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Review Article

ANTIDIABETIC, ANTI-INFLAMMATORY, ANTIBACTERIAL, ANTI-HELMINTHIC, ANTIOXIDANT AND NUTRITIONAL POTENTIAL OF *MUSA PARADISIACA*

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ABSTRACT

The medicinal and economic values of medicinal plants remain vital to the well-being, growth, and development of humans, especially those living in developing countries. It has been shown that due to the availability, less side effects, general acceptance by local people, medicinal plants contribute significantly to improving health-care delivery system by supplying important pharmaceutical and pharmacological ingredients that are affordable to the teaming majority of people. It is estimated that 30% of pharmaceutical products that are sold globally is rich in compounds derived from plant materials. It is also of interest to report that over 80% of the people in developing countries, mostly in Asia and Africa depend heavily on plant products in the treatment and management of various disease conditions. The interest in demand and utilization of medicinal plants has also increased significantly due to the high cost of orthodox medications, lack of good transportation, lack of storage facilities, inadequate availability of health professionals, and lack of the will and political power to provide basic health needs for the citizens of these developing countries. *Musa paradisiaca* is one of such medicinal plants believed to have multi-faceted health benefits and its health benefits extend to different countries of the world. It is a stable crop found in Asia, Africa, and Central and South America commonly consumed as energy-yielding food but with many medicinal values as well. It is used in the treatment and management of diabetes mellitus, inflammation, parasitic infection, microbial infections, renal, and liver dysfunction. This manuscript focuses on the antidiabetic, antioxidant, anti-inflammatory, antimicrobial, anti-helminthic, and nutritional values of *M. paradisiaca*.

Keywords: Diabetes mellitus, Inflammation, Microbial infection, Parasitic infection, Management, Diseases, Nutrition.

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INTRODUCTION

Plants have and continue to play significant roles in the health, nutrition, and development of the human race. In fact, it is believed that humans cannot survive without plants when one considers the reliance of humans on the oxygen that is readily provided by plants. Other people, however, could argue that it is a symbiotic relationship where both parties benefit: While plants provide humans with oxygen, humans, in turn, provide plants with carbon dioxide. However, humans have benefited much more and at times at the detriment of plants. Plants remain major source of food and medicine for humans. Evidence exists in the use of plants in the treatment of various diseases, restoring, and fortifying humans and animals biological systems as commonly practiced in Chinese, Japanese, and African traditional medicine [1-5]. Historically, it is important to remind ourselves that the first documentation of traditional Chinese medicine system of medicine is over 2000 years old and has been reported to enlist over 365 drugs [4,6]. Over 5000 medicinal plants have been documented, and about 1000 are used in clinical practice in China [7]. To highlights, the importance of plants, over 1800 various plant species are used by Ayurvedic and other traditional healers in South Asia [8]. In Africa, humans have been using medicinal plants for centuries, and the demand is even on the increase because of the value attached to plants for medicinal and spiritual uses. It has been reported that seven out of the twenty best products sold in pharmaceutical field, are either from natural products or direct derivatives of natural compounds, generating over US$20 billion in revenue per year [9]. It is also interesting to note that there are about 400,000 secondary plant metabolites in the world and about 10,000 of them have been isolated as useful products [10].

Musa paradisiaca (Linn.) is a herbaceous plant measuring up to 9 m in length with a robust tree-like pseudo-stem, displaying a crown of large elongated oval deep-green leaves up to 365 cm in length and 61 cm in width [11]. It belongs to the family Musaceae containing over 200 species; growing in the tropics and subtropics. It is seen as a major crop in Africa, Asia, and Central and South America, consumed as energy-yielding food; estimated to provide about 60 million people in Africa with over 200 calories/day, contributing to their diet, nutrition, and health [12]. There are two commonly known names in the genus Musa (banana and plantain). For instance, plantain is the common name for herbaceous plants of the genus Musa and the fruits produced are used for cooking, in contrast to the soft, sweet banana and it is generally opined that there is no formal botanical distinction between bananas and plantains and that the use of either name (banana or plantain) is based mainly on how the fruits are consumed [13] and that plantains are recognized to belong to the same species as banana [14]. Analysis of ripe and unripe extracts of *M. paradisiaca* shows that it contains carbohydrate, protein, fat, fiber, ash, and moisture. It is also found to provide calcium, potassium, manganese, sodium, zinc, phosphorus, nitrogen, iron, and copper [12,15].

The fruit of *M paradisiaca* is used in the treatment and management of diabetes mellitus, dysentery, intestinal lesions, diarrhea, hypertension, ulcerative colitis, and as antimicrobial, and anti-helmintic agents [16-19]. The medicinal properties are believed to be associated with its constituents such as polysaccharides, lipids, caffeic acid derivatives, flavonoids, iridoid glycosides, terpenoids, alkaloids, and specific organic acids. Its leaves and seeds have been reported to possess wound healing property, anti-inflammatory, antioxidant, and immune-promoting activities [15,20,21].

ANTIDIABETIC ACTIVITY OF *M. PARADISIACA*

Medicinal plants are abundantly available in the tropics and subtropics and could be useful sources as direct therapeutic agents, as raw material for semi-synthetic compounds, as plant-derived chemical structures

serving as model for new synthetic compounds and used as taxonomic biomarkers for the identification of new compounds. It is important to note that medicinal plants including *M. paradisiaca* have contributed to human health and nutrition [22-24]. Various ingredients have been identified from different parts of *M. paradisiaca* and include serotonin, dopamine, flavonoids, quercetin, 3-O-galactoside, leukocyanidin, 3-O-glucoside, 3-O-rhamnosyl glucoside, and acyl steryl glycosides. To investigate the antidiabetic activity of *M. paradisiaca*, Lakshmi *et al.* [24], collected different parts of the plant such as the leaves, peels, roots, stems, and ripe fruits and were authenticated by a Botanist. The various parts were extracted, and ethanolic extracts were assessed in a male rat model following induction of diabetes using streptozotocin (STZ). Results of the study showed that only leaves and ripe fruit peels showed promising antidiabetic effects. The ethanolic extract of the leaves and peels demonstrated lowering blood glucose level at 500 mg/kg body weight in STZ-induced diabetic rats. Other studies [23,25-28] have reported on the antidiabetic activities of *M. paradisiaca*.

In an attempt to contribute to global efforts in reducing the prevalence and burden of diabetes mellitus through different approaches, Iroaganachi *et al.* [29] investigated the antidiabetic effects of unripe *M. paradisiaca* in STZ-induced diabetic rats. The unripe plant obtained locally in the Eastern part of Nigeria was scientifically identified by a Botanist at Forestry Department, Michael Okpara University of Agriculture, Umudike. The STZ-induced diabetic rats were divided into three groups (2–4) consisting of six rats per group and the nondiabetic group (Group 1). The rats were fed for 28 days, after which they were sacrificed and blood samples collected for assay. The results indicated that the serum urea and creatinine levels of diabetic control rats increased significantly compared to nondiabetic rats. Diabetic rats (Group 3) fed unripe extract of *M. paradisiaca* showed significant increase in both protein and albumin with decrease in urea and creatinine levels. The authors concluded that treatment of diabetic rats with unripe *M. paradisiaca* extract was effective in reducing serum urea and creatinine levels while increasing protein and albumin levels and thus could play a role in the management of renal dysfunction in diabetic condition.

The use of unripe *M. paradisiaca* in the management of diabetes and hepatic dysfunction in STZ-induced diabetes in rats was assessed by Eleazu and Okafor [30]. The authors reported that intake of unripe extract by diabetic rats resulted in a significant decrease in blood glucose when compared to diabetic control rats; urine glucose and protein decreased with time following treatment with extract of unripe *M. paradisiaca*. The authors indicated that the study shows the potential of unripe *M. paradisiaca* extract in the management of diabetes and diabetic complications. Famakin *et al.* [31] assessed the glycemic and antidiabetic property of *M. paradisiaca*-based functional dough meals in an animal model. For this experiment, 40 diabetic male Wistar rats, randomly divided into six groups with seven per group were used. The animals were fed with *M. paradisiaca*-based diet for 28 days and blood glucose levels measured. The result showed that there was a significant reduction in blood glucose level following feeding diabetic animals with *M. paradisiaca*-based diet for 28 days.

ANTI-INFLAMMATORY ACTIVITY OF *M. PARADISIACA*

The inflammatory reaction is designed to protect the biological system from infection and injury by releasing cells and mediators that fight against foreign bodies to prevent infection. However, excessive inflammatory reaction could lead to adverse inflammatory reactions. Inflammation could be classified as acute and chronic; while acute inflammation is the initial stage of inflammation that persists for a short time, chronic inflammation, on the other hand, persists for longer period and depending on the intensity of the inflammation, mediators that are elicited in the affected area could reach the circulation and cause fever [20,21]. Inflammation is a complex pathophysiological process, mediated by different signaling molecules [15,32]. To investigate the anti-inflammatory activity of *M. paradisiaca*, Ibegbu *et al.* [13] collected the root of plantain plant from plantain plantation in Lagos State, Nigeria. To determine the lethal dose 50 for the plantain root extract, preliminary study was performed with a dose of 5000 mg/kg body weight and no death was reported, showing that the extract is not toxic. For the anti-inflammatory experiment, a total of 45 adult Wistar rats (male and female rats) were used, grouped into nine groups (n=5). The animals were divided into nine groups and received various treatment. The authors reported that aqueous extracts of plantain roots of *Musa* species demonstrate significant reduction on egg albumin-induced inflammation and that the prevention of inflammation was time and dose-dependent. High anti-inflammatory activity was documented at 20–80 min; while the anti-inflammatory potency decreased from 80 to 120 min. Egg albumin and other potent edematous agents are known to produce inflammation through the release of inflammatory molecules which, in turn, elicit increase vascular permeability, promoting fluid retention in tissues, culminating in edema. The previous study has reported and maintained that plantain root contains aucubin (a glycoside in plantain) which acts as anti-inflammatory, sedative, antiseptic, antiviral, antihistamine, and antirheumatic agent [33]. The presence of apigenin, Vitamins A, C, E, B-complex vitamins and trace elements such as magnesium, calcium, zinc, and selenium in *M. paradisiaca* has been shown to reduce inflammation reactions [34].

Bindu *et al.* [35] argues that drugs used in the treatment of inflammation are linked with severe side effects such as gastric irritation, diarrhea, rashes, stomach ulcers, liver, and kidney dysfunction; therefore, it is important to investigate the use of natural products such as medicinal plants such as *M. paradisiaca* and its anti-inflammatory potentials. He and colleagues collected and identified *M. paradisiaca* leaves, extracted it, performed phytochemical screening, assessed its toxicity effects and its anti-inflammatory activity in rat model. In the evaluation of the anti-inflammatory activity of *M. paradisiaca* leaf extract, the authors used the carrageenan-induced hind paw edema in Wistar male and female rats divided into four groups (n=6). Following the experiment and analysis of results, the authors noted that *M. paradisiaca* leaf extract at high and low doses produced significant reduction in carrageenan-induced paw edema in the rats and that the anti-inflammatory activity may be related to the presence of flavonoids, phytosterols, and tannins in the extract.

Rao *et al.* [36] report that inflammatory diseases are of public concern and that the prevalence is on the increase, therefore, as part of the global efforts to find an appropriate and cheaper treatment regime, it is vital to explore other sources including the application of herbal agents. Hence, the authors determined the anti-inflammatory activity of *M. paradisiaca* (fruit and tepal) in macrophage cell line (RAW 264.7). At the end of the experiment, the authors observed that the two parts of *M. paradisiaca* that were tested, demonstrated anti-inflammatory activity.

The anti-inflammatory activities of *Musa* species were assessed using various approaches: Inhibition of albumin denaturation, protease inhibition, membrane stabilization, heat-induced hemolysis, and hypotonicity-induced hemolysis [37]. Results showed degrees of effective inhibition of inflammation using the afore-mentioned approaches. In respect of these methods, for instance, denaturation of protein is known to cause inflammation in which proteins lose their secondary and tertiary structures in the face of acid, base, organic salt or heat. White blood cells proteinase plays key role in the development of tissue damage during inflammation reactions, and in the study of Saraswathi and Malathi [37], important protection was offered by proteinase inhibitors (*Musa* species), stabilizing red blood cell membrane as a mechanism of anti-inflammatory impact. It has also been reported that protective effect on hypo-tonic saline-induced red blood cell leakage is known to represent a good index of anti-inflammatory activity of any agent with anti-inflammatory potential.

Biswas *et al.* [38] stated that xylene-induced edema model represents a preliminary approach in the evaluation of the anti-inflammatory

activity of a plant extract. To conduct the experiment, the authors used Swiss female rats in testing the anti-inflammatory activity of *M. paradisiaca* and divided them into four groups (n=6), received various treatments for 7 days. He also repeated the experiment using carrageenan-induced rat paw edema and dextran-induced paw edema. In all these experiments, methanolic extract of *M. paradisiaca* showed significant and dose-related anti-inflammatory activity.

ANTI-BACTERIAL ACTIVITY OF *M. PARADISIACA*

The discovery and availability of antibiotics were largely welcomed by humans as antibiotics have significantly contributed to the health and well-being of people all over the world. However, resistance to antibiotics by microorganism is of grave public concern, and the problem seems to be growing. Several plants have been used in the treatment of microbial infections due to the fact that these plants contain secondary metabolites with antimicrobial activities [39]. In testing the antimicrobial activity of *M. paradisiaca*, Karadi *et al.* [39] used extract from fruit peel and tested the extract against selected bacteria and fungi: *Escherichia coli*, *Staphylococcus aureus,* and *Pseudomonas aeruginosa*; fungi: *Candida albicans* and *Candida tropicalis*. The antimicrobial activity was performed using agar diffusion method using a paper disc, and the minimum inhibition concentration was assessed by microdiffusion method using liquid nutrient media with various aliquots of the test materials. According to the authors [39], extract of *M. paradisiaca* at different concentrations produced strong antibacterial activity against Gram-positive organisms with greater zone of inhibition than the Gram-negative bacteria. Extract of *M. paradisiaca* also showed potential inhibitory action against fungal strains that were tested.

Recent reports show an increase in the use of medicinal plants as an alternative medicine to the use of synthetic medications, possibly prompted by global economic challenge, high cost of synthetic medications, lack of access, and side effects of orthodox medications [40]. Medicinal plants have been used in the treatment of alveolitis following tooth extraction. de Melo Júnior *et al.* [40] advocates that there is a need for new approach especially the use of medicinal plants in the treatment of alveolitis. To test this, the authors collected medicinal plants including *M. paradisiaca*. For the experiment, 34 male Wistar rats divided into two groups (n=10) were used. The extraction of the right upper jaw incisor of each tooth was done after the animals were anesthetized. Alveolitis was induced using adrenalin in the socket. In the second stage, biological material from the socket was obtained for identification of the microorganisms. The identified bacteria were used to test the antibacterial activity of the plant extracts, and the authors reported that the plants extract including *M. paradisiaca* showed antibacterial activity against the tested organisms that were identified and isolated from the sockets.

It is known that medicinal plants are rich in bioactive compounds, being in use for thousands of years as antibacterial agents. Increase in demand coupled with a better understanding of the mechanism of actions of plant-based-bioactive compounds has prompted an increased interest in plant-based antibacterial agents [41]. Padam *et al.* [41] evaluated the antibacterial activities of various solvent extracts of *M. paradisiaca* and reported that methanolic extract of *M. paradisiaca* shows the best antibacterial activity due to its high concentration of phenols.

Measurement of microbial enzyme activity in the evaluation of ecotoxicological effects of environmental substrates has been documented, and dehydrogenase activity has been commonly applied in such evaluations [42]. To evaluate the antibacterial activity of *M. paradisiaca*, Alisi *et al.* [43] examined the inhibition of dehydrogenase activity in pathogenic bacteria isolates by aqueous extracts of *M. paradisiaca*. In this experiment, dehydrogenase activity was assessed using nutrient broth-glucose-triphenyl tetrazolium chloride (TTC) medium supplemented with varied concentrations of plant extract. The two bacteria (*Staphylococcus* spp. and *Pseudomonas* spp.) were tested for their ability to reduce TTC to triphenyl formazan, and result was used to assess antibacterial activity of the plant extract.

ANTI-HELMINTIC ACTIVITY OF *M. PARADISIACA*

Helminthic infections are known to induce various disease conditions in humans, animals, and plants, and it has been sown that anti-helminthic agents have side effects on humans, animals, and plants with negative consequences; therefore, people have resulted to the use of medicinal plants in the treatment of parasitic infections [44,45]. Krishna *et al.* [46] in their evaluation of anti-helminthic activity of *M. paradisiaca* reported that ethanol extract of the plant was significant in effectively paralyzing and killing earthworm at different concentrations.

In vitro screening of the leaves of *M. paradisiaca* for anti-helmintic activity, the report shows that aqueous and methanolic extracts of the plant displayed anti-helmintic activity by inhibiting hatching of eggs of nematodes and that the activity is dose-dependent with aqueous extract showing strong anti-helmintic activity [47]. This *in vitro* approach can be very useful in poor resource setting due to the fact it is cheaper, economical, and faster compared to *in vivo* approach. Due to the cost-effectiveness of medicinal plants and the associated products, it has gained wide acceptance in veterinary practice and as rich source of herbal anti-helmintic in animals and human treatment of helminthiasis [48]. In an experiment conducted by Accioly *et al.* [49], it was shown that some fractions of *M. paradisiaca* displayed good leishmanicidal activity *in vitro*, suggesting that the use of herbal products can be effective in the treatment of tropical diseases caused by protozoa.

ANTIOXIDANT ACTIVITY OF *M. PARADISIACA*

In assessing scavenging potential of *M. paradisiaca*, methanolic, ethanolic, aqueous, and ethyl acetate extracts of *M. paradisiaca* was able to scavenge over 50% of 2,2-diphenyl-picrylhydrazyl radicals at specific concentrations, showing that extract of the plant displayed strong antioxidant activity [41]. Extracts of *M. paradisiaca* contain significant amount of cyanidin rutinoside-a substantial antioxidant [50]. Yin *et al.* [51] noted that extract of *M. paradisiaca* significantly reduced plasma oxidative stress. Other scientists such as Imam and Akter [11], Vijayakumar *et al.* [52] have also documented the antioxidant activity of the extracts of *M. paradisiaca*.

NUTRITIONAL VALUE OF *M. PARADISIACA*

M. paradisiaca is a common fruit with global importance in terms of nutritional and economical values, spreading far across 130 countries [53]. It can be eaten raw, fried, cooked, roasted or baked, or processed in different forms such as juice, flour, or puree. Its fruit constitutes a rich source of phytonutrients, vitamins, and phenolic compounds and contains phosphorus, sodium, potassium, zinc, magnesium, copper, calcium, iron as well as the application of *M. paradisiaca* as an ingredient in food products has been reported to contribute positively to human health. Its addition to recipes of various food products has been shown to improve total dietary fiber, resistant, and total starch [54,55]. The amount of phenolic compounds and flavonoids differs according to genotypes and locations [56]. Carotenoids identified in *M. paradisiaca* include lutein, beta-carotene, alpha-carotene, violaxanthin, auroxanthin, iso-lutein, neoxanthin, beta-cryptoxanthin, and alpha-cryptoxanthin and the concentration varies with cultivars and their presence in *M. paradisiaca* is known to protect against Vitamin A deficiency [57]. It should be known that the role of carotenoids in reducing the risk of cardiovascular diseases and improving immunity have been reported [58]. A single banana is believed to provide about 23% of daily need of potassium, helping to maintain proper functioning of the muscles while preventing spasm, promote healthy teeth, bones, tissue, boost immune system, supports healing, growth of tissue, and promotes absorption of calcium [59]. *M. paradisiaca* has also been reported to be used as a remedy for constipation, in the treatment of intestinal lesions and in the management of malnutrition in children [60].

M. paradisiaca has been used in the management of anemia and high blood pressure due to its high iron content and high potassium [60].

Serotonin in *M. paradisiaca* is believed to be useful in preventing depression by changing mood, enhancing relation; also that resistant starch present in *M. paradisiaca* is suitable in the diet of individuals with cardiovascular and diabetic problems [61]. A natural flavonoid leukocyanidin is reported to be responsible for anti-ulcerative properties of unripe *M. paradisiaca* and its protective role in gastric mucosa in aspirin-induced erosions [62]. Consumption of *M. paradisiaca* in diets has been reported to reduce fasting blood glucose and low-density lipoprotein (LDL)-cholesterol and liver glycogen [63]. *M. paradisiaca* is considered as a source of dietary fructo-oligosaccharides and has been reported to reduce the levels of serum cholesterol, improve mineral absorption, stimulate the growth of non-pathogenic intestinal micro-organisms as a result of their prebiotic impact [64] while taken of *M. paradisiaca* on a daily basis improved insulin sensitivity in diabetic patients [65]. Phytosterols present in *M. paradisiaca* inhibit the absorption of cholesterol from the small intestine by removing it from the micelles and increasing its excretion and are therefore able to decrease the level of serum LDL-cholesterol [66]. Protective effects of *M. paradisiaca* in the diet of patients with colorectal cancer in control subjects have shown that extract of *M. paradisiaca* demonstrated highest antiangiogenic activity inhibition and was able to inhibit the growth of colon cancer cell line [67].

CONCLUSION AND RECOMMENDATION

Due to the important role medicinal plants play in the health, nutritional, cultural, traditional and spiritual life of humans, interest in the use of medicinal plants continues to grow. This interest prompted the review of previous studies on the antidiabetic, anti-inflammatory, antibacterial, anti-helmintic, antioxidant, and nutritional properties of *M. paradisiaca*. It is envisaged that the comprehensive information presented in this review paper will enrich the knowledge of the public on the health benefits of the plant and stimulate further research on the plant. Further research to isolate key active ingredients in *M. paradisiaca* is suggested. There is a need to conduct clinical trials on the antidiabetic, anti-inflammatory, and antioxidant activities of *M. paradisiaca* in human beings.

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AUTHOR'S CONTRIBUTIONS

Oluwafemi Omoniyi Oguntibeju conceptualized the research idea, performed literature search, wrote and edited the manuscript; revised the manuscript and acted as the corresponding author.

CONFLICTS OF INTEREST

The author declares that there are no conflicts of interest.

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