International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Al-haydawan. (*Boerhavia elegana Choisy*): Protective Properties against Metabolic Syndrome (A review)

Alanoud A. Alharbi[1], Waheeba E. Ahmed[1, 2 *], Sahar H.S. Mohamed[1]

[1]Department of Food Science and Human Nutrition, College of Agriculture and Food, Qassim University, 51452 Buraidah, Saudi Arabia.

[2]Department of Food Science and Technology, College of Agriculture, Alzaiem Alazhari University, Khartoum Bahri 13311, Sudan.

Abstract

Insulin resistance, obesity, high blood pressure, and dyslipidemia are some of the associated risk factors that contribute to metabolic syndrome, a prevalent complex health condition. Due to its high nutrient content and potential health benefits, eating food plants has gained attention recently as a potentially managed strategy and a way to prevent metabolic syndrome. One such plant is al-haydawan, a succulent that has a long history of traditional use in a variety of cuisines. Based on earlier research, the aim of this study is to elucidate the effects of al-haydawan on metabolic syndrome. Numerous studies have demonstrated that al-haydawan includes a high concentration of bioactive compounds, including calcium and flavonoids that have anti-inflammatory and antioxidant properties. Al-haydawan bioactive extracts efficiently lower body weight, body mass index (BMI), and fat mass—factors linked to osteoporosis and obesity. This aids in the management and prevention of metabolic syndrome. Improvements in blood pressure, blood glucose, and cholesterol levels have also been associated with steroid use. In animal studies, A-lhaydawan extracts have been demonstrated to improve lipid profiles, lower insulin resistance, and improve glucose and lipid metabolism. According to these findings, neutral might have a significant part in controlling metabolic risk factors. In conclusion, because of its abundant nutritional value and possible health advantages, Al-haydawan intake functions as a dietary approach to prevent and manage metabolic syndrome.

Keywords: Type 2 diabetes, metabolic syndrome, obesity, Boerhavia elegana Choisy

Full length article **Corresponding Author*, e-mail: waheeba2003@gmail.com. W.alfaki@qu.edu.sa**;* Doi # https://doi.org/10.62877/2-IJCBS-25-27-21-2

Submitted:01-01-2025; Accepted: 18-01-2025; Published: 20-01-2025

1. Introduction

In and of itself, metabolic syndrome is not a disease. Rather, it is a collection of risk factors for heart disease, stroke, and type 2 diabetes, including high blood pressure, high blood sugar triglycerides, and extra belly fat. Three or more of these risk factors are typically present for the diagnosis. According to [1], metabolic syndrome doubles the risk of atherosclerotic cardiovascular disease and five times the risk of type 2 diabetes. Globally, metabolic syndrome affects about 25% of adults [2]. (People with insulin resistance are frequently reported to have high blood pressure, and obesity and high blood pressure are strongly related. Impaired fasting blood glucose, which is defined as a level of 100 mg/dL or greater, is another factor. Furthermore, triglyceride levels exceeding 150 mg/dL and low HDL (good) cholesterol levels (less than 40 mg/dL for men and less than 50 mg/dL for women) are considered risk factors. If a person exhibits three or more of these symptoms, the NHLBI and AHA jointly advise diagnosing metabolic syndrome [3]. One of the complicated disorders where body fat mass rises dramatically is obesity. Obesity is a medical disorder that occasionally calls for surgery rather than being merely a cosmetic issue. Obesity and being overweight are two major outcomes of numerous chronic illnesses. A person is considered overweight if their Body Mass Index (BMI) is b/w 25 and 29.9, and obese if their BMI is 30 or more [4].

A series of excessive food intakes that result in energy intake exceeding consumption, excess caloric intake, and decreased caloric expenditure cause obesity, a multifactorial chronic disease, to develop in the human body [5]. The World Health Organization (WHO) reports that between 2000 and 2016, the prevalence of adult obesity in

Arab nations rose by 10.0 percentage points. The region's low- and middle-income countries saw the biggest increase among subgroups, rising by 10.6 percentage points, followed by high-income countries by 10.3 percentage points, low-income countries by 6.7 percentage points, and the least developed Arab countries by 5.7 percentage points [5-6]. Since many people are now aware of the risks and negative effects of obesity, many have resorted to diet and lifestyle changes to lower their risk of becoming obese. Many have also looked for fat-burning beverages, herbs, and medicinal plants, as well as healthy food options high in fiber and oxidation flashes, which enhance digestion lower obesity, and boost immunity. Among these plants is the Al-haydawan (*Boerhavia elegana Choisy*) plant, which is common throughout the Arab world, particularly in Yemen. It is used in traditional medicine as a flavoring for Yemeni porridge and has numerous significant health benefits, including the treatment of liver infections, urinary tract infections, and digestive disorders.

2. Plant Description

In Yemen, this plant grows after rain. It is known among Yemenis, particularly those in Hadhramaut, where it is milled to make flour, which is used to make the well-known Yemeni porridge. It is recognizable by its sweet-smelling, fennel-like seeds. [7], Reproductive Al-haydwan seeds are a member of the *Boerhavia genus*, which has numerous species. Mexico, America, Australia, Africa, and the Pacific Islands are just a few of the tropical, subtropical, and temperate locations where the genus *Boerhavia* is widely distributed. Nearly all of the forty species in the genus *Boerhavia* are found on gravel plains or rocky slopes in tropical and subtropical regions [8]. Al Haydawan seeds are little, fennel-like particles that have a pleasant scent and add a delicious taste to food, especially warm porridge meals with sesame oil. Plant-based substitutes for synthetic antioxidants in processed foods are becoming more and more popular as a result of growing public awareness of the artificial chemicals used as antioxidants in these meals. Figure 1. When wet, the fruits have a high percentage of mucilage, and the plant flowers from March to April [9].

3. The chemical content of the plant *Boerhavia elegans*

After a thorough evaluation of their chemical and nutritional makeup as well as their functional qualities, B. *elegans* seeds were determined to have a high nutritional value that might be used in the food business. [10-16] measured the approximate composition of Al-haydwan seeds and reported that the moisture content was 6.12%. At the same time, the amounts of ash, carbs, fiber, crude protein, and crude lipids were 14.6%, 11.49%, 36.13%, 6.88%, and 30.77%, respectively. They also found that the the protein content was greater than that of eggs and cereal crops. Additionally, they discovered that Al-haydwan seeds have a greater proportion of ash and fat. The seeds had a larger amount of fat than millet and corn. Large levels of minerals, which are more abundant than grains and animal meat, are reflected in the high percentage of ash. Furthermore, the concentration of essential amino acids in bellow seeds is comparable to that of whole wheat flour, with the exception of tryptophan. Additionally, because seeds have a larger proportion of calcium and potassium than other foods, they have been discovered to be a good natural source of these minerals. These minerals can be taken as supplements by youngsters, the elderly, and pregnant and lactating mothers. Iron and zinc were also discovered to be the highest concentrated elements.

4. Nutritional uses of Al-haydwan (*B.elegans*)

Additionally, seeds from *B.elegans* are a significant source of calories. Since calories are broken down during digestion, we know that they are a measure of energy. This energy is subsequently used by the cells to carry out a number of tasks, including the synthesis of proteins and other vital materials that the body requires [11]. Earlier research clearly shows the nutritional importance of Al-Hayadawan seeds. Additionally, these seeds can be used as a novel ingredient to increase the amount of fiber in a variety of products, especially dairy products. A study by Khaliq found that the chemical content of basil seeds is comparable to that of Al-Haydawan seeds [12-13], discovered that because carbohydrates provide more energy than lipids, total energy (calorie value) in fats, proteins, and carbs was 0.49, 0.99, and 0.58 calories/g, respectively. Al-haydwan is therefore regarded as a healthy calorie source. Energy that can be saved for later use measured in calories or consumed immediately, as is widely known. [11]. According to [14], protein content of Al-haydawan seeds is similar to that of quinoa seeds, but fiber and ash content is higher than that of chia seeds. Researchers discovered that consuming Al-haydwan for 4 weeks decreased constipation and increased frequency of defecation times, demonstrating that fiber also controls bowel movements and helps processes of defecation and excretion. Additionally, the anti-inflammatory chemical qualities aid in the treatment of irritable bowel syndrome and intestinal infections [13]. The study by [9] explores the fascinating antioxidant qualities of Choisy seeds from *Boerhavia elegana*. In addition to its usage as a food source, the research findings show that *Boerhavia elegana choisy* seeds have promise as a viable source of advantageous chemicals for the creation of protection against oxidative damage and dietary supplements. The oil's relative oxidative stability was high. The composition of the tocol revealed that the concentrations of higher levels of α-tocotrienol, γ-tocopherol, and γ-tocotrienol were observed. Of the seven phenolic acids identified, ascorbic acid was the most abundant (5.44 mg·100 g−1), followed by vanillic, galic, p-coumaric, ascorbic, cinnamic, and ferulic. There is currently a paucity of research on the utilization of Al-haydwan seeds in beverage applications, despite these encouraging nutritional qualities. The possibility of using Al-haydawan as the main raw material for the creation of reasonably priced and nutrient-dense functional foods was examined in an Al-Farga study. The physicochemical and cooking characteristics of Al-haydawan seed flour, an underutilized resource, were evaluated by the researchers. The results showed that Al-haydawan seed flour had a much greater water solubility index than some legume flours, suggesting that it may retain flavor and be used as a thickening or gelling agent in a variety of culinary products. Interestingly, no research has been done on the use of Al-hydawan seeds in milk or non-milk beverages as of yet. [10], also showed that the seed extract of *Boerhavia elegana Choisy* showed antioxidant activity by a number of methods, including the FRAP, carotene bleaching, and Fe2+ chelating assays; also, the DPPH and ABTS tests evaluated its potent free radical scavenging capabilities. [15] Found that there were no discernible negative effects on fetal

development in rats given a daily dosage of 250 mg/kg b.w. of ethanolic root extract throughout pregnancy. Similarly, using the brine shrimp (Artemia salina) toxicity test, [16] found that an 80% ethanol extract of aerial parts of *Boerhavia elegana* showed negligible toxicity, with an LD50 value of 1020 mg/ml. According to [17], the main parts of *Boerhavia* species used for phytochemical and pharmacological study are the leaves and roots. However, research into other elements including seeds, flowers, and stems is required in order to use these species successfully. All members of the Boerhavia genus require toxicity investigations, even though some reports dispute the toxicity of Boerhavia diffuse using different tests.

5. Medicinal uses of Al-haydawan B. *elegans* cytotoxic action

Two human cancer cell lines, PC3 (prostate cancer) and MCF7 (breast cancer), were used for B. elegans' first cytotoxicity screening. The findings showed that, in contrast to duxorubicin, which inhibited 100% cell growth at a dose of 10µg/ml, the aerial parts of this plant (50µg/ml) inhibited 0% PC3 cells. *B.elegans* (50µg/ml) demonstrated 15.14% inhibition on the MCF7 cell line in comparison to Duxorubicin (10µg/ml, 95% inhibition) [18].

6. The activity of antioxidants

The high concentration of phenolic compounds in B. elegans may be the cause of its antioxidant qualities. There was a considerable anti-malaria effect from this plant. Its antioxidant activity might be the cause of these qualities. The potential use of B. elegans as a natural antioxidant in food industries and other medicinal preparations is supported by its strong antioxidant activity. Research revealed that a variety of solvents may be used to extract the physiologically active components of B. elegans. To determine which metabolites are in charge of the crude methanolic extract's pharmacological effects, more research is required. The DPPH stable free radical method is the simplest way to evaluate an extract's or fraction's antioxidant activity [19]. The compound that demonstrated the highest DPPH radical scavenging activity was BPME. The extract/fractions other than phenolics and flavonoids may contain primary antioxidant compounds that can donate hydrogen to a free radical in order to remove the odd electron that causes the radical's reactivity, as indicated by weak correlation between the EC50 value of DPPH and the total phenolic and total flavonoid content. One of the most lethal oxidants that either directly or indirectly destroys biomolecules is superoxide anions [20-21]. The superoxide anions' EC50 value and the total phenolic and flavonoid content are strongly correlated, indicating critical function polyphenolics play in removing superoxide anions. Cellular components have been reported to be negatively impacted by superoxide anions [2022].

6.1. Inflammatory

Additionally, fiber facilitates better excretion and aids in digestion. Probiotics that protect the digestive system, boost immunity and lessen inflammation are supported and maintained by the Al-haydwan plant through several mechanisms. This is because it contains dietary fibers like inulin, which is a component of the chemical composition of fiber, as well as compounds with anti-inflammatory and antimicrobial qualities. Which is: Through the use of inulin, a bio stimulant that humans cannot digest but which probiotics eat to increase their development and survival in the intestines. Hydrangea's anti-inflammatory qualities can aid in lowering intestinal irritation, which improves the conditions for probiotic growth and action. Due to its antibacterial qualities, which can aid in the removal of dangerous germs from the intestines, propionic development and reproduction are facilitated [22].

6.2. Antimicrobial action

Many human pathogenic bacteria, including Bacillus cereus, Bacillus subtilis, Escherichia coli, Klebsiella sp., Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhi, Shigella sp., Staphylococcus aureus, and Yersinia enterocolitica, were found to be significantly inhibited by the aqueous and methanolic extracts of *B. elegans* at a 50µl concentration [23].

6.3. Anti-diabetic effects

The genus Boerhavia contained alkaloids, glycosides, saponins, tannins, flavonoids, and phenols. Previously, antidiabetic herbs found to contain flavonoids, tannins, glycosides, catechol, alkaloids, and organic sulfur compounds. It also stated that flavonoids improve insulin secretion by encouraging the proliferation of pancreatic β-cells, which may be mechanism by which they decreased streptozotocin-induced hyperglycemia in diabetic rats [24].

6.4. Hypolipidemic and anti-obesity properties

According to earlier research, changes in lipid metabolism brought on by decreased insulin secretion and insulin function abnormalities result in abnormalities of lipoproteins, which are typically seen in diabetes mellitus, and they also raise the risk of cardiovascular diseases linked to atherogenic dyslipidacy [25-26]. Reverse cholesterol transport is a mechanism that carries cholesterol from peripheral cells to liver, and HDL cholesterol thought to be a cardio protective lipid that is crucial to this process. A broad and varied class of bioactive polyphenolic chemicals present in plants are called flavonoids. According to their chemical structures, flavonoids can be categorized into 6 subclasses: isoflavones, flavones, flavanols, flavanones, anthocyanins, and flavan-3-ols [27]. (Flavonoids and their metabolites have been used in some studies in recent years to prevent and treat a wide range of illness, including as cancer, obesity, diabetes mellitus, hypertension, hyperlipidemia, & cardiovascular disease [28]. This research suggests that the Boerhavia elegana flavonoids contribute to the hypolipidemia. Many pharmacological compounds are used as the anti-obesity medications, but they frequently have negative side effects. As a result the use of natural derivatives to treat obesity has increased, especially in many Asian nations [29]. Many organic resources, such as unpolished plant extracts and separated contaminants, have been used to reduce diet and fight obesity. Obesity and diabetes have a complex relationship; they frequently coexist and have an impact on one another. Numerous bioactive substances, including lignans, alkaloids, flavonoids, and steroids, are abundant in *B. diffusa* and lower blood glucose levels while regulating lipid profiles [30]. The chemical makeup of the *Boerhavia diffusa* and another the *Boerhavia* species is comparable. The presence of numerous phytochemical components in *B. diffusa* has been found to have a considerable anti-obesity

effect on obese rats, according to a study [30]. All things considered, the endocannabinoids are the orexogenic and seem to be important for the systems that control food and the body weight.

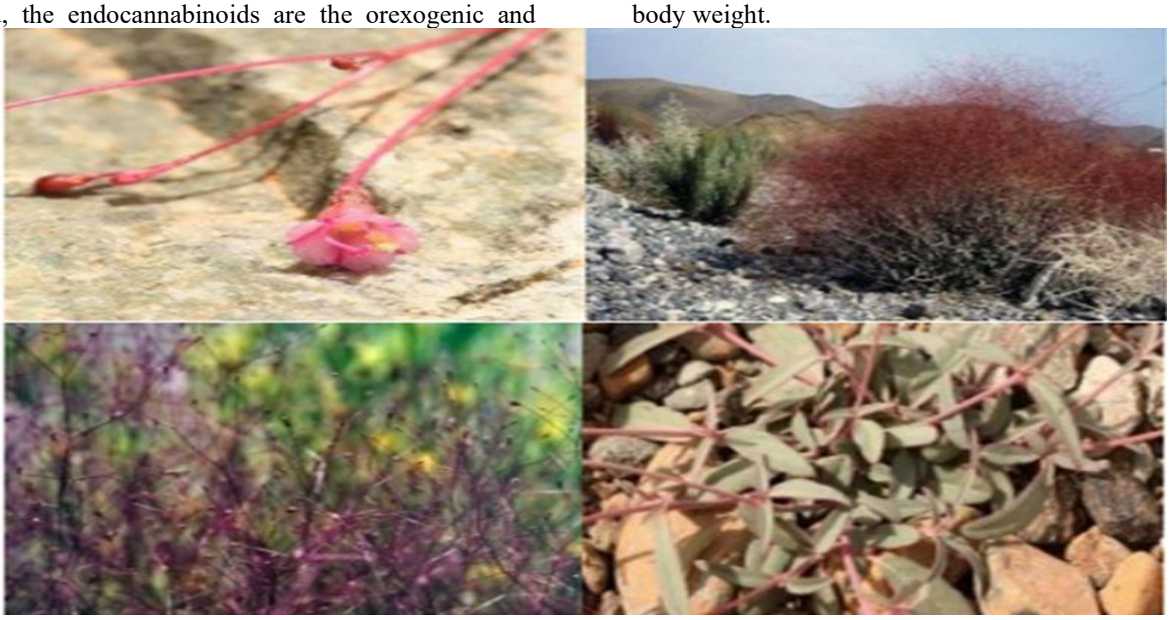

Fig.1. *B. elegans*: Flowers, Shrubs and leaf

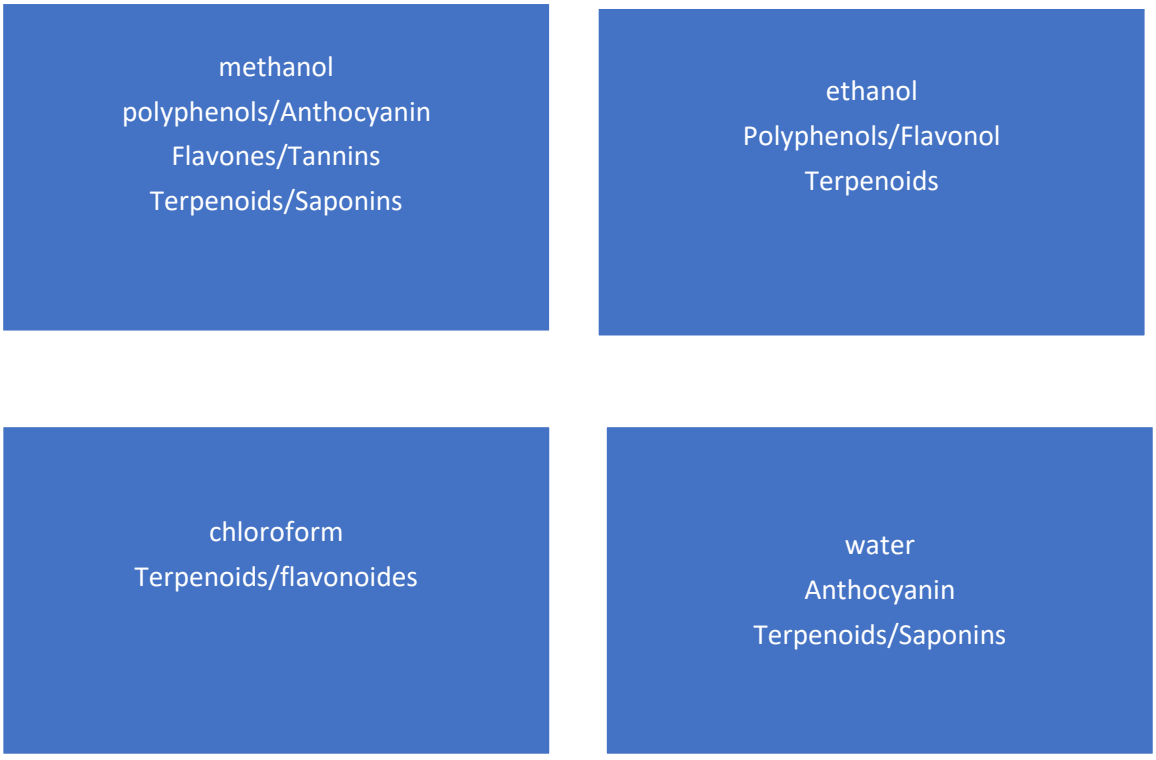

Fig.2. Some Phytochemical content is extracted with different solvents [28].

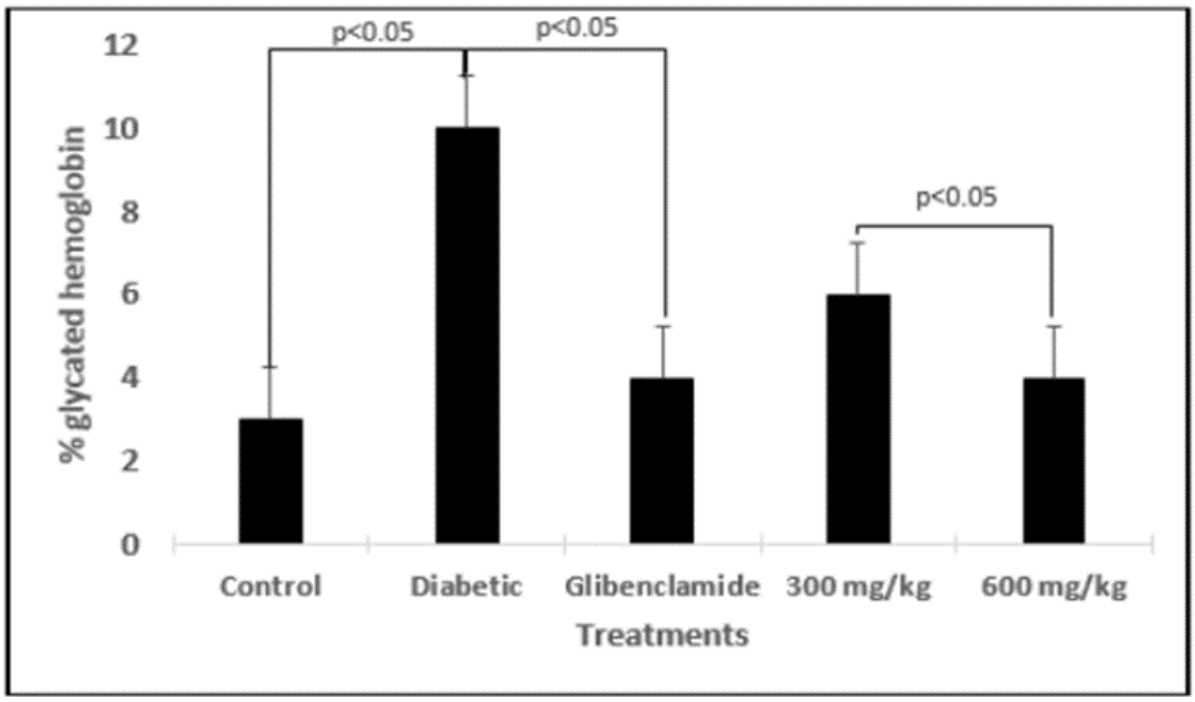

Fig. 3. Glycated hemoglobin levels in control and diabetic rats, treated or not with a Methanol fraction of steam leaves of Boerhavia diffuse for 4 weeks. Mean +SED. Significant difference ($p < 0.0\ 5$). [26] (Petrus et al., 2012).

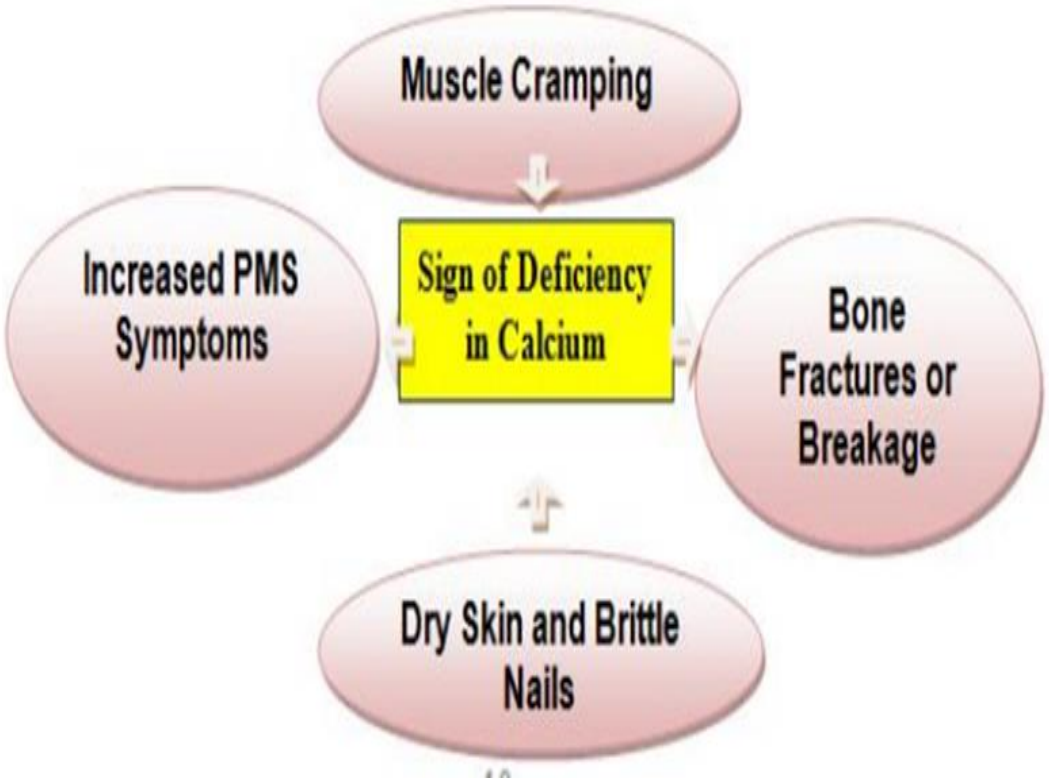

Fig. 4. Calcium deficiency health problems [31].

Our research also shows that *B. diffusa's* drinking water component inhibits the cannabinoid receptor, which has a definite anti-obesity impact on obese rats fed a high-fat diet. The phytoconstituent sitosterol is structurally similar to cholesterol and has been found to reduce cholesterol levels in plasma. HFD administration raised serum TG, TC, and LDL-C levels while decreasing HDL-C. High TC, TG, and LDL levels increase CVD risk [32]. The lipid profile may also be influenced by gastric lipase activation, intestinal fat absorption, and lipolysis. The researcher discovered that on a high-fat diet, the Wt.-F of *B. diffusa* extract (200 mg/kg) significantly decreased TC, HDL, VLDL, TG, and LDL levels ($p < 0.01$) compared to group animals with no HFD. Insulin resistance, increased adipose fat mobilization, and decreased hepatic and muscle glucose absorption are the causes of hyperlipidemia. Rats' lipid profile was improved when HFD was added to their plasma. A previous study stated that flavonoids improve insulin secretion by encouraging the proliferation of pancreatic β-cells, which may be the mechanism by which they decreased streptozotocin-induced hyperglycemia in diabetic rats. Therefore, the flavonoids, tannins, and glycosides found in B. erect extract may be responsible for the extract's anti diabetic action [33]. The body requires large amounts of the mineral calcium.

About 99% of the calcium in the body is stored in the bones and teeth, making it vital for bone health. The body uses the remaining 1% for several important processes. Muscle contraction and relaxation depend on calcium, among other aspects of muscle function. Additionally, it aids in blood coagulation, hormone and enzyme secretion, nerve impulse transmission, and more. Additionally, calcium is essential for cell communication and signaling. It aids in pulse regulation, blood pressure maintenance, and pH balance in the body [34]. [35], conducted that about thirty active bioactive components have been found in the methanolic extract of the choisy plant (Boerhavia), indicating that the plant may have medicinal use. Numerous functional groups, including, nitrogenous compounds, alkenes, [9] demonstrated that Boerhavia seeds can be used as a source of health compounds for the development of nutritional supplements and protection against oxidative stress in addition to their use for food consumption. These findings are especially pertinent to understanding the plant's potential for treating a variety of diseases & contribute to a broader knowledge of biochemistry of halophytes and their applications in diverse fields. An investigation of the chemical, nutritional, and functional characteristics of the Al-haydawan seeds flour was carried out by [13].

Additionally, the study found that Al-haydawan seed flour is nutrient-dense due to its high content of dietary fiber, protein, raw fats, carbs, and ash. These findings demonstrate flour's potential as a nutrient-dense food element. Large quantities of vital minerals and amino acids are also included in flour, which is advantageous for a number of body processes. [36] Used GC-MS to identify the active components in a study on the chemical analysis of the Al-haydawan plant, flavonoids and saturated fats were the two most significant active ingredients in Al-haydawan and their ratios. The extracted compounds' chemical content and their respective applications were categorized. [37] Investigated that minerals are essential parts of our diet, they serve a wide range of purposes, including supplying the building blocks for our bones, affecting the function of muscles and nerves, and controlling the water balance in the body. In addition, they are parts of enzymes, hormones, and other substances that have biological activity, additionally, certain minerals are crucial for the immune system's efficient operation, this pertains to both the adaptive immune response and the innate defensive system. Accordingly, the mineral supply affects the development of chronic diseases as well as an individual's vulnerability to infections. According to study, [38] mention that therapeutic plants have a high mineral and phytochemical content, numerous potentials use for medicinal plants exist in production of novel pharmaceuticals, nutraceuticals, and medical supplies.

Numerous pharmacologically active phytochemicals found in medicinal plants have been used to treat a range of illnesses. Based on the information above, we can say that Al-haydwan seed flour is a great source of dietary fiber, carbs, uncooked protein, and other nutrients. Another alternative source of dietary fiber is al-haydwan seed flour. The important minerals (calcium, potassium, magnesium, sodium, iron, and zinc) are present in adequate proportions. Furthermore, it has comparatively high protein content and the majority of necessary amino acids, which are comparable to those in whole wheat flour. Fiber also promotes healthy flora and helps digestion, which lowers the risk of obesity and digestive disorders. Isoflavones, are thought to be effective in lowering blood fat levels. The chemical composition of the herb, which is rich in phenols and flavonoids, enhances its medicinal importance as an antioxidant, eliminating free radicals, and anti-inflammatory [39]. Zinc and iron were found to be the most concentrated trace elements within these seeds. By encouraging the growth of pancreatic β-cells, flavonoids improve insulin secretion, which may be the mechanism by which they lessened streptozotocin-induced hyperglycemia in diabetic rats [40].

4. Conclusions

The compounds found in the al-haydwan plant may make it a treasure, but more research and investigation are needed, the plant also needs to be better cultivated and its growing conditions understood in order to be used commercially in the production of medical extracts and medicines its therapeutic efficacy is influenced by lipid metabolism and antioxidant substances. The precise characteristics, dosage, and interactions of Al-haydwan and its active ingredients require more investigation, all things considered, Al-haydwan can be regarded as a natural substitute for treatment and prevention of various illnesses, especially when it comes to reducing inflammation and enhancing patients' lipid profiles. Waheeba E. Ahmed: https: //orcid.org/0000-0003-2776-1347.

Author Contributions: Conceptualization, methodology, and investigation, W.E.A. and A.A.A.; data curation, W.E.A. and A.A.A.; formal analysis, A.A.A. and W.E.A.; writing—original draft preparation, W.E. A and A.A.A.; review and editing, S. H.A. A.A.A. and W.E.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. Data Availability Statement: Data are contained within the article.

Acknowledgments: The researchers would like to thank the Deanship of Scientific Research, Qassim University for funding the publication of this project.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

HFD: High fat dietary
TG: Triglyceride
TC: Total cholesterol
LDL-C: Low density level lipoprotein -cholesterol
HDL-C. High density level lipoprotein -cholesterol
CVD: cardio vascular disease.
NHLBI: National Heart Lung and Blood Institute
AHA: American Heart Association

References

[1] S.M. Grundy. (2016). Metabolic syndrome update. Trends in cardiovascular medicine. 26(4): 364-373.

[2] M.G. Saklayen. (2018). The global epidemic of the metabolic syndrome. Current hypertension reports. 20(2): 12.

[3] D.C. Goff Jr, D.B. Buxton, G.D. Pearson, G.S. Wei, T.E. Gosselin, E.A. Addou, C.M. Stoney, P. Desvigne-Nickens, P.R. Srinivas, Z.S. Galis. (2019). Implementing the national heart, lung, and blood institute's strategic vision in the division of cardiovascular sciences. Circulation research. 124(4): 491-497.

[4] World Health Organization. (2020). Obesity and overweight.Retrievedfromhttps://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

[5] Y.C. Chooi, C. Ding, F. Magkos. (2019). The epidemiology of obesity. Metabolism. 92(1): 6-10.

[6] E.A. Noorwali, A.M. Aljaadi, H.H. Al-Otaibi. (2023). In Change in growth status and obesity rates among Saudi children and adolescents is partially attributed to discrepancies in definitions used: a review of anthropometric measurements. Healthcare. MDPI: 1010.

[7] I. Hehmeyer, H. Schönig. (2012). Herbal medicine in Yemen: traditional knowledge and practice, and their value for today's world. Brill.

[8] R. Spellenberg. (2012). Boerhavia. In: Flora of North America Editorial Committee, Flora of North America. 4: 17-28. Oxford Univ. Press. New York. USA.

[9] A.-F. Ammar, H. Zhang, A. Siddeeg. (2014). In vitro antioxidant activity and total phenolic and flavonoid contents of Alhydwan (Boerhavia elegana Choisy) seeds. J Food Nutr Res. 2: 215-220.

[10] A. Al-Farga, H. Zhang, A. Siddeeg, M. Chamba, Q. Nabil. (2015). Physicochemical properties, phenolic acids and volatile compounds of oil extracted from dry alhydwan (Boerhavia elegana Choisy) seeds. Grasas Y Aceites. 66(3): e090-e090.

[11] R.L. Duyff. (2006). American dietetic association complete food and nutrition guide. John Wiley & Sons Hoboken.

[12] R. Khaliq, O. Tita, C.S. Sava. (2017). A comparative study between seeds of sweet basil and psyllium on the basis of proximate analysis. Scientific Papers Series : Management, Economic Engineering in Agriculture and Rural Development. 17: 189-194.

[13] A. Al-Farga, H. Zhang, M. Chamba, A. Siddeeg, T. Rabie, M. Obadi, N.Q.M. Al-Hajj, H. Hassanin, R. Thabit, M. Rashed. (2016). Physicochemical and Cooking Properties of a Novel Food: Alhydwan (Boerhavia elegana Choisy) Seed Flour. Journal of Academia and Industrial Research.

[14] M. Knez Hrnčič, M. Ivanovski, D. Cör, Ž. Knez. (2019). Chia Seeds (Salvia hispanica L.): An overview—Phytochemical profile, isolation methods, and application. Molecules. 25(1): 11.

[15] S. Suresh, E. Prithiviraj, S. Prakash. (2009). Dose- and time-dependent effects of ethanolic extract of Mucuna pruriens Linn. seed on sexual behaviour of normal male rats. Journal of Ethnopharmacology. 122(3): 497-501.

[16] A. Ramazani, S. Zakeri, S. Sardari, N. Khodakarim, N.D. Djadidt. (2010). In vitro and in vivo anti-malarial activity of Boerhavia elegans and Solanum surattense. Malaria Journal. 9(1): 124.

[17] K.S. Patil, S.R. Bhalsing. (2015). Efficient micropropagation and assessment of genetic fidelity of Boerhaavia diffusa L-High trade medicinal plant. Physiology and molecular biology of plants. 21: 425-432.

[18] Z. Sadeghi, J. Valizadeh, O.A. Shermeh, M. Akaberi. (2015). Antioxidant activity and total phenolic content of Boerhavia elegans (choisy) grown in Baluchestan, Iran. Avicenna journal of phytomedicine. 5(1): 1.

[19] I.I. Koleva, H.A. Niederländer, T.A. van Beek. (2000). An on-line HPLC method for detection of radical scavenging compounds in complex mixtures. Analytical Chemistry. 72(10): 2323-2328.

[20] J. Bokhari, M.R. Khan, M. Shabbir, U. Rashid, S. Jan, J.A. Zai. (2013). Evaluation of diverse antioxidant activities of Galium aparine. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 102: 24-29.

[21] R.A. Khan, M.R. Khan, S. Sahreen, M. Ahmed. (2012). Assessment of flavonoids contents and in vitro antioxidant activity of Launaea procumbens. Chemistry Central Journal. 6(1): 43.

[22] Y. Wang, Q. Xie, Y. Zhang, W. Ma, K. Ning, J.-Y. Xiang, J. Cui, H. Xiang. (2020). Combination of probiotics with different functions alleviate DSS-induced colitis by regulating intestinal microbiota, IL-10, and barrier function. Applied microbiology and biotechnology. 104: 335-349.

[23] H. Girish, S. Satish. (2008). Antibacterial activity of important medicinal plants on human pathogenic bacteria-a comparative analysis. World Applied Sciences Journal. 5(3): 267-271.

[24] D. Malhotra, F. Ishaq, A. Khan. (2014). Antihyperglycemic activity of Boerhaavia diffusa in streptozotocin induced diabetic rats. Int. J. Chem. Anal. Sci. 5(1): 21-23.

[25] M. Nisha, B.N. Vinod, C. Sunil. (2018). Evaluation of Boerhavia erecta L. for potential antidiabetic and antihyperlipidemic activities in streptozotocin-

induced diabetic Wistar rats. Future Journal of Pharmaceutical Sciences. 4(2): 150-155.

[26] A. Patil, S. Nirmal, S. Pattan, V. Tambe, M. Tare. (2012). Antidiabetic effect of polyherbal combinations in STZ induced diabetes involve inhibition of α-amylase and α-glucosidase with amelioration of lipid profile. Phytopharmacology. 2(1): 46-57.

[27] C. Manach, A. Scalbert, C. Morand, C. Rémésy, L. Jiménez. (2004). Polyphenols: food sources and bioavailability. The American journal of clinical nutrition. 79(5): 727-747.

[28] S. Kumar, A.K. Pandey. (2013). Chemistry and biological activities of flavonoids: an overview. The scientific world journal. 2013(1): 1-16.

[29] S. Hasani-Ranjbar, Z. Jouyandeh, M. Abdollahi. (2013). A systematic review of anti-obesity medicinal plants-an update. Journal of Diabetes & Metabolic Disorders. 2013: 1-16.

[30] M. Khalid, M.H. Alqarni, A. Shoaib, S. Wahab, A.I. Foudah, T.M. Aljarba, J. Akhtar, M.A. Alamri, S. Ahmad. (2022). Anti-Obesity action of Boerhavia diffusa in rats against high-Fat diet-induced obesity by blocking the cannabinoid receptors. Plants. 11(9): 1158.

[31] P. Piste, D. Sayaji and M. Avinash
Int J Res Pharm Biomed Sci 2012 Vol. 4 Pages 2229-3701

[32] A.R. Saltiel, C.R. Kahn. (2001). Insulin signalling and the regulation of glucose and lipid metabolism. Nature. 414(6865): 799-806.

[33] M. Chude, O. Orisakwe, O. Afonne, K. Gamaniel, O. Vongtau, E. Obi. (2001). Hypoglycaemic effect of the aqueous extract of Boerhavia diffusa leaves. Indian Journal of Pharmacology. 33(3): 215-216.

[34] J. Ma, R.A. Johns. (2007). Role of calcium in hormone secretion, enzyme activity, and cellular signaling: Implications for heart health, blood pressure regulation, and pH balance

[35] M.B. Hossain, A. Patras, C. Barry-Ryan, A.B. Martin-Diana, N.P. Brunton. (2011). Application of principal component and hierarchical cluster analysis to classify different spices based on in vitro antioxidant activity and individual polyphenolic antioxidant compounds. Journal of Functional Foods. 3(3): 179-189.

[36] T.M. ALRaddadi, S.O. Bahaffi, L.A. Alkhateeb, M.W. Sadaka. (2024). Analysis of bioactive compounds present in Boerhavia elegans seeds by GC-MS. Open Chemistry. 22(1): 20240068.

[37] P.C. Calder. (2020). Nutrition, immunity and COVID-19. BMJ nutrition, prevention & health. 3(1): 74.

[38] Radha, M. Kumar, S. Puri, A. Pundir, S.P. Bangar, S. Changan, P. Choudhary, E. Parameswari, A. Alhariri, M.K. Samota. (2021). Evaluation of nutritional, phytochemical, and mineral composition of selected medicinal plants for therapeutic uses from cold desert of Western Himalaya. Plants. 10(7): 1429.

[39] A. Kumar, A. Kaur, V. Tomer, P. Rasane, K. Gupta. (2020). Development of nutricereals and milk-based beverage: Process optimization and validation of improved nutritional properties. Journal of food process engineering. 43(1): e13025.

[40] K. Rao. (2004). Flavonoids promote pancreatic β-cell proliferation and reduce hyperglycemia in diabetic rats.