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Review Article

Ginger (*Zingiber officinale* R.) as a Potent Medicinal Plant for the Prevention and Treatment of Diabetes Mellitus: A Review

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ABSTRACT

Diabetes mellitus (DM) is the world's fastest-growing disease, and Indonesia ranks sixth. The raw materials used in pharmaceutical drug-assisted healing are expensive. As a result, alternative drugs that are low in cost and produced sustainably are required. The aim of this article was to examine the bioactive content of secondary metabolites from ginger (*Zingiber officinale* R.) that are involved in the prevention and treatment of DM, the mechanism of the bioactive content in the healing process, and its potential as an ingredient in herbal products. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocol (PRISMA-P) was used to carry out the review process. Identification, selection, validation, and review of articles were the steps taken. According to the outcome of the literature survey, the chemical composition of ginger includes both volatile and non-volatile compounds. The volatile compounds include monoterpene and sesquiterpene derivatives, while the nonvolatile compounds are gingerols, shogaols, and paradols. Ginger has anti-diabetic, antioxidant, anti-obesity, and hypolipidemic properties, as well as anti-inflammatory, neuroprotective, antiglycation, and androgenic properties. Furthermore, studies have shown that ginger has effects on carbohydrate metabolism, organ morphology, and metabolic profile. In North Sumatra Province, Indonesia, the production value of ginger is the highest among other biopharmaceutical plants. The findings of this review show that chemical compounds found in ginger, such as 6-gingerol and 6-shogaol, play a role in the prevention of DM, while galanolactone, diterpenoid, and gingerol aid in the treatment of DM. Ginger has promising prospects as a treatment for and prevention of diabetes.

Keywords: Diabetes, Ginger, Gingerol, Herbal, Pharmacology, *Zingiber officinale*.

Introduction

According to the American Diabetes Association, the global population with a history of diabetes mellitus (DM) will reach 387 million in 2015, rising to 471 million in 2035.[1] Almost 80% of people with DM live in developing countries, and it is estimated that this will increase by 150%.[2] The majority of those affected live in cities. As a developing country, Indonesia ranks seventh in the world in terms of the number of diabetics.[3] North Sumatra Province has the most convenient access to hospitals. It turns out that it is the most diabetic province on the island of Sumatra, as well as the province with the fewest traditional medicine industries compared to its population.[4] DM is a physiological disorder that disrupts insulin action and secretion, resulting in hyperglycemia.[5] Hyperglycemia is a basic characteristic of diabetes that causes oxidative stress,[6] atherosclerotic heart disease,[7] or myocardial hypertrophy,[8] systemic arterial hypertension, and endothelial dysfunction,[9] cataracts, diabetic retinopathy, sexual dysfunction, neurological damage, and difficulty in wound healing.[10]

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DM is divided into 2 types; Type 1 DM (T1DM) and Type 2 DM (T2DM). T1DM is a DM associated with autoimmune and insulin levels, while the T2DM is a DM associated with insulin resistance and obesity.[11] Insulin therapy, both oral and injection, is used as a form of treatment, but in DM treatment, side effects such as hypoglycemia, weight gain, and gastrointestinal disorders are common.[12] Hypoglycemia is a condition in which blood sugar levels are too low.[13,14] Although insulin plays a role in lowering blood glucose,[15,16] administration of insulin will result in a significant drop in blood sugar because insulin causes liver and muscle cells to take glucose from the blood.[17] Among other symptoms, hypoglycemia causes headaches,[18] blurred vision,[19] fatigue,[20] and tremors, and its complications include seizures,[21,22] loss of consciousness, and death.[24] Weight gain occurs because additional insulin helps the body store glucose in the form of glycogen and fat and increased fat will trigger weight gain.[25] Insulin resistance is a long-term effect of insulin injection therapy. The occurrence of resistance conditions is caused by the function of the pancreas that produces the hormone insulin, but cells do not use the hormone properly, resulting in a buildup of sugar in the blood.[26, 27]
The use of dietary supplements from plant materials for the treatment of DM was started by ancient medical practitioners who discovered that the natural biopharmaceutical activity is rich in various phytochemicals that are efficacious against various diseases. Nearly two-thirds of the world's population, use various medicinal plants to treat DM.[28–33] The majority of these plants are also available in the form of polyherbal formulations prescribed by medical practitioners, especially in developing countries.[34]
The traditional use of medicinal plants as supplements for the treatment of diabetes has prompted researchers to investigate the biopharmaceutical activity of these plant components, which are

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thought to be rich in phytochemical components. Opportunities to use plant phytochemicals as treatment ingredients encourage the investigation of natural materials as sources of alternative medicine for diabetes treatment, including the use of ginger plants. Ginger (*Zingiber officinale* Roscoe) is a world-famous medicinal plant and has been used for more than 2500 years in traditional Chinese medicine. It is used for the treatment of respiratory diseases (rhinitis, asthma), inflammation (rheumatism), heart diseases (hypertension, palpitations, cardiopathy), digestive tract (diarrhea, constipation, vomiting, poor digestion), and metabolic diseases (diabetes).[35] Ginger is used in medicine as an antidiabetic, analgesic, antiarthritic, anti-inflammatory, antitumor, antimigraine, antiemetic, antithrombotic, hypolipidemic, and antioxidant, as well as for infectious diseases and dementia.[34]

This review article was aimed at examining the bioactive content of secondary metabolites from ginger that play a role in the prevention and treatment of DM, the mechanism of the bioactive content in the healing process, and its potential as an ingredient in herbal products.

Method

The method used for this review was the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P).[36] The first step was to find articles with the keywords, "ginger, *Zingiber officinale* Roscoe, secondary metabolites, diabetes, pharmacology, potential ginger, potential ginger derivative products, and potential medicinal plant derivatives" in the Pubmed database, Google Scholar, ScienceDirect, Scopus, and Elsevier. Identification was done with a time limit, spanning from 1990 to 2020. The second step was to make a selection. The relationship between the title of the article obtained and the sub-topic of the research discussion was reviewed for selection. Validation was the third step. Validation was accomplished by examining the depth of the article's content and its relationship to the sub-topic of the research discussion. The fourth step was to read through the articles.

Results and Discussion

Ginger bioactive content

The ginger rhizome is elongated and slightly flattened, with longitudinal indentations and a golden yellow to light brown color. Ginger contains chemicals that differ depending on where it is grown and whether it is used fresh or dried. Ginger, whether in powder or solution form, causes changes in the composition of the content. Its chemical composition includes both volatile and non-volatile compounds. The volatile compounds of ginger include derivatives of sequesterpen compounds (zingiberene, kurkumen, b-sesquipelandren, and b-bisabolene) and monoterpene derivatives (a-pinene, bornyl acetate, borneol, Kampen, r-cimen, cineol, citral, cumin, b- elements, farnesene, b-phellandrene, geraniol, limonene, linalool, myrcene, b-pinene, and sabine), which are part of the essential oil and give ginger its characteristic aroma. In addition, ginger also contains nonvolatile compounds, namely gingerols, shogaols, and paradols, which give it a distinctive spicy taste. Gingerol is thermally labile and dehydrates to shogaol whose concentration increases during drying and storage. Changes in these compounds will affect the benefits of ginger in medicine because it has variations in its bioavailability, pharmacokinetics, and pharmacology. Shogaols is then converted to paradol by hydrogenation.[37] In addition, ginger also contains zingeron, gingerol, gingediacetates, gingerdiones, and gingerenones as well as flavonoids and oleoresins.[38] It contains several phytochemical compounds that pharmacologically have different roles in healing diseases. More than 40 antioxidant compounds have been detected in ginger. Ginger's main pharmacological roles include antitumor, immunomodulatory, anticancer, antiapoptotic, glucose-lowering, lipid, and antiemetic effects, as well as anti-inflammatory and anti-diabetic properties in DM. [39]

Diabetes mellitus is a chronic and inflammatory disease, characterized by hyperglycemia associated with the generation of ROS (Reactive Oxygen Species), oxidative stress, lipid peroxidation, and subsequent macro and microvascular complications.[40] Ginger can be applied as a treatment that has the potential to prevent DM complications.[34] The antioxidant content in ginger can suppress lipid peroxidation and increase the ability of antioxidant enzymes in the body. Several studies have been conducted on animals and humans with a history of DM, showing that ginger consumption was able to increase the activity of various antioxidant enzymes.[41] These antioxidant compounds will increase glucose transport by regulating the protein content of GLUT4 (Glucose Transporter Type 4) and insulin receptors and increasing the function of secretory activity in the cells. Ginger contains 6-gingerol and 6-shogaol, which improve insulin sensitivity and regulate adiponectin and PPAR (Peroxisome Proliferator Activator Receptor). Glucose uptake is regulated by GLUT4, which is modulated by insulin signaling or AMPKα (Adenosine Monophosphate Activated Protein Kinase) activation and plays a role in regulating cell metabolism. AMPKα activation can increase the absorption of glucose and fatty acids into cells. AMPKα activation is accompanied by upregulation of peroximose gamma coactivator 1-alpha (PGC-1α). Furthermore, 6-gingerol is the main component in ginger that plays a role in increasing the activation of AMPKα and PGC-1α in muscle cells. Several studies have reported that ginger consumption can lower lipid levels. Low-density lipoprotein (LDL) receptors and HMG-CoA reductase, which are enzymes that lead to cholesterol synthesis, regulate cholesterol biosynthesis in the liver. Ginger also inhibits cellular cholesterol biosynthesis, increases mRNA and protein levels of LDL receptors, and decreases protein expression of HMG-CoA reductant in the liver.[37]

Galanolactones, diterpenoids, and gingerols have anti-diabetic properties through their role as antagonists of 5-HT3 receptors (triggers of nausea in the body), which have insulinotropic properties.[39] Ginger is also an antiemetic by inhibiting the contractile response triggered by serotonin 5-HT3 and triggering an increase in glucose levels and a decrease in insulin levels. Consumption of ginger water can inhibit the occurrence of hyperglycemia and hypoinsulinemia in DM patients. Gingerol and shogaol are active ingredients that are also able to lower blood glucose levels by suppressing serotonin receptors and reducing glucose absorption by inhibiting intestinal glucosidase and amylase enzymes.[42]

Ginger's bioactive treatment mechanisms

Antidiabetic effect of ginger

Ginger contains bioactive secondary metabolites that can treat DM Type 1 (T1DM) and 2 (T2DM).[41] Its consumption in certain doses can lower blood sugar levels, insulin, glycated hemoglobin (HbA1c), homeostasis model assessment (HOMA), quantitative insulin sensitivity checks (QUICKI), LDL cholesterol, triglycerides, C-reactive protein (CRP), TNF-, MDA, apolipoprotein B (ApoB), and increase paraoxonase-1 (PON-1), TAC,[9] and diabetes-related symptoms such as dry mouth (xerostomia).[43] Shanmugam and coworkers in 2011 investigated the antidiabetic effect of ginger on experimental animals induced by streptozotocin (STZ) or alloxan.[44] STZ stimulates the production of reactive species that trigger impaired function of (beta) cells in the pancreas. Meanwhile, alloxan is cytotoxic to pancreatic cells, causing blood vessel damage, cell death, and clinical features of T1DM.[45] Treatment with ginger was reported to be able to reduce glycemic in diabetic rats and normalize levels of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) as well as increase the function of GR and glutathione (GSH). Inorganic arsenic (IA) is one of the causes of T2DM.[46,47] Its toxicity causes hepatocyte and pancreatic-cell dysfunction.[48,49] IAs also cause hyperglycemia, impaired insulin secretion, and induce oxidative stress in experimental animals. Toxicity induced by IAs will disrupt the activity of antioxidant enzymes, including SOD, CAT, GPx, and GSH levels and changes in gene expression related to glucose homeostasis.[50–52] The gingerol content of ginger, which was tested *in vitro* and *in vivo*, has antioxidant properties that can reduce oxidative stress induced by insulin autoimmune syndrome (IAS).[53] Cell viability is significantly increased by 6-gingerols, which also inhibit intracellular ROS generation. In experimental animals, IAs also increased serum concentrations of alanine aminotransferase, aspartate aminotransferase, and blood sugar. Treatment with 6-gingerols

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improved serum biomarker concentrations by increasing the activity of antioxidant enzymes such as CAT, SOD, GPx, and GSH in the IAs-intoxicated liver. In IAs-induced hyperglycemic rats, 6-gingerols increased plasma insulin and the hepatic glucose transporter (GLUT 4). IAs-induced toxicity will reduce the expression of insulin signaling-associated proteins, insulin receptor substrate, AKT, phosphoinositide 3-kinase, GLUT4, and peroxisome proliferator-activating receptor (PPAR). Also, 6-gingerols will increase the cell viability of both pancreatic cells and hepatocytes by reducing oxidative stress and increasing antioxidant biomarker activity, glucose tolerance, and insulin sensitivity through the upregulation of insulin signaling proteins.[34]

Ginger is hypotriglyceridemic, which can increase lipoprotein lipase enzyme activity, hydrolysis of circulating triglycerides (TG), and decrease serum TG. It also reduces the expression of the carbohydrate-responsive element-binding protein (ChREBP) gene in the liver. ChREBP plays a role in regulating lipid transcription and glucose metabolism, mediating the activation of several regulatory enzymes in glycolysis and lipogenesis. Decreased expression of ChREBP will reduce the expression of ACC1, fatty acid synthesis, stearoyl-CoA desaturase-1 (SCD1), and glucose-6-phosphatase, glucogenic and lipogenic proteins, and reduce fat accumulation in the liver, serum TG, and increase insulin resistance. Because of its function, ChREBP reduces the toxicity associated with fatty acid accumulation and increases hepatic insulin sensitivity. Liver-specific ChREBP inhibition increases hepatic steatosis by specifically lowering lipogenic levels.[2,54–59] Ginger can increase the activity of the liver cholesterol enzyme 7a-hydroxylase and convert cholesterol into bile acids. Furthermore, ginger can inhibit cholesterol biosynthesis in the rat liver. In addition, it is also able to suppress cholesterol levels by increasing bile secretion, excretion of cholesterol and fecal phospholipids.[60]

Antioxidant effect of ginger

Oxidation is a metabolic process that requires energy for the essential activities of cells. Oxidation stress occurs due to an imbalance between the ROS produced and released due to a decrease in the antioxidant system. Antioxidants aid in the reduction of oxidative damage in physiological processes. Complications of diabetes are caused by increased oxidative stress. Ginger consumption in patients can boost antioxidant levels, preventing micro and macrovascular complications, coronary heart disease, and nervous system disorders. Several studies using experimental animals showed that ginger extract increased the activity of antioxidant enzymes such as SOD, CAT, and GPx, increased glucose transport by GLUT-4, and increased the secretory function of pancreatic cells.[34] Ginger was able to reduce oxidative protein and lipid formation disorders after 30 days of treatment in STZ-induced diabetic rats.[61] The content of phenols, polyphenols, and flavonoids in ginger can suppress the occurrence of hypoglycemia by lowering blood glucose and acting as an antagonist to serotonin receptors. Ginger is also able to inhibit the activity of intestinal glucosidase and amylase enzymes and reduce glucose absorption. The hydro-alcoholic ginger extract protects the liver from glycogen damage by inhibiting the hepatic glycogen phosphorylase enzyme and increasing the activity of glycogen synthesis enzymes.[44]

Anti-obesity and hypolipidemic effects of ginger

Obesity and insulin resistance are the main metabolic disorders that occur due to excessive intake of high-calorie fast food. Epidemiological studies reveal that more than 90% of T2DM patients are obese. Several studies related to obesity have been carried out to examine the effects of the dose and period of ginger consumption on antiobesity and hypolipidemic effects in rats. Research shows that ginger can suppress weight gain and reduce hyperglycemia, hyperlipidemia, hyperinsulinemia, and phospholipids. Ginger is also able to suppress obesity, insulin resistance, and hyperlipidemia. AMP-activated protein kinase alpha (AMPKα) and peroxisome coactivator 1-alpha proliferator-activated gamma receptor (PGC-1α) play a role in regulating lipid profiles in obese patients.[62] Hypertriglyceridemia is a metabolic factor that triggers the development of DM. Ginger inhibits the hypertriglyceridemic effect by increasing the activity of lipoprotein lipase enzymes and hydrolysis of circulating TGs by decreasing serum concentrations of TGs. ChREBP is a transcriptional regulator of lipid and glucose metabolism and converts excess carbohydrates into TGs. Ginger can also decrease fat accumulation in the liver, by decreasing serum TG and developing insulin resistance by suppressing the expression of ChREBP, ACC1, fatty acid synthase, SCD1, and glucose-6-phosphatase.[60]

Anti-inflammatory effect of ginger

PGE2 is a biomarker of inflammation that induces several transcriptional pathways and proinflammatory mediators such as (NF)-κB and TNF-α. NF-B triggers inflammatory activation, while TNF enhances the inflammatory process in T2DM. Ginger can inhibit the production of PGE2 and TNF-.[63, 64] Its inhibitory effect on proinflammatory biomarkers suggests that one mechanism used to treat T2DM is by suppressing the inflammatory pathway of DM development.[34,65,66]

Neuroprotective effect of ginger

Nerve disorders in DM patients occur due to increased intracellular glucose concentrations and lipid peroxidation.[67–72] Oxidative stress triggers the internal depolarization of the mitochondrial membrane, the release of cytochrome C into the cytosol, resulting in the induction of apoptosis by caspase-3 (CPP32).[64,73] Ginger consumption provides a neuroprotective effect in STZ-induced DM rats, due to the content of antioxidants, including gingerols and shogaols in ginger. In contrast, the STZ significantly decreased levels of antioxidant enzymes and increased levels of malondialdehyde (MDA) in mitochondria located in the cerebellum, hippocampus, and hypothalamus of experimental mice. Continuous administration of ginger ethanol extract (200 mg/kg body weight) for 30 days was able to reduce antioxidant enzyme activity and help reduce MDA levels in the brain.[44]

Antiglycation effect of ginger

Non-enzymatic interactions of glucose-proteins (AGEs) lead to complications of diabetes, including diabetic cataracts (diabetic retinopathy), arthritis, atherosclerosis, chronic kidney failure, Alzheimer's disease, nephropathy, and neuropathy. AGEs form covalent bonds with proteins present in cells and cause changes in the structure and function of the cell-matrix, basement membrane, and cell wall components. The binding process with AGE receptors (RAGE) on the cell surface will cause inflammation.[34,74–77] Ginger exhibits antiglycation properties by suppressing cataract development in experimental rats. In addition, treatment with ginger was also able to suppress the formation of AGEs, such as carboxymethyl-lysine, and reduced stress caused by hyperglycemia in the lens of the eye. AGEs are a trigger for the inflammatory response. The anti-inflammatory content of ginger polyphenols resulted from NF-B signaling and TNF-suppression. AGEs are also a trigger for increased levels of tumor necrosis factor-alpha (TNF-α), nuclear factor Kappa B (NF-κB), and vascular endothelial growth factor (VEGF). Treatment with 6-gingerol for 24 weeks was effective in reducing the damage significantly.[6,78–82]

Effect of ginger on carbohydrate metabolism

The hypoglycemic activity of ginger is related to the normalizing activity of enzymes that play a role in carbohydrate metabolism. Streptozotocin-induced diabetic mice (STZ) showed an increase in the synthesis of hexokinase and phosphofructokinase enzymes, leading to an elevation of hepatic glucose production.[81,83–85] Ginger polyphenols were able to normalize the activity of these enzymes. Its extract is also able to inhibit the activity of α-amylase and α-glycosidase *in vitro* by controlling protein metabolism that triggers hyperglycemia.[86]

Androgenic effect of ginger

One of the complications of diabetes is the occurrence of male sexual dysfunction. Diabetes-induced sexual dysfunction occurs due to excessive ROS production. The antioxidant content in ginger can reduce disorders caused by oxidative stress by improving sperm quality and increasing the efficiency of male reproductive organs.[87–90] Ingesting ginger for 30 days had a protective effect on reproductive function in male rats. Giving ginger after alloxan treatment resulted in

relatively low glycemic levels, increased reproductive organ weight (testis, epididymis, prostate, and seminal vesicles), better sperm count and motility, serum testosterone levels, and the work of follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which is more optimal.[91]

Effects of ginger on organ morphology

In DM patients, liver weight decreases due to catabolic processes such as glycogenolysis, lipolysis, and proteolysis, thus interfering with insulin action in hepatitis. On the other hand, the liver weight increases due to excess glucose.[92–96] These changes will cause several microvascular complications that lead to diabetic nephropathy. Ginger affects tubular and glomerular degeneration, necrosis, and cystic dilatation, and fat absorption in diabetic rats. Injuries to cells that occur in diabetic rats can be healed in 30 days by consuming ginger. Through cell regeneration, ginger can repair the pancreatic damage caused by STZ and stimulate insulin secretion.[97–100] In another report, Ilkhanizadeh et al. (2016) observed the occurrence of structural changes including fibrosis and cell production of muscle and coronary cells in treated mice.[4] Treatment with ginger was able to improve cardiac tissue and biochemical changes, reduce arginase I activity, and repair the retina of these mice. This indicates that ginger has a promising potential for the treatment of vascular disorders caused by diabetes.[101–104] The antioxidant and anti-inflammatory properties of ginger can increase the total antioxidant capacity (TAC) and reduce lipid and protein oxidation in patients with diabetes mellitus and other oxidative stress conditions.[8]

Effect of ginger on metabolic profile

Gingerol and shogaol in ginger are effective in regulating glycemia and improving lipid activity.[63,105,106] Giving ginger extract with different concentrations (0.5, 1, and 5%) in STZ-induced rats was able to reduce dependence on serum glucose, cholesterol, and triglyceride levels.[107]

Prospects for ginger as an herbal product

Ginger is one of the medicinal plants that is an alternative treatment for DM patients, especially in developing countries.[108–112] Efforts to develop ginger as a hypoglycemic botanical agent for antidiabetic therapy will require the best strategy involving antidiabetic studies on ginger plants. The steps in the process of developing medicinal plants as antidiabetic agents need to be prepared by distributing products that have proven efficacy. This step refers to a process for identifying, evaluating safety and efficacy, and preparing plant-derived drugs for therapeutic use. In many cases, the use of standardized galenic drug preparations will be more effective by preparing them as tablets or injections for primary health care needs in developing countries. Details of plant identification, part to be used, preparation, chemical and biological standardization of the extract, extract stability, dosage, therapeutic and side effects, drug and food interactions, and contraindications, can be entered into national pharmacopeias or supplementary herbal formulars.[113]

The use of ginger in medicine is done traditionally by the community and is used as a raw material in the pharmaceutical industry, traditional medicinal plant industry, and traditional medicinal plant microbusiness. Trade-in of traditional medicinal plants in North Sumatra province is carried out between districts, and provinces to the international (export) level. In general, the trade-in medicinal plants, especially ginger, can be seen from the demand side. The demand for ginger by the community is always increasing, including household needs, industry and traditional medicine businesses, food, beverage, pharmaceutical, cosmetic, household, and export industries. From information regarding the bioactive content of ginger, its mechanism in curing DM and its complications, as well as the ever-increasing demand for its use as a medicinal ingredient, the opportunity for the ginger industry as a medicinal plant product is believed to be able to become an important herbal product, especially in the pharmaceutical sector in Sumatra. North.[114–116]

Ginger production in North Sumatra fluctuated from 2013 to 2017, then decreased in 2018. The total ginger traded both at the national and export levels from North Sumatra in 2017 included ginger production of 7,263,583 kg, exports of 6,327,284.50 kg, imports of 89,007 kg, and domestic consumption of 936,298.5 kg.[116] The use of ginger as a medicinal plant in North Sumatra is not only carried out by individuals (individuals or personal consumption) but also by the pharmaceutical industry, traditional medicine industry, and small traditional medicine businesses that have been operating and spread in two municipalities and five districts, all of which are managed by the private sector.[117]

The dependence of Indonesia and North Sumatra Province on imported raw materials and conventional medicines is an opportunity to optimize domestic products (medicinal plants).[118] The importance of health in agricultural revitalization programs is based on getting back to nature, triggering the rapid growth of the use of medicinal plants as raw materials for herbal products, including in Indonesia.[119] The aim of improving farmers' welfare and economic growth is to encourage the use of medicinal plants as part of the agricultural revitalization.[120, 121] North Sumatra Province is the second-largest producer of traditional medicinal herbs nationally.[122] As a metropolitan city, people in the city of Medan still have a positive perception of the use of medicinal plants as an alternative treatment. Ginger as a biopharmaceutical plant provides benefits in the treatment of various types of diseases so that it becomes an economic opportunity. By processing ginger into a pharmaceutical industry product that is ready to be accepted by the public, ginger as a biopharmaceutical plant will become a locomotive for economic acceleration in North Sumatra, especially the city of Medan.[116]

Conclusion

Ginger contains chemical compounds that can act as a prevention and treatment for DM. Chemical compounds that act as preventives are 6-gingerol and 6-shogaol, while galanolactone, diterpenoid, and gingerol are chemical compounds that act as treatments. Ginger has the potential to be a low-cost herbal product for the treatment of diabetes.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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