of physical activity.[21] In the meantime, glucose intolerance is a common problem in old age secondary to increased insulin resistance, which precludes their intake of the commonly available high glycemic index (GI) sources of energy.[4,9,22]

One natural source of energy is bee honey. Bee honey is a sweet beverage produced by *Apis mellifera* bee workers as a mixture of sugars, proteins, vitamins, phenols, trace minerals, and vitamins.[9,23,24] It exerts a wide range of health benefits such as antagonizing the production and the destructive effects of free radicals and inflammatory mediators.[25,26] Experimental evidence shows that methylglyoxal in manuka honey interacts with microbial metabolites of a wide range of pathogens, such as 5-amino-6-D-ribitylaminouracil, to produce 5-(2-oxopropylideneamino)-6-D-ribitylaminouracil—a potent activator of mucosal-associated invariant T cells. Such modulation of these antimicrobial effector cells in the immune system restores mucosal barrier integrity and promotes numerous antimicrobial defenses.[27] This effect might be crucial in the case of COVID-19 given that severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) accesses the body mainly through the nasal mucosa.[28] Indeed, naringin in honey is reported to inhibit SARS-CoV-2 in vitro, and whole honey treatment of COVID-19 patients has been reported to promote earlier recovery and reduce mortality.[10]

Glucose may be quickly consumed during strenuous and prolonged activity resulting in glycogen depletion and hypoglycemia as major causes of muscular and central fatigue.[29,30] The latter takes the form of increased brain serotonergic activity following depletion in blood

https://doi.org/10.1016/j.smhs.2021.06.002
Received 20 February 2021; Received in revised form 15 June 2021; Accepted 22 June 2021
Available online 25 June 2021

Abbreviations

COVID-19 Coronavirus disease 2019
GI Glycemic index
HSP-70 Heat shock protein
VO_{2max} Maximal oxygen consumption
SARS-CoV-2 Severe acute respiratory syndrome-coronavirus-2

glucose and brain glycogen levels, which is associated with the increased brain activity of monocarboxylate transporters in order to supply neurons with lactate and other glycogenolytic and glycolytic sources. This alternative energy supply is a protective defense mechanism to maintain brain adenosine triphosphate during exhaustive exercise.[30] Therefore, to prevent central fatigue and to restore muscular performance, athletes are recommended to consume energy-rich drinks (e.g., containing natural honey or carbohydrates such as dextrose) before and during strenuous exercise.[31,32] Honey is a low GI food while dextrose is high in GI.[31] Low GI foods release glucose slowly; and therefore, they do not cause a sudden increase in blood glucose level.[9] Slow release of glucose denotes that energy depletion is also less likely to happen following exhaustive activity.[29] In this regard, we explored the literature for the effect of bee honey supplementation on the capacity for exercising and associated effects on fatigue and physiological changes.

Search strategy

To obtain relevant studies for this review commentary, we developed a systematic search strategy in PubMed database using search terms: (bee honey OR natural honey) AND (Exercise OR physical activity), without using any constraints to restrict the search (e.g., language, type of study, or time period). A hand-search in Google Scholar was also conducted. PubMed search retrieved 48 studies including three relevant primary studies. Five other studies were retrieved through hand-search. In total, our synthesis is based on eight relevant studies (Supplementary materials) examining the effect of honey, honey extracts, or honey in combination with other natural elements (e.g., flower pollen or herbal plants) on the outcome variables. In seven studies, participants were healthy athletes while one study recruited patients with ischemic heart disease.

Results and discussion

Among healthy athletes, the intake of Acacia honey during a rehydration period after a glycogen depletion phase (Run 1: run on a treadmill at 65% maximal oxygen consumption (VO_{2max}) in the heat (31 °C, 70% relative humidity, for 60 min) was associated with running significantly longer distances in Run 2 (for 20 min) compared with the intake of plain water. Serum glucose and insulin, as well as osmolality, were significantly ($p < 0.05$) higher in honey treatment.[29] Both honey and dextrose improved the performance of athletes taking part in simulated the 64-km cycling time trial. Participants of the dextrose and honey groups generated more watts over the last 16 km vs. preceding segments ($p < 0.002$, and $p < 0.0004$, respectively).[31] A honey-sweetened beverage did not improve the performance of soccer players compared with a carbohydrate-sweetened beverage. However, the expression of some cytokines was decreased in honey treatment.[33] Likewise, honey had no effect on the performance of 1500 m runners, but it decreased fatigue biomarkers significantly.[32] Trained men athletes ($n = 20$) receiving a multi-nutrient SOmaxP supplement, which contains isomaltulose (palatinose) a carbohydrate present in honey, before and during resistance exercise for nine weeks expressed significant increases in lean mass, bench press strength, and muscular performance (1-RM bench press and repetitions to failure) along with a reduction in fat mass. Delayed digestion and absorption in the experimental group were suggested to account for the difference in body fat mass changes between the SOmaxP group and the control group.[34] In a study supplementing female athletes ($n = 18$) with a natural antioxidant formula (honey, ginger root, cinnamon bark, raw almond fruit powder, and rosemary leaf powder) for 4 weeks, the mRNA expression of heat shock protein (HSP-70) significantly increased. No improvements in oxidative status and antioxidant enzyme activity were detected. However, HSP-70 increase might improve exercise-induced adaptation and the antioxidant ability of cells over time.[35]

Although the participants in the consulted studies were all athletes, the findings may have implications for the therapeutic use of exercise, which are discussed herein. Regular consumption of honey may, in theory, improve compliance with exercise activity (Fig. 1). In this regard, a single study reports that supplementing patients with ischemic heart disease with a combination of bee honey and flower pollen improved patients' tolerance for physical loads, lipid metabolism, and rheological properties of the blood.[36] Honey exerts a protective effect against oxidative stress in non-neuronal brain cells. Oxidative stress causes neuroinflammation giving rise to the development of diseases associated with decreased motivation such as depression and Alzheimer's disease.[24] In fact, honey exerts anti-depressant effects and improves food intake in aged models as well as in humans.[23,26] Honey, as a low GI source of energy, is likely to provide the energy necessary for muscle contraction without increasing blood glucose.[9,25] Fatigue common in old age is reported to affect socially meaningful mobility behaviors in mobility-intact seniors.[37] Given that honey reduces fatigue and inflammation post exercise,[32,33] older adults who consume honey may be less likely to experience fatigue after exercise—which may promote compliance with long-term exercise programs. However, investigations are needed to

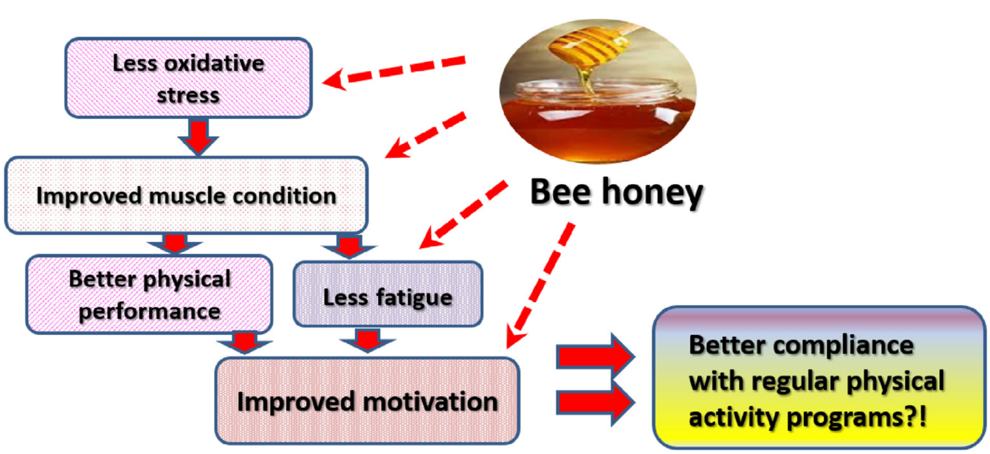

Fig. 1. Possible mechanism through which the consumption of bee honey may promote regular participation in physical activity.

evaluate the plausibility of these scenarios.

Skeletal muscle is the primary body tissue involved in the execution of physical activities.[7,8,12] Muscular structure undergoes severe damages because of pathophysiological changes that occur in aging, chronic diseases, malnutrition, and sedentary lifestyle.[7,8,38] Back pain and strain, which usually accompany muscle loss, cause dropout from activity programs.[18] Therefore, reverting skeletal muscle pathology may improve exercise capacity.[39] In fact, bee honey is reported to correct muscle catabolism and restore muscle fiber integrity in cachectic animals.[23] Likewise, strength exercise is reported to improve the production of antioxidants in the skeletal muscle of aged rats.[40] Honey and exercise exert their muscle-promoting activities through shared mechanisms: correcting gut microbial dysregulation and intestinal dysbiosis, metabolic dysfunction, oxidative stress, and inflammation.[5,9,23–25] Accordingly, it might be expected that both kinds of honey as a dietary supplement in combination with exercise may exert synergetic improvements in the condition of skeletal muscle in old age. This conclusion is based on findings of a meta-analysis reporting improved physical outcomes in pre-frail and/or frail older adults receiving physical activity programs combined with nutritional interventions.[41] In addition, mood improvement following physical activity may promote individuals' perceptions of benefits, which may subsequently reinforce compliance with regular exercise programs.[17,42] However, studies are needed to explore if honey consumption can really promote compliance with an exercise activity among seniors and individuals with lifestyle and age-related diseases.

Conclusion

Honey may improve physical performance in moderate levels of activity. It may also grant protection against fatigue and inflammation that may follow exhaustive activity though physical performance may not improve. The low GI and anti-fatigue properties of bee honey may promote compliance with planned physical activity among older adults and people with chronic debilitating disorders. Several positive health effects may result from the synergistic interaction of honey and exercise treatment. Investigations are needed to identify possible benefits and factors (e.g., race, gender, genetics, diet, etc.) that may promote or hinder the muscle and activity-promoting potential of honey in individuals prone to frailty.

Submission statement

This manuscript has not been published and is not under consideration for publication elsewhere.

Authors' contributions

All authors listed have made a substantial, direct, intellectual contribution to the work, and approved it for publication.

Conflict of interest

The authors have no conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smhs.2021.06.002.

References

1. Slullitel PA, Lucero CM, Soruco ML, et al. Prolonged social lockdown during COVID-19 pandemic and hip fracture epidemiology. *Int Orthop*. 2020;44(10):1887–1895. https://doi.org/10.1007/s00264-020-04769-6.
2. Suzuki Y, Maeda N, Hirado D, Shirakawa T, Urabe Y. Physical activity changes and its risk factors among community-dwelling Japanese older adults during the COVID-19 epidemic: associations with subjective well-being and health-related quality of life. *Int J Environ Res Publ Health*. 2020;17(18):6591. https://doi.org/10.3390/ijerph17186591.
3. Yamada M, Kimura Y, Ishiyama D, et al. Effect of the COVID-19 epidemic on physical activity in community-dwelling older adults in Japan: a cross-sectional online survey. *J Nutr Health Aging*. 2020;24(9):948–950. https://doi.org/10.1007/s12603-020-1424-2.
4. Ali AM, Kunugi H. Apitherapy for age-related skeletal muscle dysfunction (sarcopenia): a review on the effects of royal jelly, propolis, and bee pollen. *Foods*. 2020;9(10):1362. https://doi.org/10.3390/foods9101362.
5. Ali AM, Kunugi H. Corona Virus Disease 2019 (COVID-19): a pandemic that threatens physical and mental health by promoting physical inactivity. *Sports Med Health Sci*. 2020;2(4):221–223. https://doi.org/10.1016/j.smhs.2020.11.006.
6. Tison GH, Avram R, Kuhar P, et al. Worldwide effect of COVID-19 on physical activity: a descriptive study. *Ann Intern Med*. 2020;173(9):767–770. https://doi.org/10.7326/M20-2665.
7. Ali AM, Kunugi H. Physical frailty/sarcopenia as a key predisposing factor to coronavirus disease 2019 (COVID-19) and its complications in older adults. *BioMed*. 2021. under review.
8. Ali AM, Kunugi H. Skeletal muscle damage in COVID-19: a call for action. *Medicina*. 2021;57(4):372. https://doi.org/10.3390/medicina57040372.
9. Ali AM, Kunugi H. Intermittent fasting, dietary modifications, and exercise for the control of gestational diabetes and maternal mood dysregulation: a review and a case report. *Int J Environ Res Publ Health*. 2020;17(24):9379. https://doi.org/10.3390/ijerph17249379.
10. Ali AM, Kunugi H. Propolis, bee honey, and their components protect against coronavirus disease 2019 (Covid-19): a review of in silico, in vitro, and clinical studies. *Molecules*. 2021;26(5):1232. https://doi.org/10.3390/molecules26051232.
11. Ali AM, Kunugi H. Approaches to nutritional screening in patients with Coronavirus Disease 2019 (COVID-19). *Int J Environ Res Publ Health*. 2021;18(5):2772. https://doi.org/10.3390/ijerph18052772.
12. Ali AM, Kunugi H. Screening for sarcopenia (physical frailty) in the COVID-19 era. *Int J Endocrinol*. 2021;2021:5563960. https://doi.org/10.1155/2021/5563960.
13. Ali AM, Kunugi H. Apitherapy for Parkinson's disease: A focus on the effects of propolis and royal jelly. *Oxid Med Cell Longev*. 2020;2020:1727142. https://doi.org/10.1155/2020/1727142.
14. Ali AM, Kunugi H. Royal jelly as an intelligent anti-aging agent-A focus on cognitive aging and Alzheimer's disease: A review. *Antioxidants*. 2020;9(10):937. https://doi.org/10.3390/antiox9100937.
15. Kunugi H, Mohammed Ali A. Royal jelly and its components promote healthy aging and longevity: from animal models to humans. *Int J Mol Sci*. 2019;20(19):4662. https://doi.org/10.3390/ijms20194662.
16. Uusitupa M, Khan TA, Viguiliouk E, et al. Prevention of type 2 diabetes by lifestyle changes: a systematic review and meta-analysis. *Nutrients*. 2019;11(11):2611. https://doi.org/10.3390/nu11112611.
17. Larson HK, McFadden K, McHugh T-LF, et al. When you don't get what you want—and it's really hard: exploring motivational contributions to exercise dropout. *Psychol Sport Exerc*. 2018;37:59–66. https://doi.org/10.1016/j.psychsport.2018.04.006.
18. Herman S, Blumenthal JA, Babyak M, et al. Exercise therapy for depression in middle-aged and older adults: predictors of early dropout and treatment failure. *Health Psychol*. 2002;21(6):553–563.
19. Rosa JP, de Souza AA, de Lima GH, et al. Motivational and evolutionary aspects of a physical exercise training program: a longitudinal study. *Front Psychol*. 2015;6:648. https://doi.org/10.3389/fpsyg.2015.00648.
20. Van Roie E, Walker S, Van Driessche S, Delabastita T, Vanwanseele B, Delecluse C. An age-adapted plyometric exercise program improves dynamic strength, jump performance and functional capacity in older men either similarly or more than traditional resistance training. *PloS One*. 2020;15(8), e0237921. https://doi.org/10.1371/journal.pone.0237921.
21. Joksimović A, Stanković D, Joksimović I, Molnar S, Joksimović S. Royal jelly as a supplement for young football players. *Sport Sci*. 2009;2(1):62–67.
22. Ali AM, Ahmed AH, Smail L. Psychological climacteric symptoms and attitudes toward menopause among Emirati women. *Int J Environ Res Publ Health*. 2020;17(14):5028. https://doi.org/10.3390/ijerph17145028.
23. Ali AM, Hendawy AO. Bee honey as a potentially effective treatment for depression: a review of clinical and preclinical findings. *JOJ Nurse Health Care*. 2018;9(2):555764.
24. Ali AM, Kunugi H. Bee honey protects astrocytes against oxidative stress: a preliminary in vitro investigation. *Neuropsychopharmacol Rep*. 2019;39(4):312–314. https://doi.org/10.1002/npr2.12079.
25. Ali AM, Ali EM, Ahmed MS, Hendawy AO. Targeting gut microbiome and the recovery of muscle loss associated with cancer (cachexia): an overview of the possible effect of bee products. *Med Leg Update*. 2021;21(2):163–171.
26. Ali AM, Hendawy AO. So, antidepressant drugs have serious adverse effects, but what are the alternatives? *Nov Appro Drug Des Dev*. 2018;4(3):555636.
27. Tang JS, Compton BJ, Marshall A, et al. Mānuka honey-derived methylglyoxal enhances microbial sensing by mucosal-associated invariant T cells. *Food Funct*. 2020;11(7):5782–5787. https://doi.org/10.1039/d0fo01153c.
28. Mok CK, Ng YL, Ahidjo BA, Hua Lee RC, Choy Loe MW, Liu J, et al. Calcitriol, the active form of vitamin D, is a promising candidate for COVID-19 prophylaxis. *bioRxiv*. 2020.06.21;2020:162396.
29. Ahmad NS, Ooi FK, Saat Ismail M, Mohamed M. Effects of post-exercise honey drink ingestion on blood glucose and subsequent running performance in the heat. *Asian J Sports Med*. 2015;6(3). https://doi.org/10.5812/asjsm.24044.
30. Matsui T, Soya M, Soya H. Endurance and brain glycogen: a clue toward understanding central fatigue. *Adv Neurobiol*. 2019;23:331–346. https://doi.org/10.1007/978-3-030-27480-1_11.

31. Earnest CP, Lancaster SL, Rasmussen CJ, et al. Low vs. high glycemic index carbohydrate gel ingestion during simulated 64-km cycling time trial performance. *J Strength Condit Res*. 2004;18(3):466–472. https://doi.org/10.1519/R-xxxxx.1.
32. Aly MO, Elgohary R, Tayel DI. The effect of honey supplementation formula on delaying some fatigue markers on 1500 meters runners with no impact on performance. *Int J Sports Sci*. 2019;9(3):47–53.
33. Abbey EL, Rankin JW. Effect of Ingesting a Honey-Sweetened Beverage on Soccer Performance and Exercise-Induced Cytokine Response. *Int J Sport Nutr Exerc Metab*. 2009;19(6):659–672. https://doi.org/10.1123/ijsnem.19.6.659.
34. Schmitz SM, Hofheins JE, Lemieux R. Nine weeks of supplementation with a multinutrient product augments gains in lean mass, strength, and muscular performance in resistance trained men. *J Int Soc Sports Nutr*. 2010;7:40. https://doi.org/10.1186/1550-2783-7-40.
35. Daneghian S, Amani R, Hosseini SA, Ghandil P, Jafari A, Saki Malehi A. Effect of herbal antioxidant-rich formula on improvement of antioxidant defense system and heat shock protein-70 expression in recreational female athletes: a randomized controlled trial. *J Res Med Sci*. 2019;24:37. https://doi.org/10.4103/jrms.JRMS_591_18.
36. Liusov VA, Gorbachenkov AA, Dudaev VA, Gorin VV. Vliianie pchelinogo meda i tsvetochnoĭ pyl'tsy na perenosimost' fizicheskikh nagruzok, lipidnyĭ obmen i reologicheskie svoĭstva krovi u bol'nykh ishemicheskoĭ bolezn'iu serdtsa [The effect of bee honey and flower pollen on the tolerance for physical loads, on lipid metabolism and on the rheological properties of the blood in patients with ischemic heart disease]. *Kardiologiia*. 1992;32(7–8):45–48.
37. Simonsick EM, Schrack JA, Glynn NW, Ferrucci L. Assessing fatigability in mobility-intact older adults. *J Am Geriatr Soc*. 2014 Feb;62(2):347–351. https://doi.org/10.1111/jgs.12638.
38. Ali AM, Kunugi H. Hypoproteinemia predicts disease severity and mortality in COVID-19: a call for action. *Diagn Pathol*. 2021;16(1):31. https://doi.org/10.1186/s13000-021-01092-5.
39. Siegel MP, Kruse SE, Percival JM, et al. Mitochondrial-targeted peptide rapidly improves mitochondrial energetics and skeletal muscle performance in aged mice. *Aging Cell*. 2013;12(5):763–771. https://doi.org/10.1111/acel.12102.
40. Vilela TC, Effting PS, dos Santos Pedroso G, et al. Aerobic and strength training induce changes in oxidative stress parameters and elicit modifications of various cellular components in skeletal muscle of aged rats. *Exp Gerontol*. 2018;106:21–27. https://doi.org/10.1016/j.exger.2018.02.014.
41. Kidd T, Mold F, Jones C, et al. What are the most effective interventions to improve physical performance in pre-frail and frail adults? A systematic review of randomised control trials. *BMC Geriatr*. 2019;19(1):184. https://doi.org/10.1186/s12877-019-1196-x.
42. Lindegård A, Jonsdottir IH, Börjesson M, Lindwall M, Gerber M. Changes in mental health in compliers and non-compliers with physical activity recommendations in patients with stress-related exhaustion. *BMC Psychiatr*. 2015;15:272. https://doi.org/10.1186/s12888-015-0642-3.

Amira Mohammed Ali*
Department of Behavioral Medicine, National Institute of Mental Health, National Center of Neurology and Psychiatry, Tokyo, Japan
Department of Psychiatric Nursing and Mental Health, Faculty of Nursing, Alexandria University, Alexandria, Egypt

Esraa Mohammed Ali
Department of Basic Sciences, Faculty of Early Childhood Education, Alexandria University, Alexandria, Egypt

Alaaeldin Abou Mousa
King Fahd University of Petroleum and Minerals, Saudi Arabia

Mostafa Elsayed Ahmed
Department of Plant Protection, Faculty of Agriculture, Damanhour University, Damanhour, Egypt
Institute of Apiculture Research, Chinese Academy of Agricultural Science, Beijing, China

Amin Omar Hendawy
Department of Animal and Poultry Production, Faculty of Agriculture, Damanhour University, Damanhour, Egypt
Department of Biological Production, Tokyo University of Agriculture and Technology, Tokyo, Japan

* Corresponding author. Department of Behavioral Medicine National Institute of Mental Health National Center of Neurology and Psychiatry, 4Ogawahigashi, Kodaira, Tokyo, 187Japan
E-mail address: mercy.ofheaven2000@gmail.com (A.M. Ali).