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NUTRITIONAL IMPORTANCE AND THERAPEUTIC POTENTIAL OF TIGER NUT (*Cyperus esculentus*): AN UNDERUTILIZED CROP IN WEST AFRICA.

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ABSTRACT

Tiger nut is an abundant plant in the West African sub-region but its uses remains very limited. This review article aims to elucidate the chemical and phytochemical composition and biological activities of Cyperus esculentus. The tuber is a source of food components such as minerals (Na, Mg, Ca, K, P, Fe, Zn), vitamins (B_1, B_2, B_3, B_5, B_6, B_9, B_{12}, E, C) and carbohydrates. Its fat content can be as high as 44.52% and the fatty acid profile of its oil consists a percentage of unsaturated fatty acids varying between 70 and 81% with an important proportion of oleic and linoleic acids. *Cyperus esculentus* contains many phytochemicals which includes; polyphenols, flavonoids, tannin, sterols, polyterpenes, glycosides, alkaloids, salicylic acid, terpenoids, saponins, steroids, several properties are granted. The documented biological potentials of Cyperus esculentus include; aphrodisiac, regenerative, digestive, antimicrobial, larvicidal, antidiarrheal, antidiabetic, hypocholesterolemic, antioxidant, antifungal and galactogenic properties. Tiger nut use can be used in the basic food of the population to fight against malnutrition and certain human pathologies.

KEYWORDS: *Cyperus esculentus*, tiger nut, chemical and phytochemical composition, biological properties.

1. INTRODUCTION

Tiger Nut (*Cyperus esculentus*) is a plant native to ancient Egypt and its cultivation dates back to 6000 B.C. It is cited as one of the most ancient plants cultivated in ancient Egypt[1] and is also found in the Arabian Peninsula, Spain, West Africa and parts of America.[2][3] Tiger nut is widely known in West Africa and it is eaten by both children and adults. The tubers are consumed raw, dried or roasted.[4] It is sometimes used as a source of vegetable milk.[5],[6],[7] They are good sources of nutrients[2][8][9] which can be used to fight against the recurrent problems of undernourishment and malnutrition in developing countries in Africa. Africa is endowed with high diversity of food resources which are underutilized. This underutilization is mostly due to the lack of information on the nutritional and therapeutic value of plant resources. Indeed, plants have always been used to satisfy the nutritional and therapeutic needs of populations. Several ethnomedicinal considerations have directed scientific research towards the study of the biological properties of these tubers[3] Thus, this bibliographic study is undertaken to update the latest information on the chemical and phytochemical composition and biological activities of *Cyperus esculentus* based on documented scientific research.

2. Morphology and Varieties of tiger nut tuber

Tiger-nut (*Cyperus esculentus*) is an herbaceous plant of the family Cyperaceae. It produces rhizomes from the base and tubers. The tubers of tiger nut are the swollen parts of the rhizome. The forms and the dimensions of the tubers vary. The variety native to West Africa can reach 2 to 2.5 cm in length and l to 1.5 cm in thickness. The tubers are sometimes subspherical, sometimes elongated and elliptical.[10] There are several varieties of tiger nut worldwide: *Cyperus esculentus* var. hermannii (Florida), *Cyperus esculentus* var. leptostachyus (USA), *Cyperus esculentus* var. macrostachyus (USA), and *Cyperus esculentus* var. sativus (Asia).[11],[12],[13] Black, yellow and brown tubers also exist (Fig.1, 2, 3 and 4).[14],[15] However, the yellow and brown colored species are the most available in the market.[14],[15]

Figure 1: Black varieties.

Figure 2: Yellow varieties (Large size).

Figure 3: Yellow varieties (Small size).

Figure 4: Brown varieties.

3. Chemical and Phytochemical composition

Previous studies have reported the presence of significant numbers of chemical compounds such as vitamins, mineral elements, carbohydrates, lipids and proteins,[2],[15] Vitamins B (B_1, B_2, B_3, B_5, B_6, B_9 and B_{12}), C and E. Tiger nut are good source of B_9 with a content of 200µg/100 g.[8] The vitamin E content has been reported to be as high as 80 mg/ 100 g of flour.[8].[8] El Naggar (2017) research team reported an oil content of 97 mg/100 g.[16] Protein content varies between 5 à 13%,[17],[48] carbohydrate content ranges between 38.43 to 69%,[15],[4],[19] and starch content between 25 to 31%.[20],[21],[15],[22] The crude cellulose content be as high as 11.9%.[18] Marchyshyn *et al.*, (2021),[23] report a free monosaccharide content (D-saccharose), of the order of 63.72 mg/g of tubers. Tiger nuts, although a tuber, has a fat content of up to 44.52%.[24] This content varies according to the variety, the cultivation conditions and the geographical areas.[25] Results obtained indicated that the yellow variety to be 7.46%.[26] Some other authors reported 24.45% for the yellow varie,[27] 30 to 35.43% for the brown variety,[28],[29],[30] and 40 to 43.5% for the black variety,[24],[30] Its oil is similar to that of olives due to its fatty acid profile,[15],[28],[31] According to Shaker *et al*.,(2009),[20] tiger Nut oil contains 14.5% palmitic acid, 1.5% palmitic acid, 3.40% stearic acid, 69.50% oleic acid, 8.80% linoleic acid and 0.40% linolenic acid. The study by Linssen *et al.*,(1989)[32]

showed fatty acid profiles of 10.21-14.1% palmitic acid, 1.47-3.3% stearic acid, 74.70-75.72% oleic acid, 8.7-11.64% linoleic acid, and 0.4-0.64% linolenic acid; the study of El-Naggar (2016)[33] revealed a profile of 1.7% myristic acid, 15.4% palmitic acid, 5.3% stearic acid, 6.1% behenic acid, 65.8% oleic acid, 5.5% linoleic acid and 0.2% linolenic acid. Similar results were obtained by Yoon *et al.*, (2016).[31]

Phytochemical studies of tubers have revealed several compounds such as sterols, polyterpenes, glycosides, alkaloids, flavonoids, tannins, polyphenols, salicylic acid, terpenoids, saponins, steroids, and ρ-hydroxy benzoic acid etc,[18],[34],[35],[36] The phytosterol content could be up to 168 mg/100 g of oil.[37] A recent study by Imo *et al.*, (2018)[26] revealed that the tiger nut ethanolic extract contains phytochemicals such as oxalic acid, monoamide, n-propyl, dodecyl ester, 9-octadecenoic acid, 9-octadecenal, (Z)-Hexadecane, and 1-(ethenyloxy). Most of these compounds are bioactive phytoconstituents that have proven to be beneficial in human management of health and disease states.

4. Biological properties

4.1 Aphrodisiac properties

Tiger nut is known to improve sexual performance in men. This is one of the reasons that it is being used by the elderly in Senegal. In the Middle East the tubers of tiger Nut are called "Hab Al-zulom" meaning the seeds of man, thus alluding to its aphrodisiac effect.[38] The study conducted on active and moderately active rats at doses of 1 to 2 g/kg body weight per day of tiger nut meal for 30 days reveals that yellow nutsedge stimulates sexual desire by reducing the latency for arousal and intromission. Thus, during this evaluation period, a significant increase in testosterone levels was observed in the nutsedge administered rats compared to the control group.[38] These effects may be due to the presence of quercetin (flavonoids), vitamin E and C and zinc in the tiger nut.[38] Quercetin is a secondary metabolite belonging to the flavonoid family that has been documented to increase testosterone levels, improving sperm quality and erectile dysfunction. Similar results were gotten and reported by by Olabiyi *et al.*, (2016).[39] In their study, Hassan *et al.*,(2018)[40] investigated the protective effect of aqueous extract against flutamide, which is known to have negative effects on testosterone, Follicle-Stimulating Hormone (FSH) and Luteinizing Hormone (LH) levels, on spermatogenesis, resulting in sexual dysfunction and infertility. It was found in this study that tiger nut extract induced an increase in testosterone levels and a recovery of Follicle-Stimulating Hormone levels compared to the negative control group. The aqueous extract of

tiger nut shows regenerative effects on the histology of testes destroyed by lead acetate.[41] In this study, the aqueous extract of *Cyperus esculentus* relatively ameliorated the histopathological changes in the testis of mices caused by the injection of 8 mg/kg of lead acetate. Similar results were found by Udefa *et al*., (2020).[42] The improvement may be on spermatogenesis by reducing lipid peroxidation and preventing or decreasing free radical formation by acting as an antioxidant. The study conducted by Ekaluo et al (2015)[43] on rats treated with doses of aqueous extract of tiger nut respectively 0.0; 0.6; 1.2 and 1.8 g/kg of body weight for nine weeks revealed an increase in sperm quantity and quality. Sperm motility and viability increased with increasing dose. An increase of the testicles and epididymis was found following the increase of the dose. Similar results were found by Sabiu et al. (2018)[44] and Adam et al (2020).[45] These authors investigated and compared the aphrodisiac properties of ethyl acetate extract of tiger nut versus power max which is aphrodisiac in rats for four weeks. An increase in the amount of testosterone, viability and motility of sperm, FHS and LH hormones was observed. Cholesterol and glycogen levels in the testes were also increased.

4.2 Regenerative, Digestive and Antioxidant properties

According to studies, tiger nuts promote the repair of tissues, muscles, blood flow, body growth and fortify bones due to its richness in minerals such as phosphorus, potassium, calcium and magnesium. It is recommended for those who suffer from indigestion, flatulence and diarrhea to take it, as tiger nut provides digestive enzymes such as catalase, lipase and amylase.[46] Also, its sucrose-based carbohydrate content and starch (gluten-free) make it a healthy food for celiac sufferers.[20] The study conducted by Hassan and Hassan (2007),[47] showed an increase in the number of red and white blood cells and the number of blood platelets in mice by intraperitoneal injection of tiger nut oil compared to the control lot. According to several studies, it has been reported that it also helps to prevent colon cancer, due to its high soluble glucose content.[48],[49] In addition, tiger nut milk, without sugar is suitable for diabetics and helps in weight control.[50] Tiger nuts tubers have antioxidant properties due to the presence of phenolic compounds[19] and vitamin E as well as its consumption could reduce anxiety.[39] The administration of tiger nut oil in male wistar rats treated with STZ to induce liver damage shows a significant increase in the antioxidant activity of enzymes such as Glutathione Peroxidase (GPx), Reduced Glutathione (GSH) and Superoxide Dismutase (SOD) compared to the untreated group.[51] Thus, tiger nut has anti-inflammatory properties[52] and antioxidant properties.[53]

4.3 Cholesterol-lowering properties

Tiger nut oil also contributes to the reduction of cholesterol levels, the risk of coronary heart disease and atherosclerosis.[54],[55] According to Hassan (2007),[56] a supplementation of 0.1 ml and 0.5 ml/kg of body weight in albino rats for six weeks, resulted in a reduction of cholesterol levels from 110.4 to 98.4 mg/dl and from 110.4 to 88.1 mg/dl respectively and an increase in HDL-C from 32.5 to 43.5 mg/dl and from 32.5 to 64.1 mg/dl respectively for the doses 0.1ml and 0.5 ml/kg of body weight. In a study conducted by Oguwike *et al.*, (2017)[57] on the effect of nutsedge on hematological and biochemical profile in hypercholesterolemic subjects, it was found that nutsedge drastically reduced cholesterol level compared to controls. According to Innih *et al.*,(2017),[58] tiger nut aqueous extract corrects the hyperlipidemia created by injection of triton WR 1339 at a dose of 250 mg/kg of rat body weight. Aqueous extract treatment resulted in a significant reduction of total cholesterol, total glycerid, LDL and VLDL and an increase in HDL in hyperlipidemic rats induced by triton WR 1339 compared to control. The side effects such as ulceration and stenosis caused by triton WR 1339 are attenuated by tiger nut aqueous extract.[58] This cholesterol-lowering property of tiger nut tubers could prevent atherosclerosis, the development of which is correlated with hypercholesterolemia. The biological effects of tiger nut oil were tested on healthy and hypocholesterolemic rat by El-Naggar (2016)[16] at doses of 10 and 15% of nut oil. It follows from this study a reduction in lipid levels, LDL, v-LDL, total glyceride, total serum cholesterol and an increase in HDL levels in hypocholesterolemic mice. According to Zommara and Imaizumi (2018).[59] a reduction of cholesterol and triglyceride levels of 42% and 60% in serum and 44% and 53% in liver respectively was observed following supplementation of the diet of mice with 25% tiger nut flour in apolipoprotein E knockout status over a period of 11 weeks.

4.4 Antimicrobial, Larvicidal and Antidiarrheal properties

Tiger nut are endowed with antimicrobial properties due to the significant presence of phytochemicals. Thus, the *in vitro* antimicrobial activity of the aqueous extract of nutsedge tubers against six bacterial species *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Salmonella typhi, Bacillus subtilis* and *Staphylococcus aureus* was evaluated. The results showed significant effects with extract concentration range of 70 to 100 µL on all microbial species.[60] The phenolic enriched fraction of Tiger Nut was tested on the species, *Bacillus subtilis* (G+), *Pseudomona* ssp. (G-), *Aspergillus niger* and *Saccharomyces* spp. by Owon *et al.*,(2013)[61] and was reported to be activeagainst the different species. Tiger nut oil

exhibits antibacterial properties. It showed significant activity against *Candida albicans* and moderate activity against *Staphylococcus aureus*.[62] The study of Avicor *et al.*, (2021)[63] showed that the aqueous extracts of two varieties of tiger nut (black and yellow) carries larvicidal potential on mosquitoes (*Aedes aegypti* L.) and (*Culex quinquefasciatus* S.). The results of this study indicated the potential of *Cyperus esculentus* as a possible source of bioinsecticide for mosquitoes. The hydroalcoholic extract of *Cyperus esculentus* plant roots has anti-diarrheal activities in addition to reducing the number of diarrhea episodes and microbes present in the salts. This aqueous extract has comparable effects compared to Loperamide which is an anti-diarrheal drug. The percentage of inhibition of faecal and small intestine contents with 200 and 400 mg/kg of hydroalcoholic extract was 57.73; 67.21 and 56.57; 69.73% respectively.[64]

4.5 Antidiabetic and Anticarcinogenic properties

There are many data on the anti-diabetic properties of nutsedge tubers. These tests concern both the raw tubers, the tiger nut oil and milk. According to Chevallier (1996),[65] nutsedge may be involved in the regulation of diabetes. Thus, a significant reduction of the blood glucose content from 71.5 to 48.5 g/dl was observed in the work of Chukwuma et al., (2010)[66] compared to the control batch. This reduction in blood glucose content is attributed to the high arginine content,[67] which allows the release of the hormone that enables the production of insulin.[65],[68] Njoku-Oji *et al.*, (2019),[68] showed that the ethanolic extract of Tiger Nut has anti-diabetic properties. The ethanolic extract of Nutsedge shows a certain effectiveness in the significant reduction of the glucose level in the blood compared to the antidiabetic product Metformin in alloxane induced diabetes in rats. Similar results were demonstratedby Sabiu *et al.*, (2016)[69] with the aqueous extract of tiger nut. The research team also reported its inhibitory actions on α-glucosidase and α-amylase enzymes. The consequence of these effects is the reduction of starch hydrolysis to glucose.[69] Thus, the aqueous extract of nutsedge shows similar results compared to the standard product acarbose.[69] The conclusions drawn from the study of Udogadi and Onyenibe (2019)[51] on the anti-diabetic properties of tiger nut oil show that it helps to reduce blood glucose level, stabilizes glucose 6 phosphate dehydrogenase, inhibits α-Amylase, improves the status of lipid profile and improves antioxidant capacity. According to Hassan and Hassan (2007),[47] supplementation of 0.1ml and 0.5 ml/kg of nutsedge oil in albino rats for six weeks exhibited a reduction in glucose levels from 98.5 to 92.9 ml/kg and 98.5 to 77.2 ml/kg body weight

respectively for the 0.1ml and 0.5 ml/kg doses. The study of Achoro and Ming[70] demonstrated the positive effects of tiger nut against carcinogenic cells.

4.6 Hepato-protective properties

Tiger nut possess potential hepato-protective properties against carbon tetrachloride (CCl_4) hepato-toxicity induced by and validate the traditional use of tiger nut extract as liver tonic. According to Sobhy *et al.*,(2015)[71] a significant decrease in lipid peroxides level was recorded in rats pretreated with *Cyperus esculentus*. Biochemical parameters such as AST, ALT, ALP, creatinine, urea, triglyceride, glucose, total cholesterol, LDL and lipid peroxide (MDA) that were affected after injection of carbon tetrachloride (CCl_4) were found to be compared to the control. The results thus suggest that yellow nutsedge may possess natural antioxidants necessary for protection against CCl4-induced free radical damage in rat liver. The work of Onuoha *et al.* (2017),[72] showed that oral administration of yellow nutsedge milk prevents and ameliorates the hepatotoxic effects induced by Acetaminophen (2.5 g/kg). The hepatoprotective properties of tiger milk against the toxic effects of Acetaminophen (paracetamol) in rats were studied by Onuoha *et al.*, (2017).[72] This study showed decrease in AST, ALP, ALT, MDA and bilirubin compared to the negative control. However, the difference was insignificant as the valus were close to the normal control. These effects were dose dependent, correlated with the increase in the mass of tigernut milk given to the rats. SOD activity increased with increased tigernut milk mass. The dose of 2000 mg/kg was the most significant dose. Similar results on SOD was found by Olabiyi *et al.*, (2016).[39] According to Ihedioha *et al.*, (2019),[73] the effect of methanolic extract of *Cyperus esculentus* shows hepatoprotective properties against the effects caused by carbon tetrachloride injection on rats. This extract at different doses compared to 100 mg/kg Silymarin, resulted in a significant decrease ($p < 0.05$) in serum alanine aminotransferase and aspartate aminotransferase activities, bilirubin levels and relative liver weights of the tiger nut-treated groups compared to the negative control group rats. Significant protection of hepatocellular integrity, improvement of hepatic bilirubin excretion and improvement of CCl_4-induced inflammatory liver hypertrophy were noted. On this same impulse of research on the hepatoprotective properties of nutsedge tubers, Oyedepo and Odoje (2014).[74] sought to reduce the effects of CCl_4 injection in rats. Their diet was supplemented with 1%, 5% and 10% tiger nut meal. After 21 days of treatment, a reduction in the enzymes AST, ALT and ALP was noted and increased with increasing mass of meal and approached the level of the normal control. A significant decrease in the level of MDA, which is a product of lipid

peroxidation, was noted as the amount of *Cyperus esculentus* increased. Tiger nut aqueous extract is used to counter the action of Triton WR-1339 known for its toxic effects in the organism. Administration of this compound at a dose of 300mg/kg of body weight results in an increase in enzymes such as alanine and aspartate aminotranferase (ALT and AST) and a reduction in protein, albumin and globulin levels and an increase in conjugated bilirubin levels in serum. Administration of different doses of aqueous extract 300, 400 and 600 mg/kg of body weight for 29 days resulted in recovery of these enzymes and liver damage.[58]

4.7 Antiepileptic and Antifalciform properties

Tiger nut has antiepileptic properties. Thus, to study these effects, hydro-methanolic extracts of tiger nut were administered at different doses against pentylenetetrazole (PTZ)-induced seizures in mices. In PTZ administered mice, the methanolic extract shows a significant effect on the seizure induced by the increase of the latency time (time elapsed before the seizure after PTZ injection) and the reduction of the duration of the seizure compared to the positive control (administered by Sodium Valproate which is an antiepileptic) and the negative control (distilled water). The methanolic extract shows a significant anticonvulsant effect and superior to sodium valproate at the dose of 2000 mg/kg of body weight. This antiepileptic effect is due to the presence of secondary metabolites mainly alkaloids.[75] Methanolic and aqueous extracts at concentrations (100%, 50% and 20%) showed a pronounced anti-falciform activity (by inhibition of hemoglobin-S (HbS) gelation). The study revealed that after 10 minutes of incubation with crude extracts, the gelation of HbS was reduced from 100% to 48.21% and 82.14% for methanol and aqueous extracts respectively. Tiger nuts could be very beneficial for sickle cell subjects and could be exploited in the nutritional management of sickle cell disease.[4]

4.8 Anti-arthritic and anti-atherogenic properties

In their study on apolipoprotein E knockout status mice over a period of 11 weeks, Zommara and Imaizumi (2017)[37] showed that a 25% supplementation of nutsedge meal in the diet of the mice exhibits antiatherogenic effects by significantly reducing the development of atherosclerotic lesions. It was shown that tiger nut oil has interesting anti-arthritic properties compared to sodium diclofenac, a drug used to combat this anomaly. Under the treatment conditions, 0.1 mL of formaldehyde (2% v/v) is used in normal saline to induce the defect. Thus, a treatment of 500 mg/kg of nutsedge had more significant effects on reducing swelling compared with diclofenac sodium. At 10 days of treatment with tiger nut, the percentage of

inhibition reached 76.58% at the time when the maximum inhibition achieved by diclofenac sodium was 81.27% at day 21. This shows the effectiveness of nutsedge in the treatment of arthritis.[52] A reduction in the atherogenic index was found after 10 and 15% supplementation in the basal diet of rats made hypercholesterolemic compared to controls.[16]

4.9 Galactogenic properties

Tiger nut has long been considered to have galactogenic properties by West African populations. Research conducted by Ndiaye et al, (2018)[76] on laboratory mice showed significant changes in the mammary glands of the mice tested. These changes are identical to those caused by the product galactogyl known for its galactogenic effects.

CONCLUSION

This bibliographical study reveals that tubers in vitamins, minerals and bioactive compounds. Tiger nuts represent a real nutritional and therapeutic potential. It would be interesting that these tubers are used in the basic diet of the populations. It could contribute to the fight against micronutrient deficiencies and certain recurrent pathologies. Several industrial perspectives can be opened for the exploitation of its flour, in particular the preparation of tiger nut based couscous or bread which will allow its use on a large scale, and the introduction of its oil in certain products.

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