



The antidiabetic profile of okra (*Abelmoschus esculentus*): a comprehensive review

Meriem Tebani ^{a,c *}, Badra Barhouchi ^b, Hadil Benkorchia ^a, Kaouther Chemli ^a

^a Higher National School of Biotechnology, Constantine 25000, Algeria.

^b Pharmaceutical Sciences Research Center (CRSP), Constantine 25000, Algeria.

^c Laboratory of Applied Organic Chemistry, Chemistry Department, Faculty of Sciences, Badji Mokhtar University, P.O. Box 12, 23000 Annaba, Algeria

Abstract

Okra, also known as the lady's finger. It is rich in vitamins, polyphenols, flavonoids and polysaccharides, which provide antioxidant effects and various health benefits. Recent studies suggest that okra is an effective agent in reducing blood sugar levels, making it a major food for controlling diseases such as diabetes. Okra has several properties that make it an anti-diabetic agent; it promotes the division of liver and pancreas cells, improves insulin sensitivity, and increases glucose absorption by cells. In addition, it acts as an alpha-glucosidase inhibitor as it can trigger glycogen synthesis, and cause an increase in insulin secretion. The aim of this review is to epitomize recent studies on the diabetic potential of okra species (*Abelmoschus esculentus*) and highlights future areas of research on their medical applications.

Keywords:

Abelmoschus esculentus, Diabetes, Anti-diabetic, Insulin.

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*Corresponding author

Email address: tebani.meriem@yahoo.fr (Meriem Tebani)

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1. Introduction

Gumbo or lady finger are other names for okra. This plant has well-established health advantages. It is high in flavonoids like quercetin and rich in polyphenols like procyanadin, rutin, epigallocatechin, and catechin, as well as vitamins like tocopherol, niacin, riboflavin, and ascorbic acid. It additionally contains polysaccharides such as hemicellulose and pectin. Antioxidant properties of this plant include anti-fatigue, antidiabetic, neuroprotective, radical-scavenging, and antihyperlipidemic properties. The plant can scavenge radicals in both the liquid and aqueous phases thanks to its lipophilic and hydrophilic antioxidant components [1][2].

Okra has a number of nutritionally significant ingredients, including fiber, protein, fat, and polyphenolic chemicals. All of these ingredients are important for enhancing the body's general health and mitigating the negative consequences of diabetes. Okra is frequently consumed by humans. In some regions, the okra plant's leaves are also used as food [2].

Okra is known as a "super food" because of its ability to manage conditions like diabetes. Known scientifically as *Abelmoschus esculentus* or *Hibiscus esculentus*, but most people just call it ladyfinger. According to recent studies, okra is a key meal for decreasing blood glucose levels, both *in vitro* and *in vivo*. Actually, studies from several nations have demonstrated that okra works well to lower blood sugar. Following a detailed analysis of the okra plant's composition, it was discovered that the insoluble fiber that makes up okra significantly contributes to lowering blood glucose levels by reducing the rate at which glucose is absorbed from the digestive tract [2][3].

Additionally, okra helps prevent blood sugar rises that occur after meals. This results from its advantageous impact on the pace at which body cells absorb blood glucose. The efficient uptake of glucose by bodily cells contributes to a reduction in blood glucose levels, improving blood glucose regulation and control of diabetes [2][4].

2. Okra (*Abelmoschus esculentus*)

2.1. Description

The plant *Abelmoschus esculentus* L. is commonly referred to as lady finger or okra. It is classified as part of the Malvaceae family, is native to Africa, and is grown throughout the continent in tropical, subtropical, and warm temperate areas, as well as in Southern Europe, America, and Asia.

Okra is a crop with significant economic importance in the world's subtropical regions. It originated in Ethiopia and spread to North Africa, the Mediterranean, Arabia, and India [1]. Okra fruit is rich in nutrient-dense, and an excellent source of vitamins and minerals. Okra contains mostly carbohydrates as mucilage, which is widely used in a variety of industrial applications as well as in medicine. Okra's fruits, seeds, and leaves have uses because of its makeup and characteristics [2].

2.2. History of okra

One of the earliest crops to be cultivated worldwide is okra. While the exact origins of okra are unclear, it is believed to have originated in the regions of Ethiopia and Sudan. It has a long history of cultivation and consumption in many cultures such as ancient Egypt in 1216 A.D. (**Figure 1**), where it was highly valued for its edible pods and seeds. It then made its way to the Middle East, Asia and Europe through trade routes. Arab traders introduced okra to India, whereas the slave trade played a significant role in spreading okra to America. Today, okra is cultivated in many countries around the world. Its versatility, nutritional value and unique texture continue to make it a popular ingredient in different culinary traditions globally [3] [4].



Fig. 1. Egyptian use of okra [5].

2.3. Botanical description of okra

The okra plant has many of important characteristics:

- **Roots:** Okra plants absorb nutrients and water more easily thanks to their taproot system and lateral roots.
- **Stem:** Okra plants have stout stems that maintain their leaves, flowers, and fruit as they grow, eventually having a woody base.
- **Leaves:** Large, lobed okra leaves are essential to photosynthesis, which is the process by which sunlight is converted into energy.
- **Flowers:** Okra plants produce showy and yellow flowers that are pollinated by insects, primarily bees (Figure 3).
- **Fruit:** The fruit is a structure that resembles a capsule and stretches out to become the delicious okra pod. The green, ribbed pod has a maximum length of several inches. It has several seeds encased in a gelatinous material. When the pod is still juvenile, it is picked because as it ages, it becomes fibrous and tough (Figure 2).
- **Photosynthesis:** Okra plants use chlorophyll in their leaves to convert sunlight, carbon dioxide and water into energy.
- **Transpiration:** Through their stomates, Okra plants produce water vapor, which helps control temperature and nutrient intake.
- **Reproduction:** Okra plants generate fruit pods with seeds inside of them after they bloom, which is how they reproduce sexually. Following successful pollination, the blooms mature into seed-containing fruit pods. It is possible to gather and sow these seeds for future growing seasons in order to propagate them [6][7][8].



Fig. 2. Okra pods [7].



Fig. 3. Okra flower [8]

2.4. Beneficial healthy properties of the okra mucilage

Okra mucilage is a mixture of natural polysaccharides containing D-galactose, L-rhamnose, and galacturonic acid, (1-2)-rhamnose and (1-4)-galacturonic acid residues with disaccharide side chains and a degree of acetylation (DA = 58) were discovered to be the repeating units of the gum (**Figure 4**) [9].

Studies published *in vivo* and *in vitro* have demonstrated the health benefits of okra mucilage, including its anticancer, antioxidant, antibacterial, hypoglycemic, and antiulcerogenic qualities. It also possesses the potential to bind bile acids and cholesterol, which helps with liver detoxification and regulates variables linked to type 2 diabetes.

The improvement in lipid profile, blood glucose levels and glycated hemoglobin values serves as an indicator of the formulation's effectiveness as a potent antidiabetic agent [10].

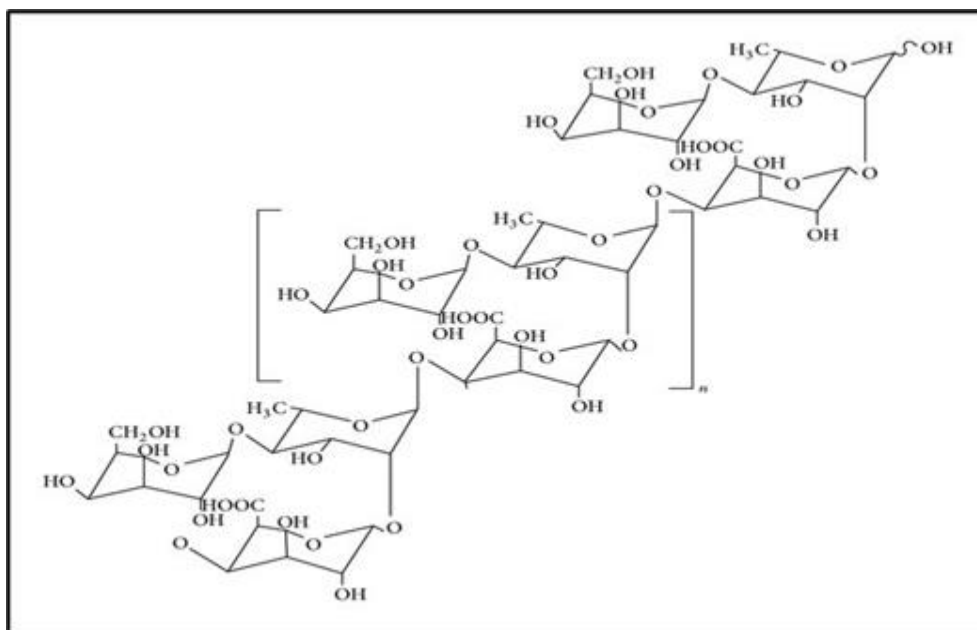


Fig. 4. Chemical structure of polysaccharide of Okra mucilage [7].

Okra mucilage's natural polysaccharides have strong antioxidant properties which protect cells from oxidative stress brought on by reactive oxygen species. Additionally, they can raise SOD levels, which support antioxidant processes and lessen the risk of beta cell damage from lipid peroxidation [1].

2.5. Nutritional and bioactive compounds

Here are some key nutritional components and bioactive compounds found in okra:

Okra seeds are a potential source of oil, with concentrations ranging from 20% to 40%, depending on the extraction method. "Okra" seed oil is a rich source of linoleic acid (up to 47.4%), a polyunsaturated fatty acid essential for human nutrition [11][12].

- **Dietary Fiber:** Okra is a rich source of dietary fiber, soluble and insoluble fiber, and a unique protein balance of tryptophan and lysine. Consequently, it supports digestive health. Compared to other plant protein sources, okra seed has a higher concentration of high-quality protein, particularly when it comes to important amino acids. Consequently, it is essential to human nutrition [13].
- **Vitamins and Minerals:** Okra contains various vitamins and minerals, including vitamin C, vitamin A, vitamin K, folate, and potassium [14].
- **Antioxidants:** Flavonoids, phenolic compounds, and vitamin C are examples of nutrients rich in antioxidants found in okra. By scavenging dangerous free radicals from the body, these antioxidants help lower oxidative stress [15].

- **Polyphenols:** Quercetin, epicatechins, and other polyphenolic substances are found in okra. These substances help prevent chronic disease because of their anti-inflammatory and antioxidant qualities [16].
- **Lectins:** Lectins are proteins found in okra that have been researched for possible impacts on cancer cells. Okra lectins have been shown to inhibit the growth of several cancer cell types, but more research is required to completely understand their mechanisms and their uses [17][18].

It is important to remember that okra's nutrient makeup and bioactive chemicals might change based on age, variety, and cooking techniques, among other things. It is advised to eat okra by steaming, stir-frying, or gently heating it to maintain its nutrients in order to get the maximum nutritional benefits [1].

3. Diabetes

Chronic hyperglycemia is an indicator of diabetes, a long-term metabolic illness caused by either an inefficient pancreas that produces insufficient insulin or a body that cannot utilize the insulin that is generated and there are 3 types of diabetes [19].

- Type one diabetes is an autoimmune condition in which the pancreatic beta cells, which produce insulin, are attacked by the immune system. Insulin production is hampered by the death or destruction of beta cells, which leads to persistently elevated blood sugar levels [1][5][19].
- Insulin resistance and a progressive decrease in the pancreas' ability to produce insulin combine to form the complex condition known as type 2 diabetes [20].
- Women who have never had diabetes before can acquire gestational diabetes during pregnancy. The pathophysiology of it is explained in general here [21][22].

3.1. Diabetes traitement

Blood Glucose control is Self-monitoring, frequent fasting, and the use of medication, such as glycated hemoglobin (HbA1c) as a marker for long-term management, are all part of the treatment plan for diabetes. The ultimate goal is to maintain normal blood glucose levels. This includes using insulin or other prescription drugs, maintaining a healthy weight, exercising, and eating a balanced diet.

Healthy Lifestyle: Maintaining a healthy lifestyle, which includes a balanced diet, frequent exercise, controlling weight, abstaining from tobacco and excessive alcohol use, is essential for managing diabetes.

Medication: Medications, such as oral antidiabetic drugs and insulin, may be prescribed to control blood sugar levels based on the type and severity of diabetes.

Frequent Medical Follow-up: Follow-up visits are crucial for tracking the efficacy of treatments, modifying dosages, identifying side effects, and evaluating general health through additional testing [23][24].

4. Mechanism of okra in diabetes

Okra has the potential to prevent diabetes due to a number of factors, including its ability to boost cell uptake of glucose, decrease lipid peroxidation, improve insulin sensitivity, and stimulate the proliferation of liver and pancreatic cells. It also functions as a-glucosidase inhibitor [25].

4.1. Antioxidant activity and flavonoid compounds

Okra's polysaccharides constituents are responsible to maintain blood glucose level in normal range through controlling sugar absorption from the small intestine. *Abelmoschus esculentus* possesses several components such as Kaempferol, Myricetin, Oleanolic acid and *Béta Sistostenol*, altogether these substances play a role in controlling diabetes.

- Myricetin

One type of plant pigment recognized for its antioxidant qualities is called a flavonoid, and myricetin is one of them. It has been linked to a number of health advantages, including reducing inflammation and fending off

some forms of cancer. It may be found in a wide variety of fruits and vegetables, including okra. Myricetin's antioxidant action and capacity to scavenge free radicals are what protect it against diabetes [7][26].

Figure 5 shows the supplement of myricetin sold in markets while figure 6 shows the chemical structure of myricetin.



Fig. 5. Myricetin supplement [26].

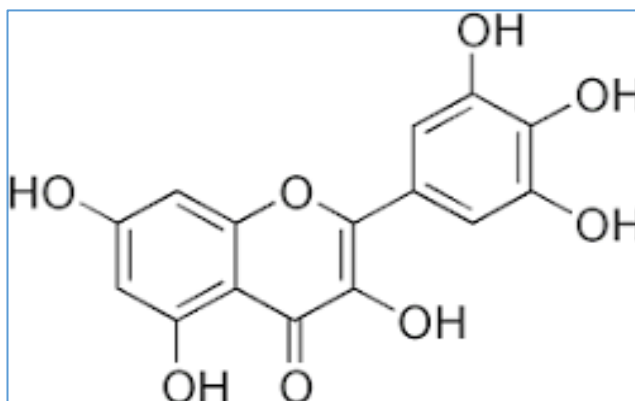


Fig. 6. Chemical structure of myricetin [7].

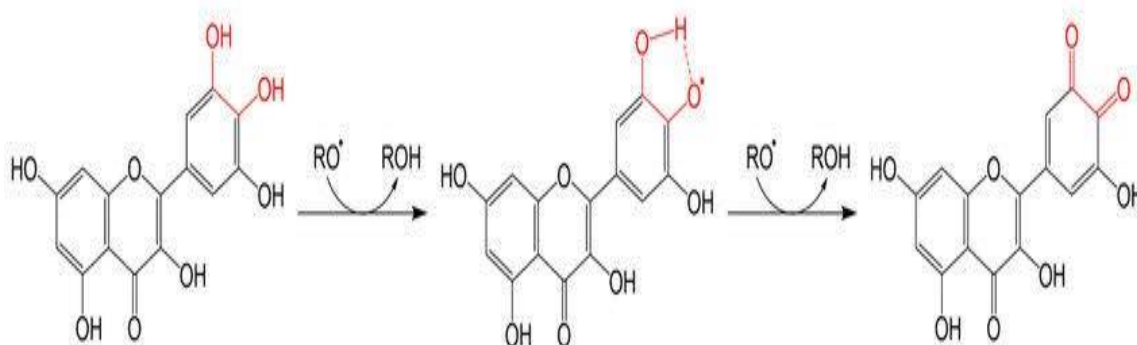


Fig. 7. Myricetin neutralizing free radicals, scavenging of ROS by flavonoids [27].

It is well known that the fruit of the okra plant stimulates the synthesis of glycogen and decreases the rate at which intestinal glucose is absorbed. These results demonstrate the complexity of the multidirectional mechanisms by which okra fruit controls diabetes. These mechanisms may include delayed glucose absorption, increased glycogenesis, and pancreatic cell regeneration, which raise insulin secretion. These in turn help manage diabetes mellitus's pre-prandial hyperglycaemia [20].

- Okra fiber

There are various types of polysaccharides found in okra. One such form is pectin, a soluble fiber that has been shown to enhance digestion and decrease cholesterol. Insoluble fibers like cellulose and hemicellulose can help facilitate digestion and increase fullness. Okra is a fantastic source of dietary fiber, which is necessary for optimum health and helps to control blood sugar levels by controlling the rate at which sugar leaves the digestive system [28-29].

- Inhibition of LXR and PPAR signaling

Okra polysaccharide has been shown to efficiently block LXR and PPAR signaling, which has a therapeutic impact on metabolic diseases such as diabetes. Members of the nuclear receptor superfamily, the lipid-activated transcription factors PPAR (PPAR α , β/δ , γ) and LXR play a crucial role in controlling lipid homeostasis and metabolic disorders [30].

- Inhibition of alpha-amylase and alpha-glucosidase

Because it slows down digestion and the absorption of carbohydrates, inhibiting alpha-amylase and alpha-glucosidase helps control diabetes by preventing a sharp rise in blood glucose levels after meals. By inhibiting these enzymes, postprandial hyperglycaemia (high blood sugar after a meal) is prevented by reducing the quantity of glucose released from carbohydrates and, consequently, the amount of glucose that enters the bloodstream.

This approach works especially well in patients with type 2 diabetes since the disease impairs the body's response to the hormone insulin, which controls blood sugar levels. As part of a comprehensive diabetes care strategy, alpha-amylase and alpha-glucosidase inhibition is frequently used in conjunction with other treatments, such as medication and lifestyle modifications. The image below explains the inhibitory mechanism [30-31].

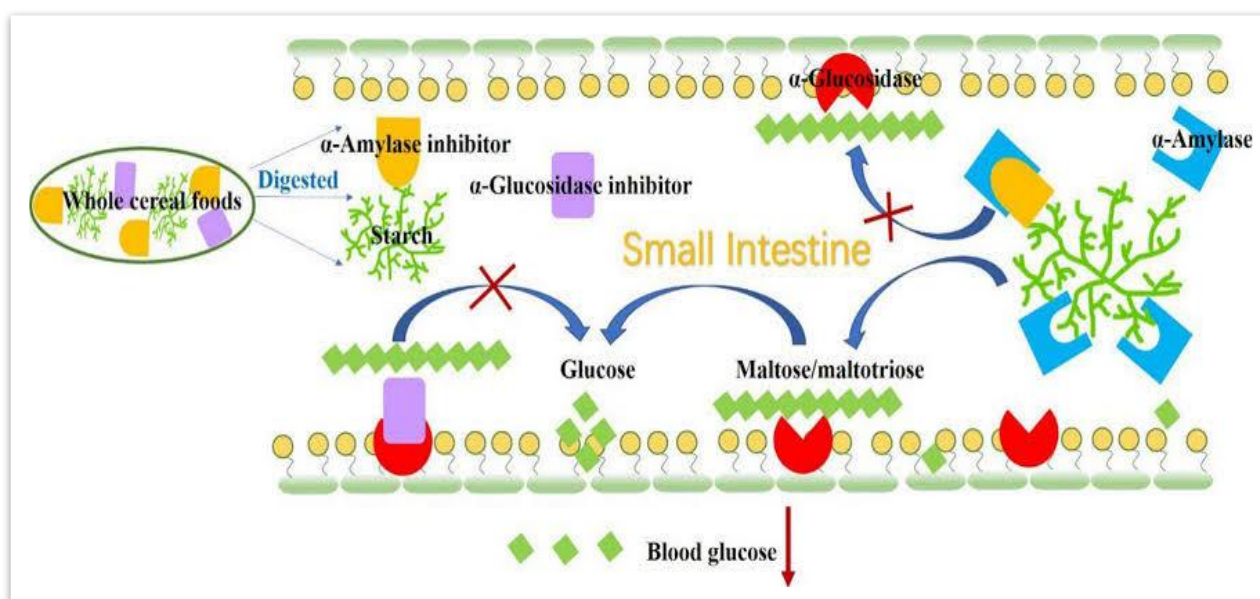


Fig. 8. Mechanism of okra in diabetes mellitus treatment [31].

4.2. Description

As demonstrated in the above picture, okra's potential polyphenols, flavonoids, and antioxidants, including myricetine, rutine and quercetin, aid in the treatment and control of diabetes mellitus in all of its manifestations. As the active components of okra, these substances aid in lowering diabetics' plasma glucose levels and enhancing the ability of pancreatic cells to utilise blood plasma glycose.

In addition, the antioxidants found in okra, such as glutathione S-transferase (GST), improve the structure of islands by preventing the generation of free radicals, or ROS/RNA, which oxidize proteins and lipids and promote lipid peroxidation.

Inhibiting alpha-amylase and alfa-glucosidase reduces pathogenic activity, which aids in the intervention and control of diabetes mellitus as well as the prevention of diabetic complications [31].

5. Past research

Study 1

This investigation into the function of mucilage and okra seed was carried out on streptozotocin-induced diabetic rats. In this study, 40 male wistar rats were divided up into 4 groups. After three weeks, the results showed that the two groups that received 2 g/kg bw/day of okra seeds and 2 g/kg bw/day of mucilage had

increased serum glucose total cholesterol and decreased serum insulin in diabetic rats. Consuming mucilage increased insulin levels while decreasing glucose and total cholesterol.

Consuming seeds raised insulin levels while lowering triglycerides, HDL, LDL, glucose, and antioxidant capacity. Thus, it was determined that eating okra raised insulin levels and decreased glucose levels [31].

Study 2

In order to determine the impact of okra in treating diabetes status, a group of diabetic rats was exposed to this okra extract which was extracted using modified extraction procedures in a 2017 study. Models of type-2 diabetes were created by injecting 35 mg/kg BW streptozotocin into them while they were fed a high-fat diet. After the hyperglycemic effects were verified, they received varying dosages of okra extract. These various subfractions assisted in reducing the effects of hyperglycemia, triglycerides, and low density lipoproteins, insulin intolerance. Following a 12-week trial, it was determined that okra, whether consumed as a vegetable or as a nutritional supplement, reduces the negative effects of diabetes and can be employed as a therapeutic agent [32].

Study 3

To see how it affected type 2 diabetes, another trial was done. Of the patients, 50 were of the same age and did not have diabetes, whereas the other 50 had type 2 diabetes. The aim of this study was to evaluate the serum magnesium levels and normal blood glucose levels (125 mg/dl) in individuals with type 2 diabetes, and then to compare the results with those of an unaffected group. Over the course of seven days, ten healthy rats were given diabetes injections. After that, 20 rats received 250 mg of okra after receiving okra seed for 7 days, after which their levels were monitored. Additionally, it aims to evaluate the relationship between the serum magnesium level and the modal quality treatment, similar to how okra affects treatment. In addition, the level of serum magnesium in diabetics and non-diabetics differed significantly. The average variation was between 1.67 and 2.03 mg/dl [33].

Study 4

Pregnant rats were used in one study. They were divided into two groups: one for therapy and the other for people with diabetes mellitus. In order to cause gestational diabetes in the group without diabetes mellitus, 45 mg/kg of streptozotocin was injected. Following that, they were given an okra seed-containing diet or 200 mg/kg/d of okra seeds. And the only food and water given to the other groups was water. Before any foetuses were delivered, blood samples and the weights and serum glucose levels of all the groups of foetal rats were taken on the nineteenth day of pregnancy. The results of this investigation indicated that the foetal rats in the treatment group and the unaffected group had high weights. Following the administration of okra to rats, there was a notable reduction in the serum glucose level.

Twenty rats were used in this investigation, and they were split up into four groups of five rats each. Each class received okra extract at a dosage of 0 mg/kg, 1250 mg/kg, 2500 mg/kg, or 5000 mg/kg of crushed fruit. compared to the negatively controlled group, blood glucose levels were seen to have decreased to 44%, 67%, and 78% in the 1250, 2500, and 5000 mg/kg bodyweight groups after 14 days of treatment.

Alpha-lipoprotein was 21% higher while total cholesterol and triglyceride concentrations were 27% and 39% lower, respectively, in the rats in the 5000 mg/kg bodyweight group. Compared to control groups, the group that received 2500 mg/kg bodyweight of fruit had reduced serum alanine and alkaline phosphatase levels. Thus, it may be said that the groups receiving more extract had lower glucose levels [33].

Study 5

The dosage of streptozotocin employed in this investigation is 60 mg/kg bodyweight. Okra seed pellet was fed to diabetic rats for over 42 days, starting after 14 days when the glucose level was steady. On the 28th day, blood samples were collected to determine the blood glucose level. When administered in two doses, one at a higher level than the other, okra seed had anti-diabetic effects. When the doses of 250 and 500 mg were administered, the sugar level was 0.001% lower than in the mice with high blood glucose that were under the other process' supervision [22].

Study 6

The purpose of this study is to determine how well okra assists in reducing blood glucose levels in rats that have diabetes due to streptozotocin. It involves taking okra extract orally for forty days in order to manage diabetes, which is brought on by administering 50 mg/kg of bodyweight of streptozotocin. Six classes of Sprague Dawley mice are used: one class has normal blood glucose control, while the other has high blood glucose control. The extract of green-colored okra is administered intraperitoneally at a weight of 5 mg/kg, and the quercetin dose is administered at a weight of 10 mg/kg. The amount of quercetin in the okra extract acts as an anti-hyperglycemic, according to the results [25].

Study 7

The objective of this study was to examine the preventive benefits of okra powder produced in rats with type 2 diabetes. Five groups of female rats weighing an average of 200–220 g were randomly assigned to this investigation. A typical diet was given to the first group. For 30 days, 200 mg/kg of okra powder was administered to the second group of healthy female rats. After receiving a 30-day high-fat diet, the third group was given okra powder at a reduced dosage of 35 mg per kilogram of body weight. For 30 days, the fourth group of diabetic female rats was given okra powder at a dose of roughly 200 mg/kg body weight. Rats with diabetes in the fifth group were given 200 mg/kg body weight of the medication used to treat diabetes for 30 days. Biochemical parameters were assessed after the experiment. The outcome shown that they were able to regulate the impact of diabetes and hypoglycaemia in rats [34].

Study 8

It is reported that a study was done on a group of rats with elevated blood sugar levels to observe how okra peel powder affected the blood glucose level. Following a 14-day assessment during which the blood glucose level was stable, okra seed and peel powder was administered for 28 days. On the 28th day, a sample was collected to assess the levels of glycosylated haemoglobin, serum glutamate pyruvate transferencees' total protein, and lipid profile. The findings indicated that okra seed and peel powder, when taken at a dosage of 2000 mg per kg body weight, did not exhibit any toxic effects or result in death. For the first time, the study reported that okra seed and okra peel powder had a substantial effect on treating high blood glucose and high cholesterol levels [29].

Study 9

In order to determine the antioxidant qualities of okra, a rat experiment was carried out in 2016. For a continuous thirty-five days, male rats were used in this study. Two groups were created: one was left untreated, while the other received treatment with alloxan, an acidic substance. Alloxan monohydrate was administered into the rats at a dose of 150 mg/kg body weight, dissolved in sterile 0.9% normal saline. The erythrocyte plasma membrane redox system, erythrocyte lipid peroxidation, and advanced oxidation protein products increased by 153%, 31%, and 290% within a week following alloxan treatment, while intracellular reduced glutathione and total antioxidant potential of plasma in terms of ferric reducing ability decreased by 75% and 22%, respectively. These medications offer defense against the chemical alterations brought about by the acid substance administered to the rats. Based on the findings, it was determined that okra plays a significant protective function against oxidative stress and can help avoid excessive blood sugar levels [8].

Study 10

This study looked at the effects of okra ethanol extract and flavonoids, such as isoquercetin and quercetin 3-O-gentiobioside, which have antioxidant properties that can lower high blood sugar levels. Rats were given a high-fat diet for three months in addition to two weeks of ethanol extraction of Okra. During this time, the rats were observed to have low fasting blood glucose levels. This was done in an effort to induce obesity in the rats. Two hours after the oral administration of ethanol extraction of Okra, another blood glucose sample was obtained, and this time, the blood glucose levels were higher. This resulted from the presence of polysaccharides in the Okra ethanol extraction. Similarly, mice's blood glucose levels fell when an intraperitoneal glucose injection was administered 30 to 60 minutes later [24].

Study 11

Experiments have demonstrated that *Abelmoschus esculentus* decreased the concentration of triglycerides and lipoprotein in rats. This study sought to determine how oral administration of an okra peel aqueous abstract affected hyperglycaemia [24].

Study 12

Four groups of twenty-four rats were established and each group received oral treatment with 2% carboxymethyl cellulose for 10 days. The hyperglycaemic group received 10 mg per kg of dexamethasone. The results demonstrated that dexamethasone decreased weight and raised blood glucose. *Abelmoschus esculentus* lowers the blood glucose-lowering effects of dexamethasone. So, *abelmoschus esculentus* may protect against hyperglycaemia brought on by Gc [35].

Conclusion

Okra has been used extensively for centuries as a therapeutic herb, either whole, in an extract form, or as a powder, and it has never had any negative effects on the functions of the body. Over the last twenty years, a number of researches on both humans and animals have clearly demonstrated how beneficial okra is for reducing diabetes. Okra contains several polyphenols, including quercetin and myricetin, which stimulate the pancreas to produce more insulin by promoting the regeneration of Langerhans cells. Because of their antioxidant properties, these polyphenols are capable of neutralizing free radicals, which helps to reduce the degeneration of Langerhans cell islands and promote recovery and regeneration. According to a comparison of multiple research studies, those with diabetes may benefit from okra. Okra's high fiber content may help in blood sugar regulation, and its other minerals and antioxidants can promote general health and wellbeing. While more investigation is required to completely comprehend the mechanisms of action and ideal dosages, the study's positive findings imply that okra can be a beneficial addition to a diabetic's balanced diet.

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