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Exploring the Mood-Boosting Potential of Bananas: A Comprehensive Review

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ABSTRACT

Food, like bananas, can be used as depression therapy. Bananas are known for their high tryptophan content. Tryptophan is the precursor of the neurotransmitter serotonin, which is closely related to the pathophysiology of anxiety and depression. This comprehensive review examines the available research on the link between banana consumption and mood. Screening of original articles or reviews was done on the Google Scholar database, Science Direct, MedLine (PubMed), Scielo, and Proquest with the keywords "banana," "Musa," "depression," and "anxiety" published no later than March 31, 2023. From 8.469 articles found, 18 studies were selected. From the experimental trial articles obtained (9 studies), most reported positive antidepressant and antianxiety effects, but not all were significant. The results of the three clinical trials were also inconsistent. Bananas have antianxiety and antidepressant properties, but the scientific literature on their efficacy is limited. Therefore, more evidence is needed to justify its use as a primary or adjunctive treatment for depression and anxiety.

Keywords: anxiety, banana, depression, mood disorders

INTRODUCTION

Mood disorders, such as major depression disorder, are commonly treated with selective serotonin reuptake inhibitors (SSRIs), although many adverse effects are found (Edinoff et al., 2021). Currently, SSRIs have been the first line of treatment for anxiety disorders(National Institute for Health and Care Excellence (NICE), 2011). However, SSRIs have various limitations, such as the time lag until the onset of pharmacological effects (a few hours before therapeutic effects, within two weeks for sub-chronic therapy) (Blier, 2001). Hence, the patient's mood may deteriorate (Asher et al., 2017). Patients treated with SSRIs were also anxious about drug dependency and stigma (Dome et al., 2019). Sometimes, conventional treatment also does not give the expected effect.

A more comprehensive understanding of the pathophysiology of depression has encouraged using compounds with anti-inflammatory, antioxidant, and neuroprotective effects as an alternative therapy or supportive therapy for depression (Dobrek, 2023; Jembrek et al., 2023; Moragrega & Ríos, 2021; Tayab et al., 2022; Winiarska-mieczan et al., 2023). Explanations of depression theories other than from the perspective of monoamine deficiency have been supported by evidence showing an increase in inflammatory biomarkers and oxidative stress and a decrease in the capacity of antioxidants in the body, such as vitamins A and C, glutathione peroxidase, superoxide dismutase, and catalase (Winiarska-mieczan et al., 2023). The presence of inflammation is related to decreased levels of tryptophan in the body because inflammation causes hyperactivation of the enzyme that converts tryptophan into N-formylkynurenine (indoleamine-2,3-dioxygenase), which is then metabolized into kynurenine (Paul et al., 2022). It has also been proven that tryptophan concentrations are inversely proportional to pro-inflammatory cytokine levels (Dowlati et al., 2010).

Natural products are used to treat depression because they are believed to have lower toxicity, better compatibility, better cultural acceptability, and are more affordable and accessible to get (Al-Harrasi et al., 2023; Dwyer et al., 2011; Peng et al., 2022). One of the natural products that can be used to treat depression is food. Foods can affect human mood significantly. Healthy foods such as vegetables and fruit can improve mood and mental health (AlAmmar et al., 2020; Gibson et al., 2020; Grases et al., 2019; Martínez-González & Sánchez-Villegas, 2016). Since the monoamine theory is believed to contribute to the pathophysiology of depression and anxiety disorders, therapy to increase serotonin levels in patients with both illnesses makes sense.

Previous studies have shown that eating a diet high in tryptophan can help treat depression (Chojnacki et al., 2023; Lindseth et al., 2015; Parker & Brotchie, 2011). Tryptophan is an essential amino acid obtained from food. However, only a small amount is stored in the body, which is critical for human physiological functions (Friedman, 2018; Haleem, 2023; Modoux et al., 2021). Tryptophan is a precursor in the production of serotonin. This neurotransmitter plays an essential role in the pathophysiology of depression and anxiety (Davidson et al., 2022; Kałużna-Czaplińska et al., 2019; Roth et al., 2021; Torrente et al., 2012; Waløen et al., 2017). The daily need for tryptophan is around 4-5 mg/kg of adult body weight (Institute of Medicine, 2005; Joint WHO/FAO/UNU Expert Consultation, 2007). This need can be met by consuming tryptophan-rich foods such as meats, milk, wheat bread, chocolate, tuna, cheese, peanuts, oats, dried prunes, bananas, and apples (Ramakrishna et al., 2011; Richard et al., 2009).

Even though the amount of tryptophan in bananas may not be as high as in other types of food, the ratio of tryptophan to other amino acids is relatively high compared to other foods mentioned previously (Richard et al., 2009). The high ratio of tryptophan to other amino acids is important because, as the only precursor of serotonin, up to 95% of tryptophan distributed throughout the body is bound to albumin (Hood et al., 2005).

Free tryptophan can penetrate the BBB when approaching the blood-brain barrier (BBB) (Baier et al., 2022). Tryptophan competes with other large neutral amino acids such as histidine, isoleucine, methionine, phenylalanine, threonine, tyrosine, and valine for the cerebrovascular transport system (Lucini et al., 1996). However, tryptophan has a higher affinity for that transport system because of its sizeable hydrophobic side chain (Smith, 1988). Therefore, the bioavailability of tryptophan is expressed in the ratio of tryptophan to other amino acids that compete for the same transporter (Lucini et al., 1996). Higher concentration of tryptophan available for serotonin synthesis can be achieved by increasing the amount of tryptophan or decreasing the amount of other competing amino acids.

Banana (Musa sp.) is an herbaceous fruit plant from Southeast Asia that has spread to Africa, South America, and Central America (De Langhe et al., 2009; Elayabalan et al., 2017; Perrier et al., 2011). Bananas are a popular fruit cultivated and consumed in Indonesia because they are cheap but nutritious. Moreover, based on the 2022 gross production value, Indonesia was ranked number one in global banana production (FAO, 2022).

Banana has high tryptophan content among other fruits (26.15±0.37 μg/g) (Islam et al., 2016). A previous research reported a higher content of tryptophan (1000 μg/g) in banana peel powder (Soeliono et al., 2023). Another study showed increased serotonin in human platelets after banana administration (Xiao et al., 1998). Providing unripe banana pulp powder for 30 days can significantly increase serotonin levels in the brains of Swiss albino mice (Erigbali et al., 2017). Increased serotonin expression also occurred after administration of bananas in the form of banana flakes (5%; 3 weeks) and banana peel extract (16 mg/kg; 3 days) (Fatchurohmah et al., 2019; Meliala et al., 2020).

However, the antianxiety and antidepressant effects of bananas are still debatable. Understanding the potential mood-enhancing properties of bananas can provide valuable insight into nutritional strategies to improve mental well-being. Therefore, this comprehensive review examines the available research on the relationship between banana consumption and mood. By integrating and assessing available data, this review aims to show how bananas may alter mood and emotional well-being.

METHODS

This study investigates the depression or anxiety effect of bananas. The following databases were screened: Google Scholar, Science Direct, MedLine (PubMed), Scielo, and Proquest. The main keywords searched include "banana," "Musa," "depression," and "anxiety." Each keyword was searched in the article title. The articles collected were imported to Mendeley software (Elsevier, USA) to remove duplicates. The inclusion criteria are all studies investigating the antianxiety and antidepressants of bananas, published no later than March 31, 2023; written in English or Indonesian; available in full text; and original article or review. The abstracts of all articles were screened, and the selected articles' full text was retrieved. All data were tabulated and analyzed in Microsoft Excel 2021 (Microsoft Corporation, USA).

Table I. Search strategy

Search strategy
PubMed (MEDLINE)
#1 "Musa"[Mesh]) AND "Anti-Anxiety Agents"[Mesh] → 5 results
#2 "Musa"[Mesh]) AND "Antidepressive Agents"[Mesh] → 4 results
Google Scholar
#1 (Musa OR Banana OR pisang) AND (anxiety OR depression OR cemas OR depresi) → 8.440 results
Science Direct
Title, abstract, keywords: (Banana OR musa) AND (anxiety OR depression) → 17 results
Scielo
#1 (banana OR musa OR plátano) AND (depression OR depresión) → 2 results
#2 (banana OR musa OR plátano) AND (anxiety OR ansiedad) → 1 result

RESULT AND DISCUSSION

Characteristics of the articles

Eight thousand four hundred sixty-nine articles were screened through all databases (Table I). After reading the title and abstract, 8.451 studies were excluded. With careful analysis, 18 studies were selected (nine experimental studies (Table II), three clinical studies (Table III), and six review articles. Most of the articles retrieved were experimental studies (47%) from India (Figure 1).

It is well-known that the location of plant growth affects the pharmacological effects (Li et al., 2010). The pharmacological effects of plants are highly dependent on the content and production of secondary metabolites. Secondary metabolites are not directly involved in growth and reproduction processes. Factors that influence the production of secondary metabolites include harvest time, season, soil type, nutrient supply, altitude, geographical location, maturity level, genotype or cultivar, biotic and abiotic stress (such as temperature, drought, salinity, and light intensity), as well as fruit maturity and post-harvest handling and processing (Bachheti et al., 2021; Vu et al., 2018).

The ripeness level of banana peel affects the type of secondary metabolites that can be extracted. Previous research on *Musa paradisiaca* L. proved that the ethyl acetate extract of unripe banana peel does not contain tannin and alkaloids; meanwhile, the results were positive in the ripe banana peel. Likewise, in the ethanol extract, the results of the tannin content test were positive and saponin negative; in the unripe peel, the test results were the opposite (Widoyanti et al., 2023). Some studies show higher antioxidant compound content in green bananas than in ripe bananas, but some studies report the opposite (Fatemeh et al., 2012; Sundaram et al., 2011; Vu et al., 2019). When the green color of the banana peel changed to yellow, the chlorophyll content degraded by around 90%; meanwhile, the carotenoid increased by 50%, and the flavonoid increased by 27% (Vu et al., 2019).

Unfortunately, although the level of banana ripeness determines the content of secondary metabolites that impact pharmacological effects, the preclinical and clinical studies cited in this review did not detail the level of ripeness of the banana samples used. Soltani et al. (2011) mentioned that banana ripeness levels are generally expressed in 7 stages based on color comparison with a graphic scale. In stage 1, the banana peel is entirely green. In stage 2, the banana peel is green with a hint of yellow. In stage 3, the banana peel is greener than yellow. In stage 4, the banana peel is more yellow than green. In stage 5, the banana skin is yellow with a hint of green. In stage 6, the entire banana skin is yellow. Finally, in stage 7, the whole banana skin is yellow with brown spots.

Table II. Preclinical studies of bananas as an antidepressant and antianxiety

References	Banana Species	Developmental Stage	Dosage	Laboratory studies	Result
Parle and Malik (2010)	*Musa paradisiaca* from Hisar	Not mentioned	3 grams/day of banana paste (5,10, 20%) p.o. for 15 days	• FST and TST • MAO-A, MAO-B, and MDA levels in the brain	• There was a significant reduction in the duration of immobility in both tests ($p<0.01$), and the effect is comparable with fluoxetine and imipramine. • Combining BFP with prazosin, baclofen, and p-CPA significantly decreased the effect of BFP ($p<0.01$ and $p<0.05$). • BFP significantly reduced brain MAO-A, MAO-B, and MDA ($p<0.01$) → antioxidant effect.
Hallikeri *et al.* (2012)	*Musa paradisiaca*	Unripe	95% alcohol extract 500 mg/kg p.o. for five days	Anti-punishment activity and anti-frustration (Skinner Box)	The banana peel extract increased anti-punishment and anti-frustration activity compared to the control.
Samad *et al.* (2017)	*Musa sapientum* from Punjab	Not mentioned	Banana pulp paste 600 mg/kg p.o. and 70% acetone peel extract 400 mg/kg p.o.	MWM, LDA, EPM, FST	• Anxiety test: increasing time spent in open arm in EPM (peel > pulp); increasing time spent in lightbox in LDA (peel > pulp). • Depression test: decreasng immobility time in FST (peel ~ pulp). • Memory test: decreasing time to reach the platform in short- and long-term memory (peel ~ pulp).
Reddy *et al.* (2017)	*Musa sapientum*	Not mentioned	Aqueous extract of stem 25, 50, 100 mg/kg p.o.	EPM, OFT	The dose of 100 mg/kg was most consistent in showing the difference in the EPM test parameter with control, and it had a comparable effect with diazepam on locomotor activity.
Salako (2019)	*Musa sapientum* Linn. from Papa Alanto	Not mentioned	Aqueous extract of leaves 50, 100, 200 mg/kg p.o.	FST, TST, EPM, hole board (mice)	• There was a reduction in immobility duration with the highest reduction in the 200 mg/kg group (79,6% in FST, 66,9% in TST)) • There was no difference in open-arm exploration in EPM • There was no difference in head dips of the hole board test • Combination with sulpiride/prazosin/ metergoline → ↑ immobility • Combination with yohimbine → ↓ immobility

References	Banana Species	Developmental Stage	Dosage	Laboratory studies	Result
Meliala (2020)	*Musa balbisiana Colla* (kepok banana) from Sleman	Not mentioned	Peel flakes diet 5%, 10%, 20%	TST in Diabetic Rats (immobility time for 6 minutes)	There was a significant difference in diabetic + 20% flakes with diabetic control. The effect was higher with a higher concentration.
Samad *et al.* (2020)	*Musa sapientum*	Not mentioned	Fruit paste 600 mg/kg/ day for two weeks	OFT	• The exploratory activity was increased along with the dose. The time spent in a lightbox and open arm, as well as immobility time and memory, were increased in the unstressed and stressed groups. • Administration of BFP inhibited noise stress-induced behavioral deficits (anxiolytic and antidepressant effects) and improved cognitive abilities.
Samad *et al.* (2021)	*Musa sapientum*	Not mentioned	70% acetone extract of banana peel (BPE) 400 mg/kg p.o. 14 days	• Open field activity • Home cage activity • LDA • EPM • FST • MWM • MDA • SOD, CAT, GPx	• The exploratory activity was increased along with the BPE dose. • Time spent in a lightbox and open arms increases in unstressed, stressed animals treated with BPE. • Immobility time was decreased in unstressed, stressed animals treated with BPE. • It had decreased in time to reach the platform in short- and long-term memory in groups treated with BPE. • MDA level was decreased in the treated group. • BPE increased the activity of SOD, CAT, and GPx.
Meliala *et al.* (2021)	*Musa balbisiana* Colla	Not mentioned	Banana peel floss (BPF) as diet supplementation (15%, 30%, or 60%) *ad libitum*	• CMS + MWM • CMS + TST • Cortisol + serotonin	• The rats fed a control meal supplemented with 30% banana peel floss (BPF) had a substantially reduced escape delay and spent less time in the target quadrant than the other groups. • They decreased in immobility time. • The cortisol level did not decrease with BPF administration. Meanwhile, the serotonin level was increased in the control meal supplemented with 30% and 60% BPF.

BFP: banana fruit paste; BPF: banana peel floss; CAT: catalase; CMS: chronic mild stress, EPM: elevates plus maze, FST: forced swim test, GPx: glutathione peroxidase; LDA: light dark activity, MAO: monoamine oxidase, MDA: malondialdehyde, MWM: Morris water maze, OFT: open field test, p-CPA: para chlorophenyl alanine, TST: tail suspension test, SOD: superoxide dismutase.

Table III. Clinical studies of bananas as an antidepressant and antianxiety

Reference	Randomized	Population	Intervention	Control	Outcome
Setyarini *et al.* (2020)	No	60 subjects Female, schizophrenic Moderate-severe anxiety With antipsychotic drugs Without anxiolytics, chronic illness, mental retardation	• Banana type: *Musa paradisiaca sp.* (ambon banana) ± 130 gram/fruit • Treatment groups (12 people/group): - New patient two bananas per day - New patient three bananas per day - Old patient two bananas per day - Old patient three bananas per day • Duration:14 days (New patient: first hospitalized with a medical diagnosis of schizophrenia and had never received antipsychotic treatment. Old patient: had been hospitalized with a medical diagnosis of schizophrenia and had received antipsychotic treatment.)	Without banana	Hamilton Anxiety Rating Scale (HARS) scores were decreased in all groups after 7- and 14-day interventions. HARS scores were highest in the control group. There was no difference between 2 and 3 bananas/day.
Ji *et al.* (2020)	Not mentioned	24,673 participants (13,327 males, 42.3 ± 12.0 years; 11,346 females, 40.6 ± 11.7 years) This cohort includes nearly all occupations and retired persons over the age of 18 who are living in residential communities of Tianjin	No intervention Asking the mean frequency of banana consumption in the last month: Group 1: rarely (reference); Group 2: <1 time/week; Group 3: 1–3 times/week; Group 4: ≥4 times/week.	Rarely eat a banana	The Chinese version of the Self-Rating Depression Scale (SDS) Prevalence of depression: male 16.1%, female 18.4% Male: Group 1: OR 0.86 Group 2: OR 0.76 Group 3: OR 0.97 Female: Group 1: OR 1.11 Group 2: OR 0.99 Group 3: OR 1.22
Kobayashi *et al.* (2022)	Yes	20 participants	13 subjects: 2 bananas daily for two weeks	No banana intake	50% of people who ate bananas had a decrease in intestinal environmental markers, stress markers, and autonomic nervous system activity markers → banana intake for two weeks improved the intestinal environment that also increased the parasympathetic activity, and provided stress release

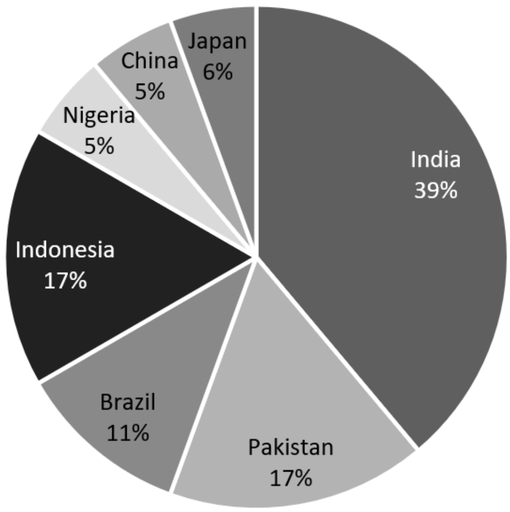

Figure 1. Countries of studies

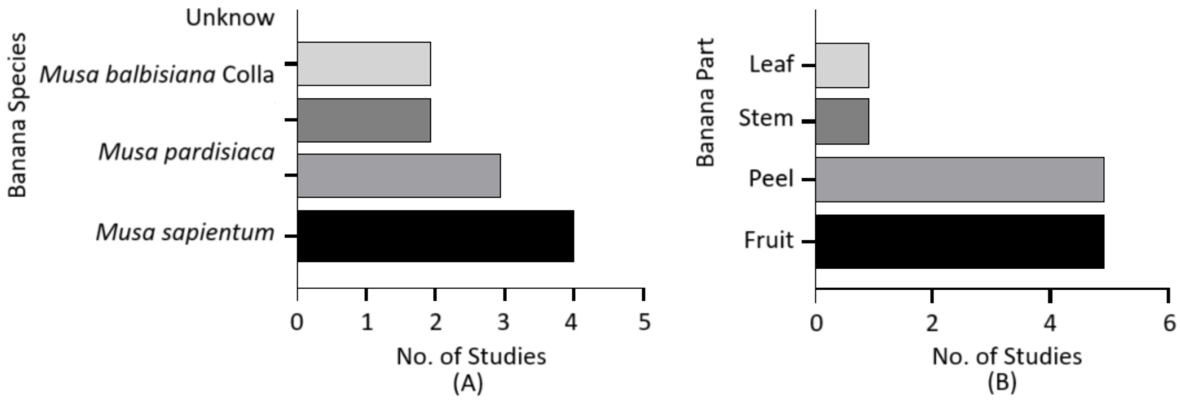

Figure 2. Banana species (A) and banana part (B) used in studies

Most articles use forced swim, tail suspension, elevated plus maze, and open field tests (Table II). The most studied species were *Musa paradisiaca* and *Musa sapientum* (Figure 2A). Four studies reported antidepressant effects, three reported antianxiety effects, and five reported both effects. Both antianxiety and antidepressants were reported positive, but not all were significant. Most studies used banana fruit or peel (Figure 2B).

The properties of banana

This study reviews the antidepressants and antianxiety effects of bananas. Bananas contain carbohydrates, protein, vitamins, and minerals (Netshiheni et al., 2020; Sidhu & Zafar, 2018). Raw and mature bananas contain bioactive compounds such as phenolic compounds, steroids, biogenic amine, carotenoids, and phytosterols that have a positive effect on health, especially as antioxidants (Afzal et al., 2022; EA et al., 2019; Lopes et al., 2020; Mengstu et al., 2021; Netshiheni et al., 2020; Prasad & Das, 2024; Qamar & Shaikh, 2018; Singh et al., 2016).

The phenolic compounds in bananas are mainly flavonoids, which have antioxidant effects based on their ability to scavenge oxygen free radicals and inhibit oxidative enzymes that cause the emergence of reactive oxygen species (Dong et al., 2016). The flavonoid content of bananas ranged from 0.40-7.45 quercetin equivalent per 100-gram dry weight (C. V. Borges et al., 2014). The antioxidant effect rises as the banana ripens (Prasad & Das, 2024).

Moreover, banana fruit and peel are rich in carotenoids and vitamins A and C, contributing to antioxidant activity (Pereira & Maraschin, 2015; Toh et al., 2016). Carotenoids (provitamin A) are precursors of vitamin A that the mammalian body cannot synthesize (Hammond & Renzi, 2013). The banana's yellow color is a good predictor of its carotenoid content (Englberger et al., 2006). The banana's carotenoid content varies with cultivars and ripening stage; some reported total carotenoids as high as 6405.03 ± 217.06 μg/100 g d.w (C. V. Borges et al., 2019; Chandra et al., 2020).

Furthermore, Bananas contain phytosterols, such as fatty acids, sterols, and steryl esters, which are known to reduce cholesterol levels in the blood and can increase cardiovascular (CVD) risk (Sheng et al., 2017; Vilela et al., 2014). FDA has stated that for lowering CVD risk, the amount of plant sterol and stanol esters are minimally 1.3 and 3.4 g per day ("Food Labeling: Health Claims; Plant Sterol/Stanol Esters and Coronary Heart Disease. Food and Drug Administration, HHS. Interim Final Rule.," 2000). The lipophilic extract of banana contains 11.1-28.0% sterol, some of which are campesterol, stigmasterol, and β-sitosterol (Mondal et al., 2021; Vilela et al., 2014).

Banana fruit and peel also contain bioactive amines such as serotonin and dopamine, contributing to antioxidant activity (González-Montelongo et al., 2010; Pereira & Maraschin, 2015a). Moreover, banana contains tryptophan, a protein that will be converted into serotonin inside the body; thus, eating a banana will relax, improve mood, and increase happiness (Kumar et al., 2012; Rajesh, 2017).

Bananas are high in nutrients, and various parts of the banana plant have shown efficacy as a medicinal plant. Banana flowers cure dysentery, ulcers, and bronchitis (Kumar et al., 2012). Banana sap contains astringent chemical compounds and treats hysteria, epilepsy, leprosy, fever, dysentery and diarrhea, bleeding, hemorrhoids, and insect bites (Kumar et al., 2012). Banana leaves have been developed as dressing for burn patients and skin graft donor areas (Gore & Akolekar, 2003b, 2003a; Guenova et al., 2013). Banana roots have been proven to have androgenic properties that support their traditional use as an aphrodisiac treatment (Yakubu et al., 2013). Traditionally, banana peel ingredients are used to treat burns, anemia, diarrhea, ulcers, inflammation, diabetes, coughs, snakebites, and menorrhagia (Pereira & Maraschin, 2015). Nowadays, banana peel is also used as a teeth-whitening agent, anticancer, antimicrobial, antidiabetic, anti-ulcerative, analgesic, mosquito bite, and skin wound treatment (Bhavani et al., 2023; Kemisetti et al., 2022). In addition, banana peels show activity to prevent or treat depression (Kemisetti et al., 2022). Based on Iranian and Indian traditional medicine, bananas are prescribed for depression (Pereira & Maraschin, 2015b). The chemical content of banana peels and fruits is primarily carotenoids, phenolic compounds, and biogenic amines (serotonin, norepinephrine, and dopamine) (Pereira & Maraschin, 2015b; Vu et al., 2018; Waalkes et al., 1958).

Tryptophan's role in banana

Tryptophan, as a supplement, has been used in the UK as a monotherapy or adjuvant for depressant patients resistant to treatment (Joint Formulary Committee, 2021). The tryptophan content made bananas a potential treatment for depression. Tryptophan is an essential amino acid required in serotonin production. Serotonin can help a person relax and improve overall mood and happiness (Jyothirmayi & Rao, 2015; Lal et al., 2017; Singh et al., 2016). A survey by MINDS, an Indian NGO, showed that people with depression felt much better after eating a banana (Kumar et al., 2012; Rajesh, 2017).

Tryptophan, an essential amino acid and a precursor to serotonin, has been proven to elevate the mood of healthy individuals (Kikuchi et al., 2021). Tryptophan in the body is converted into serotonin. In humans, acute dietary depletion of tryptophan is related to increased depressive symptoms or increased severity of depression (K. A. Smith et al., 1997). It has been found that patients with depression have a lower tryptophan/neutral amino acid ratio (Manosso et al., 2013).

Tryptophan is transported from blood to the brain by a transport carrier that is not specific for tryptophan but also for other amino acids (Ruddick et al., 2006). After tryptophan has entered the extracellular or cerebrospinal fluid, tryptophan can be uptake into cells and incorporated into several metabolism pathways, one of which is serotonin synthesis (Ruddick et al., 2006). Serotonin is a bioactive compound and one of the neurotransmitters involved in many physiological functions such as cardiovascular, pain, feeding, and reproduction and behavioral functions such as cognition, impulsivity, aggression, and mood (Vadodaria et al., 2018).

Once in the brain, tryptophan is hydroxylated to 5-hydroxytryptophan (5-HTP) by tryptophan 5-hydroxylase, a step that requires vitamin C as a cofactor. 5-HTP is then decarboxylated to 5-hydroxytryptamine, which requires pyridoxine as a cofactor. Serotonin is then metabolized by monoamine oxidase to 5-hydroxy indole acetic acid. Biotransformation of tryptophan to serotonin also occurs in the gut, platelets, and mast cells (Knapp et al., 2003).

The meta-analysis of 108 studies reported improved depressive symptoms with L-tryptophan or 5-hydroxytryptophan supplementation (Shaw, Turner & Del Mar, 2002). It has been mentioned before that bananas have a high content of tryptophan. Therefore, the consumption of bananas is thought to have the same effect.

Serotonin compound in banana

In addition to containing tryptophan, bananas contain serotonin. Serotonin is a physiologically active amine and neurotransmitter that regulates mammals' mood, sleep, and anxiety (Paredes et al., 2016). In plants, it is synthesized from tryptophan. Tryptophan is first catalyzed into tryptamine and then into serotonin (Ramakrishna et al., 2011). It is known that serotonin, but not tryptophan and 5-HTP, does not cross the blood-brain barrier. However, a previous study reported that the level of mice's brain serotonin was increased after 30 days of banana-feeding (Erigbali et al., 2017). The author hypothesized that the increase of serotonin in the brain was because the precursor, tryptophan, crossed the blood-brain.

Previously, serotonin could be detected in other high quantities in banana plants (*Musa* spp.). *Musa acuminata* fresh fruit contains 9.48±0.09 μg/g serotonin (second highest after kiwi), 26.15±0.37 μg/g tryptophan (second highest after watermelon), and 0.959±0.28 tryptamine (the highest) μg/g fresh fruit (Islam et al., 2016). Previous studies have also shown increased platelet serotonin after administering bananas (Xiao et al., 1998). Another review regarding the serotonin content in *Musa sapientum* peel and pulp reported a higher serotonin content in banana peel, and the serotonin is lower in the ripening stage (Ramakrishna et al., 2011). It was mentioned that serotonin is involved in growth regulation, flowering, xylem sap exudation, ion permeability, and plant morphogenesis (Paredes et al., 2016). Biogenic polyamines and amines also contribute to the antioxidant activity of bananas, where their antioxidant abilities correlate with the number of amine groups. Biogenic amines are aliphatic organic that play a role in animal, plant, and microorganisms' metabolic and physiological functions. In plants, amines such as serotonin can be protective compounds against insects and fungi. Dopamine and serotonin have antioxidant and anti-inflammatory effects (Lopes et al., 2020).

Antioxidant activity of banana

Banana has antioxidant properties that can counter the stress effect in our body so that sympathetic neuron activation will decrease (Aboul-Enein et al., 2016; Alhabsyi et al., 2014; Ehigiator et al., 2018; Fidrianny et al., 2014, 2018; Hallikeri et al., 2010; Jami'ah et al., 2018; Lopes et al., 2020; Manzoor & Ahmad, 2021; Marikkar et al., 2016; Mentari et al., 2019; Nifinluri et al., 2019; Pane, 2013; Phuaklee et al., 2012; Pratiwi & Krisbianto, 2019; Rebello et al., 2014; Samad et al., 2018; Schmidt et al., 2015; Sukmawati et al., 2015). Oxidative stress, a damaging effect of free radicals, increases in people with depression. The increased oxidative stress markers are evidence of this (Black et al., 2015). A previous study has mentioned that banana pulp consumption in mice can increase antioxidant enzyme activities while decreasing brain lipid peroxidation (Samad et al., 2020). The content of phenolic compounds in banana peels varies between 4.95 – 47 gallic acid equivalent/g dry matter (GAE/g d.m.), which is 1.5-3 times higher than that found in the fruit flesh. The activity of capturing and reducing the number of free radicals is much higher than in other fruit peels (Sukmawati et al., 2015).

Phenolic compounds are secondary metabolites in high amounts of bananas and provide many benefits, such as preventing cardiovascular disease, cancer, diabetes, and obesity. Phenolic compounds in bananas show antioxidant effects by limiting the production of reactive oxygen species (ROS), scavenging ROS, and activating antioxidant enzymes (Zou et al., 2022).

There are more than 40 phenolic compounds in banana peels that have been identified and can be divided into four groups, namely hydroxycinnamic acid (predominantly ferulic acid), flavonols (predominantly rutin and its conjugates), flavan-3-ol (the most dominant group of phenolic compounds), and catecholamines (Vu et al., 2018). Methanol and acetone extract from the bark of *Musa paradisiaca* L. showed quite a high polyphenol content (17.89 ± 0.16; 15.44 ± 0.19 mg/g d.w.) as well as vigorous antioxidant activity (IC_{50} 56.22 ± 8.61; IC_{50} 55.45 g/mL) (Aboul-Enein et al., 2016).

*Musa acuminat*a Colla AAA showed high activity in scavenging 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline)-6-sulphonic acid (ABTS) free radicals and in inhibiting lipid peroxidation (González-Montelongo et al., 2010). *Musa* AAA flour also showed high total phenolic content (about 29 mg/g GAE) with very high antioxidant activity (FRAP 14 M/g TE, ABTS 242 M/g, ORAC 436 M/g) (Jami'ah et al., 2018).

Research on the fruit and skin of eight banana cultivars in Malaysia showed differences in total phenolic content and antioxidant activity. The highest total phenolic content (76.37 ± 1.79 mg GAE/g d.w.) was obtained from the fresh fruit of the Raja cultivar, which was freeze-dried. The maximum activity of DPPH (19.39 ± 0.15 mg TE/g d.w.) was achieved by the chloroform extract of dried *mas* banana peel. Most of the chloroform extracts of dried fruit showed the highest ferric-reducing antioxidant potential (FRAP), especially in the *awak* cultivar (22.57 ± 0.13 mg TE/g d.w.).

Another study showed a high content of phenolic compounds in milk banana flowers (80.13 ± 4.64 mg GAE/g extract) and high antioxidant activity (ABTS+ 24.73 ± 0.04, DPPH 25.10 ± 0.15 mol of TE /g extract) and *cavendish* bananas and *salalah* bananas (Alhabsyi et al., 2014; Amri & Hossain, 2018; Manzoor & Ahmad, 2021).

Ethanol extract from *Musa sapientum* banana fruit and peel showed vigorous antioxidant activity (IC50 19.10; 44.07 g/ml) (Dahham *et al.*, 2015). In another study, *Musa sapientum* had the highest phenolic content in the decoction extract of unripe fresh banana peel (117.68 ± 0.19 mg GAE/g) and the best antioxidant activity in 50% ethanol extract of dried raw banana peel (EC_{50} 7.33 ± 0.55 g/ml) (Phuaklee et al., 2012).

In Indonesia, there have been several studies on the topic of banana antioxidant potential, including *tongka langit* banana flour (*Musa troglodytarum* L.), which shows a relatively high antioxidant activity (DPPH IC_{50} 159.41 mg/mL), *goroho* banana peel extract (*Musa acuminata* L.) (ethanol extract 75.71%, methanol extract 74.29%, acetone extract 73.37%), and *agung* banana peel extract (DPPH IC50 684.69 ± 120.73 mg/mL) (Fidrianny et al., 2018; Mentari et al., 2019; Pratiwi & Krisbianto, 2019; Soeliono et al., 2023). Research comparing the antioxidant activity of the skin of various banana cultivars in Indonesia, including *raja bulu* banana, *muli* banana, and Ambon banana, using n-hexane, ethyl acetate, or ethanol as solvent reported that the highest DPPH scavenging capacity was from *muli* banana ethanol extract (IC_{50} 4.39 ppm). Meanwhile, in an antioxidant test using ABTS, ethyl acetate extract of ambon lumut banana has the highest capacity (IC_{50} 1.91 ppm) (Fidrianny et al., 2014).

Based on the evidence presented, bananas, particularly their peels, are rich sources of antioxidants. These compounds, primarily phenolic compounds, are crucial in neutralizing harmful free radicals, thereby mitigating oxidative stress. They can contribute to various health benefits, including antidepressants and antianxiety.

Anti-inflammation activity of banana

Evidence has shown an association between inflammation and depressive symptoms. There was an increasing concentration of pro-inflammatory cytokines and cell-mediated immune activation in the depression pathophysiology. Those inflammatory states are also influenced by lifestyle, such as a diet rich in tryptophan, including bananas (Strasser et al., 2016). Various types of bananas also show effectiveness as an anti-inflammatory, which may be due to the content of polyphenols, alkaloids, and terpenes. Its antioxidant activity and radical scavenging can produce an anti-inflammatory effect, modulation of cellular activity of inflammatory cells, the activity of pro-inflammatory enzymes, production of other pro-inflammatory molecules, and expression of pro-inflammatory genes (Bellik et al., 2013). That is because of an increase in reactive oxygen species (ROS) in inflammatory conditions. During the inflammatory process, mast cells and leukocytes are recruited to the site of cell damage, causing an oxidative burst in which ROS production increases (Reuter et al., 2010). The anti-inflammatory effect test on *M. paradisiaca* stem methanol extract (200; 400 mg/kg, p.o.) showed a significant anti-inflammatory effect (Biswas et al., 2012). Likewise, the anti-inflammatory test results of *M. paradisiaca* bark extract (100, 200, 400 mg/kg) showed significant results, especially at a 400 mg/kg dose compared to positive controls (Pane, 2013). In another study, the ethanol extract and water fraction at a 200 mg/kg dose showed significant inhibition compared to the diclofenac sodium (Rebello et al., 2014). Ethanol extract of *kepok* banana peel at doses of 75 mg/kg BW, 150 mg/kg BW, and 300 mg/kg BW, as well as ethanol extract of Ambon banana leaf at doses of 500, 750, and 1000 mg/kg BW, were also shown to have anti-inflammatory activity (Ehigiator et al., 2018; Marikkar et al., 2016).

Preclinical and Clinical Studies of Banana as Antianxiety and Antidepressant

In preclinical studies (Table II), bananas showed antianxiety and antidepressant properties. Several studies report positive antianxiety effects. The antianxiety effects are indicated by an increase in time in the open arm on the EPM test and an increase in time on the lightbox in the LDA test (Reddy et al., 2017; Samad et al., 2017, 2021). In addition to the significant EPM or LDA, OFT test results show an increase in exploratory activity after giving bananas (Samad et al., 2020). However, one study reported the adverse antianxiety effects of bananas (Salako et al., 2019).

The results of the antidepressant test were shown by the results of the FST and TST tests in units of immobility time, which showed a significant decrease (Meliala et al., 2021; Parle & Malik, 2010; Salako et al., 2019; Samad et al., 2017, 2018, 2021). A memory test was also carried out with the MWM test, which showed an increase in short and long-term memory (Meliala et al., 2021; Samad et al., 2017, 2021). Although all the review articles in this study supported bananas as antianxiety and antidepressants, the clinical study did not. Some studies reported an increase in memory function and cognitive abilities. The effects were increased in a dose-dependent manner.

Nevertheless, the clinical studies' results were inconsistent (Table III). One clinical study reported decreased anxiety scores, but no difference was found in the intervention of two or three bananas daily (Setyarini & Wasita, 2020). The other study was inconsistent because the reduction in depression prevalence seems not to increase with the number of bananas eaten daily (Ji et al., 2020). However, the current clinical study showed that some people who eat bananas for two weeks have an improved intestinal environment and increased parasympathetic activity (Kobayashi et al., 2022).

Future perspectives for bananas as an antidepressant

Bananas contain both tryptophan and serotonin and can show antioxidant and anti-inflammatory activity. The results of preclinical trials and clinical trials of bananas as antianxiety and antidepressants are still limited in number. Further testing is needed to determine the mechanism of action underlying this effect. These findings can help to better understand the potential of bananas as antianxiety and antidepressants and the development of bananas as a natural remedy for patients with anxiety or depression.

CONCLUSION

The use of bananas as antianxiety and antidepressant treatment still seems far from expectations. Although sufficient scientific reasons exist to enforce the use of bananas for treatment, the number of preclinical and clinical studies was rare. More clinical studies are needed to support using bananas as a mood booster.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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