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Review Article : The Effect of Quercetin Compounds on Type II Diabetes Mellitus

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A B S T R A C T

The immune system of the body targets the insulin-producing pancreatic cells, which results in diabetes mellitus. Synthesized antidiabetic drugs cause side effects of liver and kidney damage. Quercetin are known to have the same mechanism as synthetic antidiabetic drugs, so it can be an alternative treatment for diabetes. This article is a review with a literature search using PubMed, MDPI and Google Scholar. Quercetin activate AMPK which affects the decrease in blood glucose levels, protect cell damage due to free radicals so as to prevent a decrease in insulin levels and repair tissue damage due to hyperglycemia. Quercetin plays a role in reducing the risk of Type II DM complications. Quercetin compounds affect Type II Diabetes Mellitus with various mechanisms.

INTRODUCTION

Diabetes mellitus (DM) is a chronic illness that ranks among the world's main killers. Hyperglycemia, or elevated blood sugar, is the first sign of diabetes mellitus and is brought on by insufficient insulin secretion, insufficient insulin action, or both. Diabetes mellitus that is left untreated can result in death from ketoacidosis and nonketotic hyperosmolar syndrome, as well as hyperglycemic coma, severe damage to the kidneys, blood vessels, nervous system, and cardiovascular system. Insulin resistance or low insulin levels in skeletal muscle, adipose tissue, and other target tissues cause this metabolic disorder. High levels of oxidative stress, free radicals, and other metabolic disorders are strongly correlated with the development, pathophysiology, and complications of diabetes mellitus (Ansari dkk., 2022). According to the International Diabetes Federation (IDF), 1.9% of people worldwide have diabetes mellitus (DM), making it the seventh most common cause of death worldwide. In the year 2013, 382 million individuals worldwide suffered from diabetes mellitus, with type 2 diabetes accounting for 95% of all cases. 85–90% of cases of type 2 diabetes are prevalent (Petersmann dkk., 2018). The immune system's destruction and attack of the body's pancreatic cells, which are responsible for producing insulin, results in diabetes mellitus. DM also causes patients to be less active, for example in terms of work which has an impact on reduced income, as well as a lack of quality of life due to complications from the disease (Hasibuan dkk., 2022; Sagita dkk., 2020).

WHO report data in 2003 showed that only 50% of DM patients in developed countries adhered to the recommended treatment. Uncontrolled DM disease can lead to complications. According to the consensus of the Indonesian Endocrinology Association (PERKENI, 2011), there are pillars of DM control, namely, physical exercise, medical nutrition therapy, pharmacological intervention, and education. Patient compliance in managing daily food and diet is the success of the DM control process. A balanced diet should be consumed by patients with diabetes mellitus, taking into account their unique calorie and nutrient requirements. Emphasis should be placed on the value of regularity in terms of mealtimes, types, and quantities for patients with diabetes mellitus (DM), particularly for those who take insulin or blood glucose-lowering medications. Of the 16 major diseases, the DM population adheres to recommended medical measures with the lowest rate of adherence (67.5%). The primary challenge in managing diet for diabetes mellitus is getting patients to follow their diets to the letter, which is essential for success. Even though following a diet or following medical advice is necessary, patients rarely follow disease management programs to the fullest extent possible (Vadila dkk., 2021).

Sugar, flour, and oil consumption in excess leads to diabetes mellitus. Numerous studies have found a link between the incidence of DM and high sugar intake. It was discovered that the risk of obesity rises with each additional serving of carbonated beverages consumed. Recent research indicates that consuming soft drinks may increase the risk of obesity and diabetes mellitus because soft drink manufacturers use a lot of fructose corn syrup, which raises blood sugar levels. High consumption of red meat, sugary foods, and fried foods

raises the risk of developing insulin resistance, as does the consumption of dietary soft drinks, which contain glycated chemicals that significantly increase insulin resistance (Sami dkk., 2017). Type I and type II diabetes are two different categories for diabetes mellitus. Although the cause of type 1 diabetes mellitus, also known as insulin-dependent diabetes mellitus (IDDM), is unknown, the majority of patients with this type of DM typically have an autoimmune etiology. Diabetes mellitus type II is brought on by malfunctioning or abnormal insulin-responsiveness of insulin target cells. Blood sugar levels will rise above normal ranges (hyperglycemia) when insulin production and function are compromised, which eventually results in elevated blood pressure (hypertension). (Budianto dkk., 2022; Lestari, L., & Zulkarnain, 2023).

Oral and injectable medication are the two forms of pharmacologic therapy for diabetes mellitus. Metformin, sulfonylurea, nonsulfonylurea secretagogue, α-glucosidase inhibitor, thiazolidinedione, glucagon-like peptide-1 analog, and dipeptidyl peptidase-4 inhibitor are among the many classes of anti-diabetic medications that are frequently used. Insulin injection is an adjunctive therapy to oral treatment or can also be used alone (Putra & Permana, 2022). Long-term use of oral and injectable anti-diabetic drugs can cause gastrointestinal problems with metformin drugs, the risk of hypoglycemia with sulfonylurea drugs and the potential impact on vital organs such as the liver and kidneys (Adiputra, 2023). In addition, the high severity and accompanying complications in DM patients also have an impact on the high cost of treatment incurred ((Abd Rahman dkk., 2024). Medicinal plants have been used globally as alternative treatments for various diseases, including DM. There are about 80-85% of the world's population who use extracts and active components of herbal plants as a source of traditional medicine in primary health needs (Kifle dkk., 2021).. Public beliefs about the benefits, availability, affordable costs and experience of using medicinal plants from ancestors are some of the reasons that influence people to use medicinal plants as an alternative (Alzahrani dkk., 2019).

Medicinal plants containing quercetin have been traditionally used to treat infectious diseases, diabetes mellitus, and even cancer (Ansari dkk., 2022). Quercetin is the most abundant and widely studied type of flavonoid. Bioflavonoids such as quercetin are found in citrus fruits, green leafy vegetables, seeds, flowers, buckwheat, bark, broccoli, nuts, olives, onions, apples, green tea, red wine, and berries. After consumption, quercetin contained in food will be absorbed in the intestines, then quercetin undergoes phase II metabolism and is conjugated into derivatives, then quercetin will undergo methylation, sulfation, and glucuronidation processes in the circulatory system and finally excreted through bile, urine, and feces. Quercetin compounds have the ability to increase insulin secretion, protect β-pancreatic cells from oxidative stress and strengthen antioxidant abilities in cells, so they have anti-hyperglycemia activity (Abd Rahman dkk., 2024). Recent research found that the quercetin compound found in local apples caused a decrease in blood glucose levels in rat test animals after 14 days of intervention (Authoria dkk., 2023).

Quercetin compounds are known to have the same mechanism as pioglitazon and metformin drugs. Where, quercetin functions as a ligand of the Peroxisome Proliferator-Activated Receptor (PPAR) and shows PPAR-y trans-activation activity. Additionally, by making peripheral tissues more sensitive to insulin, quercetin can suppress the production of glucose by the liver and inhibit the process of gluconeogenesis (Apriani dkk., 2023). In skeletal muscle, quercetin stimulates Adenosine Monophosphate Kinase (AMPK), which in turn activates GLUT4 and Akt receptors in the cell membrane. Through GLUT4-facilitated diffusion, glucose enters the cell and is metabolized, which allows it to be regulated in terms of glucose levels. Quercetin can raise the AMP/ATP ratio in β-cells and scavenge ROS in type II diabetes. Variations in the AMP/ATP ratio cause mitogenesis, increase insulin secretion, and activate the mitochondrial target of rapamycin (mTOR) (Dhanya, 2022). This review was created to ascertain the risk factors, pathological, and effects of quercetin compounds on type II diabetes mellitus based on the antidiabetic pharmacological activity of quercetin.

LITERATURE REVIEW

1. Type II Diabetes Mellitus

A genetic and clinical metabolic disorder, diabetes mellitus is heterogeneous in its manifestations and primarily manifests as a loss of carbohydrate tolerance. Diabetes mellitus type II is characterized by hyperglycemia brought on by cellular insulin intolerance. Insulin levels could be within the normal range or somewhat lower. As long as pancreatic β-cells continue to produce insulin, type II diabetes mellitus is regarded as non-insulin dependent. Elevated blood sugar levels resulting from decreased insulin secretion by β-pancreatic cells and/or impaired insulin function are the hallmarks of type II diabetes mellitus. Insulin target cells malfunction or are unable to respond to insulin normally, which is the cause of type II diabetes mellitus rather than a lack of insulin secretion. Insulin resistance is the term used to describe this condition (Ikrima Rahmasari, 2019).

2. Type II Diabetes Mellitus Symptoms

a. Polyuria (Frequent Urination)

Urinating more frequently than usual especially at night (polyuria) can be caused by blood sugar levels exceeding the kidney threshold (>180 mg/dl), so sugar will be excreted through urine. In order to reduce the concentration of urine excreted, the body will absorb as much water as possible into the urine so that large amounts of urine can be excreted and frequent urination. Under normal circumstances, daily urine output is about 1.5 liters, but in uncontrolled DM patients, urine output is five times this amount. Frequent thirst and desire to drink as much water as possible (polyploidy). With the excretion of urine, the body will become dehydrated. To overcome this problem, the body will produce thirst so that patients always want to drink water, especially cold, sweet, fresh and large amounts of water (Lestari, L., & Zulkarnain, 2023).

b. Polyphagia (Feeling Hungry Quickly)

Lack of energy and polyphagy, or increased appetite. DM patients experience issues with insulin, which reduces the amount of sugar that is taken up by the body's cells and results in less energy being produced. This explains why patients experience low energy. Furthermore, cells start to lose sugar, which leads the brain to believe that a shortage of food is the cause of low energy. As a result, the body attempts to stimulate food intake by raising the hunger signal (Lestari, L., & Zulkarnain, 2023).

c. Weight Loss

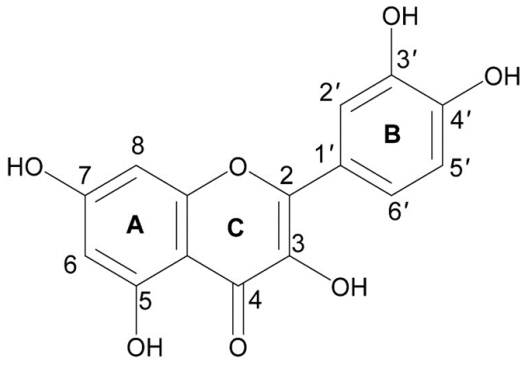
The body will rush to process fat and protein in order to be converted into energy when it cannot obtain enough energy from sugar because of an insulin shortage. Patients with uncontrolled diabetes mellitus may lose up to 500 grams of glucose per 24 hours through their urine (which is the equivalent of 2000 calories lost from the body per day). Other symptoms that are typically indicative of complications include tingling in the feet, itching, or non-healing wounds. In women, vulvar pruritus, or itching in the groin area, is sometimes present, while in men, balanitis, or pain at the tip of the penis, is the symptom (Lestari, L., & Zulkarnain, 2023).

3. Risk Factors and Pathophysiology of Type II Diabetes Mellitus

Genetic, metabolic, and environmental factors are complexly combined and interact to influence the prevalence of type II diabetes. Evidence from epidemiological studies indicates that many cases of type II DM can be prevented by improving significant modifiable risk factors, such as obesity, low physical activity, and unhealthy eating habits, even though individual susceptibility to type II DM due to non-modifiable risk factors (ethnicity and genetic history/genetic susceptibility) has a strong genetic basis (Galicia-garcia dkk., 2020).

In terms of the disease's pathophysiology, abnormally high blood glucose levels are caused by a feedback dysfunction between insulin action and secretion. Insulin secretion is decreased in pancreatic β-cell dysfunction, which restricts the body's capacity to sustain physiological glucose levels. Conversely, insulin resistance causes the liver to produce more glucose while reducing the amount of glucose in the muscle, liver, and adipose tissue. Insulin resistance and β-cell dysfunction both occur early in the pathogenesis and contribute to the progression of the disease, but β-cell dysfunction is typically more severe. However, type II diabetes develops when hyperglycemia rises and β-cell dysfunction and insulin resistance coexist (Galicia-garcia dkk., 2020).

4. Quercetine



Picture 1. Chemical Structure of Quercetin

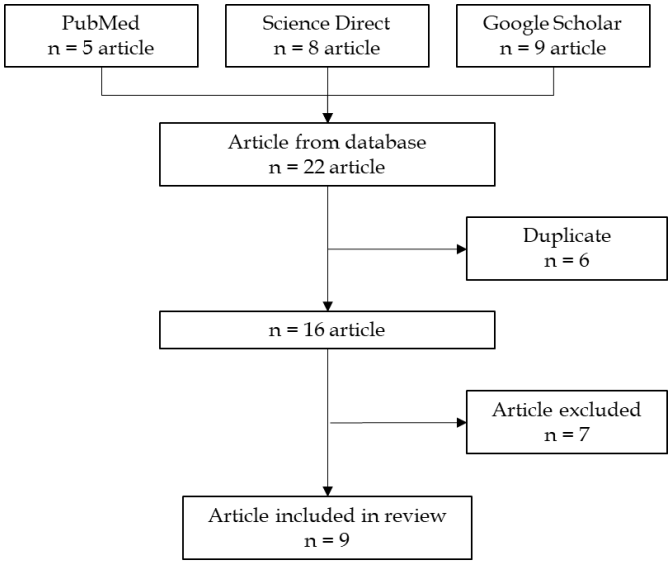
Major flavonoid quercetin is a member of the flavonol class. The yellow compound quercetin (3,3′,4′,5,7-pentahydroxyflavone) is insoluble in cold water, slightly soluble in hot water, and completely soluble in lipids and alcohol. This compound, which has five hydroxyl groups (OH) that can be substituted in different ways, and two aromatic rings (A and B) connected by a three-carbon bonded γ-pyrone ring (C), was first isolated as a flavonoid glycoside in 1854. The molecule of quercetin contains a ketocarbonyl group, and the oxygen atom on the first carbon is basic and can form salts that are strongly acidic. A dihydroxy group between ring A, an o-dihydroxy group B, ring C C2, a double bond C3, and 4-carbonyl make up its molecular structure. Because it contains double bonds and phenolic hydroxyl groups, quercetin has potent antioxidant properties (Ansari dkk., 2022; Yang dkk., 2020).

Apples, almonds, fruit, buckwheat, broccoli, cauliflower, cabbage, olive oil, onions, and red wine are among the foods that are commonly known to contain quercetin. Numerous investigations have demonstrated the protective properties of quercetin against a range of illnesses, including osteoporosis, some types of cancer, heart and lung conditions, and aging. It also possesses anti-inflammatory, antiproliferative, anticarcinogenic, antihypertensive, and anti-diabetic properties. Quercetin works to treat diabetes by inhibiting the digestive enzymes that break down carbohydrates (pancreatic α-amylase and intestinal α-glucosidase), lowering the rate at which glucose is absorbed, reducing starch hydrolysis, and, in vitro, slowing the development of postprandial hyperglycemia (Anand David dkk., 2016; Ansari dkk., 2022).

METHODOLOGY

A literature search was conducted on PubMed, MDPI, Google Scholar using the keywords quercetin, type-2 diabetes, flavonoids, insulin, blood sugar, antidiabetes. Reference lists and related notes were also reviewed. The scientific literature search had no restrictions on language, study design, and outcome measures. Studies were included if they met the following eligibility criteria: experimental research design, in vivo animal studies, using appropriate control groups, measuring glucose levels before and after the intervention, using

quercetin, and published in English and Indonesian journals. Ineligible studies, such as in vitro, or ex vivo model studies, patient studies, review studies, conference abstracts, abstracts without details, and scientific literature that did not have full-text access were excluded. Scientific literature was screened based on title and abstract. Then, irrelevant literature was excluded. Data extraction was based on study design, study animal species, mode of administration, disease induction method and inclusion/exclusion criteria.



Picture 2. Article Criteria

RESEARCH RESULT

The results of the literature study on the effect of quercetin compounds on Type II DM are attached in Table 1. It was obtained that there were 9 studies that conducted in vivo tests on the effect of quercetin on type II diabetes mellitus with experimental animal models. Most of the studies used a single quercetin compound, while some used a combination of quercetin with plant extracts. Diabetes inducers used in the study were single streptozocin and a combination of streptozocin with nicotinamide. The doses of quercetin and extracts tested varied, adjusted to the objectives of the study.

Table 1. Effect of Quercetin on Type II Diabetes Mellitus

No	Dose	Diabetes Inducer	Pharmacology Activity of Quercetin	Refrence
1.	Quercetin 100 mg/kg·bw	Streptozotocin	The protective effect on the pancreas organ occurs partly due to the inhibition of ferroptosis	(Li dkk., 2020)
2.	Quercetin 20 mg/ kg·bw	Streptozotocin dan Nicotinamide	Reduction in blood glucose levels by inhibiting the activity of the α-glucosidase enzyme	(Fitriani, N.E, Akhmad, S.A,

			can slow down the absorption of glucose	Lestariana, 2014)
3.	Quercetin in Apel extract P1 : 32,5 mg/kg·bw P2 : 65 mg/kg·bw P3 : 97,5 mg/kg·bw	Streptozotocin dan Nicotinamide	Activates adenosine monophosphate kinase (AMPK) in skeletal muscle, which causes the GLUT4 receptor on the cell membrane to be stimulated. Then glucose will enter the cell and blood glucose will decrease	(Authoria dkk., 2023)
4.	Fruit extract Averrhoa Bilimbi G4 : 25 mg/kg·bw G5 : 100 mg/kg·bw	Streptozotocin	The quercetin compound contained in the extract triggers increased insulin secretion in pancreatic β cells so that it can reduce HbA1c levels and reduce liver enzyme levels in test animals	(Kurup & Mini, 2017)
5.	Quercetin G3 : 25 mg/kg·bw G4 : 50 mg/kg·bw G5 : 75 mg/kg·bw	Streptozotocin	Protects pancreatic β cells. Effectively controls blood glucose by increasing insulin secretion and regeneration of pancreatic β cells	(Srinivasan dkk., 2018)
6.	Quercetin 10 mg/kg·bw	Streptozotocin	Enhances antioxidant activity pathways by increasing superoxide dismutase (SOD-1) expression and decreasing glutathione peroxidase (GPX-1) activity	(da Purificação dkk., 2022)
7.	Quercetin 20 mg/kg·bw	Streptozotocin dan Nicotinamide	Reduces insulin resistance by increasing the levels of adiponectin hormone produced by adipose tissue. Also works by directly destroying ROS and increasing the activity of antioxidant enzymes such as SOD, CAT and GSH-Px	(Monika, A.M,Lestatriana, 2014)
8.	Quercetin 10 mg/kg·bw	Streptozotocin	Decrease fasting blood glucose levels	(Iwara dkk., 2022)
9.	Combination swertiamarin and quercetin 50 dan 100 mg/kg·bw	Streptozotocin	The combination of swertiamarin and quercetin has a synergistic effect by triggering a mechanism to increase stimulation for pancreatic β cells that still survive in the islets of	(Jaishree & Narsimha, 2020)

			Langerhans to balance insulin release.	

DISCUSSION

Mechanism of Quercetin in Type II Diabetes Mellitus

Research by Li dkk (2020) conducted research on the role of quercetin in alleviating the process of pancreatic β-cell ferroptosis in Type II DM. This study used 4 treatment groups. A low dose of streptozocin was used as a compound to induce Type II DM in mice. The lowest insulin concentration (15.22 ± 1.58 mmol/L) was produced by the treatment group given quercetin intervention. In the morphological test using HE staining, the quercetin intervention group showed a protective effect based on the size and structure of the islets of Langerhans in the pancreas. Quercetin also increased insulin antigen on cells in the islets of Langerhans. The role of quercetin in iron overload was seen in the quercetin intervention group, which reduced ferritin levels to 35.7%. In fighting Type II DM, quercetin compounds have a mechanism by restraining iron deposition in the pancreas and ferroptosis in pancreatic β-cells.

In the study of Fitriani dkk (2014), the combination treatment group of gibenclamide with quercetin produced a significant difference ($p<0.05$) in type II DM rats compared to the single administration of quercetin at a dose of 20 mg/Kg·bw. Several factors that can influence this include the synergistic mechanism of action of gibenclamide and quercetin. Where, gibenclamide has a mechanism to maintain insulin secretion, while quercetin can slow the absorption of blood glucose. Another factor is the route of administration. Quercetin is administered orally in experimental animals, so the absorption rate of this compound in the body may be lower than the intraperitonial route of administration.

In the study of Fitriani et al. (2014) the combination treatment group of gibenclamide with quercetin produced a significant difference ($p <0.05$) in type II DM rats compared to the administration of Single quercetin at a dose of 20 mg/Kg·bw. Several factors that can influence this include the synergistic mechanism of action of gibenclamide and quercetin. Where, gibenclamide has a mechanism to maintain insulin secretion, while quercetin can slow down blood glucose absorption. Another factor is the route of administration. Quercetin is administered orally to experimental animals so that the absorption rate of this compound in the body may be lower compared to the intraperitoneal route of administration.

A study used local apple fruit extract to determine the effectiveness of quercetin contained in it on body weight and fasting blood glucose in experimental rats. The largest difference in decreasing fasting blood glucose levels (158.298 mg/dL) was produced by treatment group 1 (P1) with a dose of apple extract of 90 mg/kg·bw (containing quercetin of 32.5 mg/kg·bw). The diabetes inducer streptozotocin-nicotinamide was given to all treatment groups.

This study used a negative control group (no intervention), positive control (glibenclamide), P1 (apple extract 90 mg/kg·bw), P2 (apple extract 180 mg/kg·bw) and P3 (apple extract 270 mg/kg·bw). All treatment groups with apple extract administration resulted in a decrease in blood glucose levels with varying differences, where the greater the dose of apple extract, the smaller the difference in decreasing fasting blood glucose levels in experimental animals. The quercetin compound in apple fruit extract plays a role in activating adenosine monophosphate kinase (AMPK) in skeletal muscle which can affect the reduction of blood glucose levels, protect against cell damage due to free radicals, thereby preventing a decrease in insulin levels and pancreatic β cell mass and repairing tissue damage due to hyperglycemia (Authoria dkk., 2023).

The treatment group of Averrhoa bilimbi fruit ethyl acetate extract at a dose of 25 mg/kg·bw (Group IV) showed a significant decrease in serum glucose and HbA1c levels ($p<0.05$) compared to the diabetes control group (Kurup & Mini, 2017). Plasma insulin increased significantly ($p<0.05$) in Group IV when compared to plasma insulin in the diabetes control group. HPLC analysis conducted in this study showed the presence of quercetin as the largest component contained in the ethyl acetate extract of Averrhoa bilimbi fruit. The quercetin compound has antidiabetic activity by increasing the ability of the pancreas to secrete insulin from β cells in an animal diabetes model induced by streptozocin. Administration of ethyl acetate extract of Averrhoa bilimbi fruit and metformin to experimental animals significantly reduced rapidly increasing blood glucose levels, this may occur through increased insulin release in existing or newly regenerated β cells. This may be due to the presence of the quercetin compound in it (Kurup & Mini, 2017).

Administration of quercetin at doses of 25, 50 and 75 mg/kg·bw in the study of Srinivasa dkk. (2018) resulted in an effective response as a high antihyperglycemic in experimental animals induced by streptozotocin. The dose of 75 mg showed the highest antihyperglycemic activity among other doses of quercetin and also metformin. It is known that the quercetin compound is effective in controlling blood sugar levels by increasing insulin secretion and regeneration of pancreatic β cells, thus playing a role in preventing the risk of cardiovascular disorders, diabetes complications and improving the health of type II DM patients (Srinivasan dkk., 2018). In this study, quercetin can increase insulin signaling and sensitivity in experimental animals with insulin resistance. Quercetin has antihyperglycemic activity by triggering increased insulin sensitivity through inhibition of α-glucosidase and increasing insulin signals in experimental mice.

Effects of Quercetin in Alleviating Complications of Type II Diabetes Mellitus

In patients with Type II DM, HbA1c levels in the blood tend to be high. Increased HbA1c levels indicate that red blood cells are more susceptible to oxidative stress in DM patients, which can trigger complications. Research conducted by Kurup & Mini (2017) found that there was a significant decrease in HbA1c levels in a group of diabetic experimental animals given ethyl acetate extract of Averrhoa bilimbi fruit. Decreased HbA1c levels indicate the beneficial

effects of the quercetin compound contained in the extract in preventing complications of diabetes pathogenesis caused by glucose metabolism failure.

The liver plays an important role in regulating glucose metabolism. Type II Diabetes Mellitus can be associated with increased activity of liver marker enzymes, such as AST and ALT due to the high concentration of both enzymes flowing from the liver to the bloodstream and due to the toxic effects of streptozocin induction in experimental animals. Kurup & Mini (2017) study found that there was a decrease in AST and ALT activity in the diabetic experimental animal group given Averrhoa bilimbi extract. The decrease was greater than the experimental animal group given metformin. In addition to affecting insulin release and having antihyperglycemic activity, the quercetin compound in Averrhoa bilimbi extract also has a therapeutic effect on liver disorders. When compared to the normal control group (without any treatment), the Averrhoa bilimbi extract group did not affect liver toxicity markers, so it can be said that the quercetin compound in the extract does not cause significant toxicity and is safe (Kurup & Mini, 2017).

In diabetic patients, lipid compounds such as LDL and VLDL carry cholesterol to peripheral tissues, while HDL carries cholesterol from peripheral tissues to the liver for excretion and metabolization. Increased concentrations of LDL and VLDL can cause atherogenic processes and trigger complications in patients with type II diabetes. Testing the effects of quercetin on diabetic experimental animals conducted by Srinivasa dkk. (2018) showed a decrease in LDL and VLDL concentrations in the bloodstream, thus proving that quercetin compounds are able to lower plasma lipids. Research by Monika dkk. (2014) also showed something similar. Where, quercetin compounds combined with glibenclamide were shown to significantly lower LDL in diabetic experimental animals compared to placebo.

Hyperglycemia can increase the risk of cardiomyopathy caused by increased oxidative stress on the heart and inflammation. Histopathological tests of myocardial tissue in the study of da Purificação dkk (2022)showed a decrease in enzymes that trigger oxidative stress in diabetic experimental animals given quercetin intervention (10 mg/kg·bw). Quercetin stimulates increased expression of the antioxidant superoxide dismutase (SOD) in the hearts of diabetic rats, indicating that SOD can help reduce reactive oxygen species formed due to diabetes induction in experimental animals.

CONCLUSIONS AND RECOMMENDATIONS

Quercetin has therapeutic activity for diabetes and hyperglycemia by increasing insulin release from pancreatic β cells, this compound plays an important role in regulating glucose metabolism in the blood and has other insulin regulation mechanisms in varying doses. Giving quercetin to patients with Type II Diabetes Mellitus as an alternative treatment can be considered, considering that several studies using diabetes-induced mouse models have provided effective results in lowering blood glucose levels

ADVANCED RESEARCH

Adjustment of the quercetin dose needs to be studied to determine how much dose is needed to produce antidiabetic and antihyperglycemic activity.

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