Lemongrass and Ginger Potency for Blood Glucose Control

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ABSTRACT
Lemongrass (*Cymbopogon citratus*) and ginger (*Zingiber officinale*) are herbs that have been used to flavour food and beverages, in addition, they are also believed to possess health benefits. One of them is their ability to control blood glucose levels. Blood glucose control not only is beneficial for those who already have blood glucose regulating problems, but it may also be beneficial for the prevention of blood glucose-related diseases such as type 2 diabetes. The purpose of this research is to determine lemongrass and ginger potency for blood glucose control as well as the various populations that will benefit from blood glucose control. This research was conducted using literature reviews of various journals. From this study, it was found that lemongrass and ginger have a good potency in blood glucose control and are able to benefit people who are interested in diabetes prevention, those who are at high risk to developing diabetes, PCOS patients, people with skin concerns, and people with poor mood and/or energy levels.

Keywords: *Lemongrass, Ginger, Blood glucose control, Diabetes prevention, Cymbopogon citratus, Zingiber officinale.*

1. INTRODUCTION

In order for the body to maintain its normal bodily functions, the body functions on negative feedback in order to keep blood sugar levels at a normal level [1]. Blood sugar levels are considered normal when it is below 100 mg/dL when fasting and is less than 140 mg/dL two hours after eating [2]. After eating, glucose levels in the blood rise triggering the release of the hormone called insulin produced by the pancreas. Insulin is responsible for facilitating glucose uptake to cells and when in excess, this hormone signals glycogen synthesis as a form of storage for glucose. When blood glucose levels are low, the pancreas releases a hormone called glucagon which releases glucose to the bloodstream [1].

However, an unhealthy lifestyle may cause this function to be defected [3]. For example, when blood glucose levels are consistently high due to things such as the frequent consumption of food high in refined carbohydrates, it causes the constant production of insulin to the bloodstream. When this occurs frequently, the body may develop insulin resistance [3], where the cells are unable to respond to insulin, causing the inability of glucose to enter the bloodstream which leads to blood sugar levels to be above normal [4]. This condition is called hyperglycaemia, and the inability to respond normally to insulin is called type 2 diabetes [5].

Anyone could be at risk of developing this condition, hence why it is important to prevent blood sugar levels from having spikes or is often at a higher range to reduce the risk of developing type 2 diabetes [6]. In addition, good blood glucose control has been shown to improve certain health conditions such as PCOS, acne, as well as improvement of mood and energy.

There are various ways in order to maintain a healthy blood sugar level, including adapting a healthy diet, regular exercise, and being a healthy weight [7]. Medications are also prescribed in order to keep blood sugar in check for people with diabetes as well as in prevention [8], [9]. In Indonesia, people often utilize herbal remedies for its various health benefits which includes lowering high blood sugar. Various herbal plants have been believed to have benefits in controlling high blood glucose levels based on

anecdotal evidence [10]. In the modern age, more herbals are being analysed scientifically to determine whether herbal plants are indeed able to manage blood sugar levels [11].

Cymbopogon citratus and *Zingiber officinale,* or more commonly known as lemongrass and ginger respectively are examples of popular plants that have been utilized in Indonesia to flavour food as well as ingredients used in beverages, they are often used together due to their complementary flavour profile. They are also believed to have health benefits and one of them is in lowering high blood sugar levels. The long history of usage for both species as food and medicinal treatment have also shown its potency in terms of safety. However, in order to commercialize a product with claims of controlling high blood sugar legally, there has to be scientific evidence to back up those claims [12]. Hence why it is important to provide research that supports its efficacy and safety.

Safety and efficacy are often a point of consideration in the commercialization of synthetic drugs. In the utilisation of lemongrass and ginger-based products with health claims, its safeness as well as its efficacy should also be evaluated.

2. METHOD

Papers included were searched using Google Scholar. The literature review includes how blood sugar control can benefit non-diabetic individuals, effect of glycemic levels in increasing or decreasing risk of diabetes, effect of glycemic levels in increasing or decreasing complications in PCOS patients, and types of population that are at a higher risk of developing diabetes.

For lemongrass and ginger safety and efficacy analysis, papers used were both in-vitro and in-vivo studies. In-vitro studies included the ⟨-amylase inhibitory and/or ⟨-glucosidase activity of *Zingiber officinale* and *Cymbopogon citratus* or its bioactive components in order to display its blood glucose lowering capability. For in-vivo studies, papers that were included showed that *Cymbopogon citratus* and *Zingiber officinale* or its bioactive compounds are able to significantly lower blood glucose levels or improve sensitivity.

If the level of reduction in blood glucose levels was not included in the study, it was determined by using the formula:

$$\% \text{ blood glucose reduction} = \frac{(Final - initial)}{Final x 100\%} \quad (1)$$

Notes:

Final : final blood glucose level of treated subject

Initial : blood glucose level before treatment or of untreated subject (depending on the study)

Insulin levels was also calculated the same way where:

Final : final insulin level of treated subject

Initial : insulin level before treatment or of untreated subject (depending on the study)

Calculation of HOMA-IR to display improvement in insulin sensitivity is also using the same formula:

Final : final HOMA-IR value of treated subject

Initial : HOMA-IR value before treatment or of untreated subject (depending on the study)

3. RESULTS AND DISCUSSION

3.1. Benefits of blood glucose control in healthy individuals

Blood sugar control is crucial in the prevention of type 2 diabetes [6], not only that, it has other health benefits as well. Blood sugar control can have an impact on mood and energy levels. This is shown in a study where participants that were put on low glycemic diets had lower fatigue, total mood disturbance, and depression symptoms compared to those put on a high glycemic diet [13].

Furthermore, in a study done by Levitan et al., in 2004, it is found that individuals with higher post challenge glucose levels is at higher risk of developing cardiovascular heart disease (CVD) compared to the group that had the lowest post challenge glucose levels, indicating non-diabetic hyperglycaemia may be a risk factor of CVD [14].

In relation to skin health, one of the possible side effects of insulin resistance and hyperinsulinemia is Acanthosis nigricans. Although often observed in people with diabetes, this condition may also affect relatively healthy people and may appear in kids, but it is more prevalent in adults [15]. A clinical trial done on a 27 years old male with obesity showed that improvement in insulin resistance through diet control helps with in treating AN [16]. In addition, in a review that looks at case reports and clinical trials, it was shown that the administration of metformin drugs is effective in the treatment of AN [17].

High glycaemic diets that lead to the large productions of insulin and insulin growth factors (IGF) may also exacerbate skin problems such as excess sebum production and acne [18]. Few studies have shown that a high glycemic diet that causes blood sugar spikes resulted in the increased production of acne and sebum production [19], [20]. The high levels of IGF are able to bind to the receptors in the pores enlarging the oil gland which elevates oil production and inflammatory mediators [19]. Moreover, this IGF also elevates the androgen hormones that also triggers the receptors in the pores [21]. Furthermore, some studies have shown that taking diabetic drugs, namely metformin, is able to lower blood glucose levels showed an improvement of acne in acne patients [22]. This indicates that people with acne or excessive oil production may benefit from controlling high blood sugar levels.

3.2. Benefits of blood glucose control in PCOS patients

Elevated levels of inflammation due to oxidative stress in the body directly causes the ovary to produce excess androgen [21]. Inflammation in the body may be triggered from diet such as glucose or increased adipose deposits in the abdominal region. Moreover, inflammation triggered by the ingestion of glucose is linked to insulin resistance [21]. It is important for PCOS patients to regulate blood sugar levels in order to prevent hyperglycemia.

To emphasize the importance of glycemic control, a 2015 research showed that hyperglycemia effects glutathione peroxidase activity, which indicates the increase susceptibility to oxidative stress in non-obese women with PCOS [23]. Moreover, oxidative stress is the marker for insulin resistance and testosterone levels [23].

In a 2019 study, the result showed that obese women put on glycemic control through a low glycemic diet exhibited an improvement in insulin sensitivity, hyperandrogenism, hirsutism, acne, and menstrual irregularities [24]. In a double-blind, placebo-controlled study of women with PCOS, the administration of metformin improved pregnancy rates and live-birth rates, it is also found that it showed an even more significant improvement in obese PCOS patients [25]. Moreover, acarbose, an alpha glucosidase inhibitor, is able to reduce testosterone, TG, and VLDL, and increase HDL in the treatment of PCOS as shown from a meta-analysis data [26].

Since insulin resistance is mainly caused due to poor blood sugar levels control, taking care of it may reduce the risk of PCOS in women [27]. Other than that, since up to 70% of PCOS patients have insulin resistance [27], it is also important for them to control their blood sugar levels in order to prevent serious complications such as the development of type 2 diabetes (Diamanti-Kandarakis & Dunaif, 2012).

3.3. Benefits of blood glucose control in people with higher risk of developing type 2 diabetes

Though everyone can benefit from controlling blood glucose levels to prevent type 2 diabetes, people who are obese, elders, or have a family history of diabetes are at higher risk to developing this disease hence they may obtain experience the benefit more significantly than those who doesn't have these conditions.

Several studies have shown obese or overweight people are at higher risk of developing insulin resistance making it difficult for them to control blood sugar levels [29]–[31]. According to a research, this is because in people who are overweight or obese, there is an excess in visceral fat and increased inflammation which are linked to insulin resistance [30]. This is further supported by another study that observed that there is correlation between weight gain in adults and insulin resistance mediated by visceral and liver fat [29].

Elders are at higher risk of blood sugar related diseases as with age, some people's ability to regulate blood sugar levels decline [32]. This is further supported by another study that looks at carbohydrate metabolism in elderlies, it was found that aging increases glucose intolerance [33]. Hence why it is important for elders to monitor their blood sugar levels, however, studies show elderlies may find it difficult to stay physically active [34]. This is where they may benefit from consuming herbal products to help lower high blood sugar levels.

It was also found in a study, that people who have a family history of diabetes also are at higher risk of developing said diseases, though the specific reason is not completely understood, it is mainly due to genetics [35]. Those who have family with diabetes should take measures necessary in order to control blood sugar levels [5]

3.4. Lemongrass in blood glucose control

Lemongrass also has shown promising AGI activity [36] and blood glucose lowering capabilities

[37]. Table 1 displays various studies done that analyses the effectiveness, mechanism, and also the method of the research of various parts of lemongrass in glycemic control.

Various lemongrass extracts and its bioactive components have shown their ability in lowering blood glucose levels significantly in studies done on both diabetic [38] and healthy animals [39] even though the results were often not significant. There are also several in-vitro studies displaying its AGI and AAI activities. In all relevant studies, the administration of lemongrass increased insulin sensitivity [37], [40]. In some studies, however, some found that the administration of lemongrass and its bioactive effects had an impact on either increasing [41] or decreasing insulin levels [40].

Upon a closer look at the research, it can be seen that in studies that reported a rise of insulin levels, its untreated diabetic control had insulin levels lower than non-diabetic control. The treatment only raised insulin levels closer to those of the control animals [37], [41]. Moreover, in the study where the healthy mice were given lemongrass, its insulin did not change significantly [37].

On the other hand, where the diabetic untreated animals had higher insulin levels above its healthy control counterpart, the administration of lemongrass decreased insulin levels that are high to begin with, bringing the value closer to control [40]. This may occur due to the effect of lemongrass in increasing insulin sensitivity, hence making the body require less insulin in signalling the cells [40]. These findings suggest that, depending on the type of diabetes, the body is able to respond accordingly to the effects of Cymbopogon citratus.

In the studies, there were no reported adverse effects observed towards the test subjects. Furthermore, the specific safety of Cymbopogon citratus can be seen on table 2. Based on toxicology reports, it can be concluded that lemongrass is indeed safe and has no adverse effects in long term use. Based on toxic levels of substances, Cymbopogon citratus is not near what is considered harmful. The amount of lemongrass consumed to have negative effects only happens at very high concentrations of it. Moreover, lemongrass has been used in various food and beverage products for a long time, and the National Agency of Drug and Food Control also considered it to be safe and allowed as ingredients in products [42]. So, it can be said that lemongrass is safe to be consumed over long periods

Table 1 Lemongrass blood glucose controlling capabilities

Preparation	Model	Mechanism	Efficacy	Dose	References
Aqueous extraction with heat	Healthy Mice	Hypoglycemic effect	Fasting blood glucose 26.1% lower than control	500 mg/kg day	[43]
Essential oil	In Vitro	⟨-amylase inhibition	IC50(maltose): 6.97 ⌈L/mL	-	[44]
Aqueous maceration	In Vitro	⟨-glucosidase inhibition	IC50 (sucrase): 132.89 mg/mL	-	[45]
Aqueous extraction with heat	In Vitro	⟨-glucosidase inhibition	IC50(sucrase): 14.46 mg/mL	-	
Aqueous extraction with heat, spray dried	In Vitro	⟨-glucosidase inhibition	IC50(sucrase): 18.22 mg/mL	-	
Spray dried	Diabetic Mice	Improve maltose tolerance	LG AUC: 14472 ± 3205 mg min/dl Control AUC: 24349 ± 2878 mg min/dl	4.33 g/kg BW	
		Improve sucrose and glucose tolerance	Sucrose LG AUC: 17037 ± 1875 mg min/dl Control AUC: 22739 ± 2343 mg min/dl Glucose LG AUC: 16034 ± 2045 mg min/dl Control AUC: 25530 ± 1924 mg min/dl	6.67 g/kg BW	
90% ethanolic maceration	Healthy Mice	Hypoglycemic	Blood glucose 23.58% reduced by day 30	200 mg/kg BW	[39]
Aqueous maceration	Healthy Mice	Hypoglycemic	Blood glucose 21.59% reduced by day 30	200 mg/kg BW	

50% methanolic maceration	In Vitro	⟨-glucosidase inhibition	73% sucrase inhibition at 0.02 mg/mL	-	[46]
Aqueous extraction with heat, pre-evaporation	In Vitro	⟨-glucosidase inhibition & ⟨-amylase inhibition	AGI: 100% sucrase inhibition at 0.3 g/mL AAI: 81.77% inhibition at 0.3 g/mL	-	[47]
Spray dried aqueous extract + maltodextrin + Arabic gum	In Vitro	⟨-glucosidase inhibition & ⟨-amylase inhibition	AGI: 61.69% sucrase inhibition at 0.3 g/mL AAI: 49.49% inhibition at 0.3 g/mL	-	
Aqueous maceration	In Vitro	⟨-glucosidase inhibition	IC50 (maltase): 302.27 mg/mL	-	[48]
96% ethanolic maceration	In Vitro	⟨-glucosidase inhibition	IC50 (sucrase): 8.74 mg/mL	-	
		⟨-glucosidase inhibition	IC50 (maltase): 18.93 mg/mL	-	
Aqueous extraction with heat of:					[49]
Fresh lemongrass	In Vitro	⟨-glucosidase inhibition	IC50 (sucrase): 17.93 mg/mL	-	
Dried lemongrass			IC50 (sucrase): 24.5 mg/mL	-	
Combined lemongrass and ginger extract			61.74% sucrase inhibition	-	
(Lemongrass 24.5 mg/mL and ginger 19.61 mg/mL, ratio 1:1)			57.77% maltase inhibition	-	
Aqueous extraction with heat:					[50]
Sterilized	In Vitro	⟨-glucosidase inhibition	33.9% sucrase inhibition	-	
Pasteurized			24.4% sucrase inhibition	-	
Pasteurized and refrigerated			69.5% sucrase inhibition	-	
Spray dried			No sucrase inhibition	-	
Aqueous maceration of:					[51]
Lemongrass roots	Dexamethasone induced diabetic mice	Reduce fasting and postprandial glucose levels	Blood glucose levels 21.8% lower by day 14	100 mg/kg day	
Lemongrass flower			Blood glucose levels 3.6% lower by day 14	100 mg/kg day	
Lemongrass tea	Diabetic Mice	Improve glucose tolerance, insulin sensitivity, β-cell functions and dyslipidemia Raise insulin to normal levels	Reduce Fasting and postprandial glucose levels (until 60.3%) Insulin levels 29.17% higher than diabetic control (DC)	250 mg/100 mL water	[37]
	Diabetic Mice		Reduce Fasting and postprandial glucose levels (until 60.3%) Insulin levels 31.35% higher than DC	500 mg/100 mL water	
	Healthy Mice	-	No significant effect	500 mg/100 mL water	
Extraction, dried, diluted in acetone	In Vitro	⟨-glucosidase inhibition & ⟨-amylase inhibition	AGI is at 1 mg/mL AAI in EC50	-	[52]
Acetonic extract			AGI: 70.55% AAI: 0.65 mg/mL	-	
Methanolic extract			AGI: 45.42% AAI: 0.31 mg/mL	-	
Ethyl acetate extract			AGI: 95.02% AAI: 1.2 mg/mL	-	
Hexane extract			AGI: 100% AAI: 1.3 mg/mL	-	
Essential oil	PX-47 induced diabetic rats	Improve insulin sensitivity, reduce insulin levels (closer to normal control)	Blood Glucose 29.65 % lower than diabetic control Insulin levels 12% lower than DC HOMA-IR 19.75% lower than DC	400 mg/kg BW	[40]

			Blood Glucose 47.31% lower than DC Insulin levels 14% lower than DC HOMA-IR 65.84% lower than DC	800 mg/kg BW	
Aqueous maceration (liquid)	Alloxan induced diabetic rats	Anti-hyperglycemia	Blood glucose 26.6% reduced	1.5 mL/100g BW	[53]
d-limonene	Streptozotocin induced DM1 rats	Raise insulin levels	Blood glucose 36.41% reduced after 28 days Insulin 36.3% higher than DC	50 mg/kg BW	[41]
Linalool	Streptozotocin induced DM rats	Anti-hyperglycemia	Blood Glucose 28.31% reduced	20 mg/kg BW	[54]
Limonene			Blood Glucose 25.65% reduced	20 mg/kg BW	
Linalool + Limonene			Blood Glucose 46.15% reduced	10 mg/kg BW	
Citral	Streptozotocin induced DM rats	AAI & Anti-hyperglycemia	Blood Glucose 26% reduced	16 mg/kg BW	[55]
Ethanolic extract	Streptozotocin induced DM hyperlipidaemic rats	Anti-hyperglycemia	Blood glucose 45.18% lower than control	1000mg/kg BW	[38]

Table 2 Lemongrass toxicology results

Toxicology	Toxic Level	Method	Reference
Acute oral toxicity: > 5000 mg/kg BW	>50<500 mg/kg	Healthy mice	[43], [56]
5 g/kg b. w. for the oral administration to rats*	-	Healthy rats	[57], [58]
LD50: 2500.20mg/kg	LD50: 50-500 mg/kg	Streptozotocin induced DM hyperlipidaemic rats	[38]

3.5. Ginger in blood glucose control

Ginger, similar to lemongrass, has been shown to have antidiabetic activity through alpha glucosidase inhibition and presence β-Sesquiphellandrene which increases insulin sensitivity [11], [36]. Table 3 shows literature review of the capability of Zingiber officinale in improving glycemic control.

Ginger and its bioactive components have consistently shown that they are efficacious in lowering blood sugar controls through various mechanisms and have AGI or AAI properties. Additionally, in several studies, it was shown that insulin sensitivity is improved through measurement of HOMA-IR [59]–[61]. The improvement in insulin sensitivity resulted in the lowering of circulating insulin levels as the cells no longer require as much insulin to be signalled [59]–[61].

Interestingly, in some cases, ginger also has an effect on increasing insulin secretion where the diabetic control had low insulin levels compared to its non-diabetic control [62]–[64]. The increase of insulin secretion is observed in studies done on diabetic rats or mice. The different result may be caused by the fact that some types of diabetes cause hypoinsulinemia, thus ginger and its bioactive properties were found to help repair this function. In a study by Samad et al., it was found that gingerol, a bioactive substance contained in ginger, improves insulin secretion through activation of GLP-1 and also regulating insulin granule exocytosis [62]. In addition, in the studies by Akhani and Samad et alThe insulin levels measured are postprandial insulin levels instead of fasting, which may be another reason for this contradicting results [62], [64].

Although most significant results are seen in diabetic animals, Zingiber officinale is still able to lower blood sugar levels in healthy [65] and obese [66] test animals, as well as, HF or HFHC diet mice [60], [61]. These findings suggest that ginger is able to benefit people who are healthy, overweight or obese, or have an unhealthy diet.

From the research, there were no reported negative effects of gingers and the toxicology results can be seen on table 4. The toxicology reports concluded that ginger is generally safe and only unsafe in very high amounts. Even though gingerol seems to be in the harmful range, however the amount of gingerol present in ginger is very little with 75.25mg/100g fresh weight [67]. Hence the daily consumption of *Zingiber officinale* is deemed safe. Moreover, based on the database of the National Agency of Drug and Food Control of Indonesia (BPOM), there are also various products both registered as food and herbal medicine

containing *Zingiber officinale* that is consumed on a daily basis [68]. Thus, it can be said that ginger is safe to be used in food and drinks for daily consumption.

Table 3 Ginger blood glucose controlling capabilities

Preparation	Model	Mechanism & Actives	Efficacy	Dose	References
Ethyl Acetate Extraction	In vitro	Gingerol (17.22%) and Shogaol (0.72%) α-glucosidase inhibition anti-inflammatory	AGI: IC50 = 1⁄4 980.21 mg/ml Anti-inflammatory: IC50 = 145.04 mg/ml	-	[69]
Methanolic Extraction	Obese mice	Improve insulin sensitivity Decrease insulin levels	Blood glucose 20.6 % lower than control	250mg/kg p.o.	[66]
Ethyl Acetate Extraction	Obese mice		Blood glucose 17.8% lower than control		
Aqueous cold maceration, Freeze drying	Streptozotocin induced diabetic rats	Increase peripheral utilisation of glucose, correct impaired liver and kidney glycolysis, limit gluconeogenic formation	Blood glucose 67.85% lower by 30th day	500 mg/kg	[70]
Ethanolic extract	Healthy and streptozotocin induced diabetic rats	Anti-hyperglycemia	Maximum blood glucose reduction of 50.25% & 53.14% in healthy & diabetic rats respectively	800 mg/kg p.o.	[65]
Ginger juice	Streptozotocin induced diabetic rats	Inhibit 5-HT-induced hyperglycemia and hypoinsulinemia	Postprandial blood glucose 23.2% lower and insulin levels 41.1% higher than diabetic control	4 mL kg^{-1}	[64]
Ginger Powder	Streptozotocin induced diabetic rats	Prevent hypoinsulinaemia and hyperglycemia	Blood glucose 52% lower and insulin levels 25% higher than diabetic control	200 mg/kg body weight	[63]
Isolated [6]-Gingerol from ethanolic extract	DM type 2 mice	[6]-Gingerol Improve glucose tolerance and inhibit rise of postprandial glucose levels	Fasting blood glucose 54.8% lower than diabetic control by day 12 Plasma insulin concentrations 46.2% lower than diabetic control by day 12 Blood glucose AUC 40.5% lower than diabetic control by day 12	100 mg/kg body daily	[71]
Dried Ginger in Capsule	32 diabetic Male Patient (40-60 years old)	Anti-hyperglycemia	Blood glucose 17% lower than control	500 mg/capsule	[72]
Aqueous Extraction with heat of:					[73]
Fresh Ginger	In vitro	α-glucosidase inhibition	IC50(sucrase): >47 mg/ml	-	
Dried Ginger	In vitro	α-glucosidase inhibition	IC50(sucrase): 19.61 mg/ml IC50(maltase):13.38 mg/ml		
Aquaeous Maceration of:					[74]
White Ginger	In vitro	Non-phenolic phytochemicals α-amylase inhibition α-glucosidase inhibition	AAI IC50: 3.14 mg/ml AGI IC50: 1.68 mg/ml	-	
Red Ginger	In vitro	α-glucosidase inhibition	AAI IC50: 3.51 mg/ml AGI IC50: 2.01 mg/ml	-	
[6] Gingerol isolated using ethanol	High fat diet mice	Improve insulin sensitivity	Fasting blood glucose 52% lower and plasma insulin 38% lower than untreated mice (closer to SD) HOMA-IR index decrease by 83.1%,	75 mg/kg	[61]
6-paradol	In vitro (Glucose utilization assay)	Promote glucose utilization Reduce postprandial glucose levels	Insulin absent EC50(3T3-L1 adipocytes): 65.4 μM EC50(C2C12 myotubes): 54.9 μM Insulin present	-	[75]

			EC50(3T3-L1 adipocytes): 53.2 μM EC50(C2C12 myotubes): 54.2 μM		
6-shogaol			Insulin absent EC50(3T3-L1 adipocytes): 63.9 μM EC50(C2C12 myotubes): 26.4 μM Insulin present EC50(3T3-L1 adipocytes): 41.5 μM EC50(C2C12 myotubes): 21.5 μM		
6-paradol	High fat diet mice		Fasting blood glucose 37.6% lower than untreated mice Postprandial glucose levels AUC 28.57% lower than untreated mice	33.75 mg/kg/day	
[6] Gingerol	DM type 2 mice	Enhance glucose-stimulated insulin secretion Increase glucose uptake in skeletal muscle	Postprandial blood glucose 46.4% lower than diabetic control Insulin secretion 40% higher than diabetic control	200mg/kg	[62]
Isolated [6]-Gingerol from ethanolic extract	High fat high carbohydrate diet (HFHC) mice and standard diet mice (control)	Increase AMPKα phosphorylation and total AMPKα in skeletal muscle tissue Prevent insulin resistance	Postprandial blood glucose 31% lower than untreated HFHC mice and 24.6% lower than control Circulating insulin levels 58.8% lower than untreated HFHC mice HOMA-IR 71.7% lower than untreated HFHC mice	200mg/kg	[60]
Dried Ginger in Capsule	DM type 2 patients	Reduce CRP and PGE_2 levels Improve insulin sensitivity Reduce insulin levels	Minor reduction in FPG, insulin levels 44.6% lower, HOMA-IR 54.8% lower than pre-treatment	800mg capsule twice a day before lunch and dinner	[59]

Table 4 Ginger toxicology results

Toxicology	Toxic Level	Model	Reference
LD50: 4525.5 mg/kg	LD50: >50<500 mg/kg	Streptozotocin induced diabetic rats	[70]
LD50: 1551 ± 75 mg/kg	LD50: >50<500 mg/kg	Healthy mice	[65]
Gingerol at 1 ng/ml to 100 μg/ml did not affect cell viability of 3T3-L1 cells	-	3T3-L1 pre-adipocytes cells	[71]
Minor gastrointestinal upsets, including eructation, heartburn, and indigestion	-	27 healthy humans	[76]
LD50: 10.25 g/kg BW (ethanolic maceration)	LD50: >50<500 mg/kg	Healthy mice	[77]
LD50: 11.75 g/kg BW (Aqueous maceration)			
6-gingerol LD50: 250 mg/kg BW	LD50: >50<500 mg/kg	Healthy mice	[78]
Shogaol LD50: 687 g/kg BW			

4. CONCLUSION

Constantly unmanaged blood sugar levels lead to high circulating insulin levels which may have an impact on skin health and also reduce insulin sensitivity over time leading to poor blood sugar regulation. Hyperglycemia caused by poor blood glucose levels regulation leads to increased risks in CVD, PCOS and type 2 diabetes and there are certain individuals who are at a higher risk of developing

these diseases. Not only to prevent diseases, improved glycemic control can also benefit skin health, mood, and energy levels. Hence, controlling blood sugar levels is able to benefit healthy individuals as well.

Lemongrass and ginger are proven able to lower blood sugar levels safely alongside having a comparable efficacy with common pharmaceutical medicine. Other than that lemongrass and ginger are also able to normalize insulin levels and improve insulin sensitivity.

ACKNOWLEDGMENTS

Special thanks to Swiss German University's staff and lecturers who helped in the making of this paper.

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