The effect of EKORMIN on rats with diabetes mellitus model: effectiveness on fasting blood glucose, MDA, and insulin levels

Pengaruh EKORMIN pada tikus model diabetes mellitus: efektifitas terhadap kadar gula darah puasa, MDA, dan insulin

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Abstract

Antioxidant use for additional diabetes mellitus therapy is growing, such as okra (Abelmoschus esculentus) and turmeric (Curcuma longa), which are rich in flavonoids and have beneficial effects on diabetes mellitus. This study aimed to determine the effects of okra turmeric extract (EKORMIN) on Fasting Blood Glucose (FBG), malondialdehyde (MDA), and insulin levels in diabetic rats. The research was conducted from December to January 2022 at PSPG UGM using experimental research with a pre-posttest-controlled group design. White male Wistar rats (n = 35) randomly grouped into five: negative control (STZ-NA), positive control (STZ-NA+metformin 1,8 mg/200 gBW), P1 (STZ-NA+EKORMIN low dose 130,5;110,5 mg/kgBW), P2 (STZ-NA+EKORMIN moderate dose 261;221 mg/kgBW), P3 (STZ-NA+EKORMIN high dose 522;442 mg/kgBW). The intervention lasted 14 days. Data analysis was performed using one-way analysis of variance statistical tests and post hoc follow-up tests. EKORMIN in all doses, EKORMIN reduced FBG and MDA levels and increased insulin levels ($p<0,05$). P2 and P3 were not significantly different from the metformin (PG) group ($p>0,05$). The decrease in FBG ($-167,05\pm2,8$ vs $-175,86\pm1,4$ mg/dL) and MDA levels ($-6,32\pm0,33$ vs $-7,98\pm0,07$ nmol/ml) P3 was higher than P2. Similarly for increased insulin levels ($121,47\pm3,03$ and $164,09\pm4,48$ pg/ml). EKORMIN was effective in reducing FBG and MDA levels and increased insulin levels in diabetic rats. EKORMIN has antidiabetic effects and has potential for type 2 diabetes mellitus treatment.

Keywords: Abelmoschus esculentus, curcuma longa, diabetes mellitus, MDA, insulin

Abstrak

Kombinasi terapi antidiabetes saat ini dengan antioksidan alami dalam mengelola diabetes mellitus belakangan ini terus berkembang. Okra (Abelmoschus esculentus) dan Kunyit (Curcuma longa), kaya akan flavonoid dan bermanfaat pada penanganan diabetes mellitus. Penelitian bertujuan untuk mengetahui efek ekstrak okra-kunyit (EKORMIN) terhadap kadar gula darah puasa, MDA dan insulin pada tikus diabetes. Penelitian dilakukan Desember-Januari 2022 di PSPG UGM dengan menggunakan design eksperimen pretest-posttest control grup. Tikus Wistar (Rattus norvegicus) putih jantan (n=35) dikelompokkan secara acak menjadi lima, yaitu kontrol negatif (STZ-NA), kontrol positif (STZ-NA dan metformin 1,8 mg/200gBB), P1(STZ-NA dan EKORMIN dosis rendah 130,5;110,5 mg/kgBB), P2 (STZ-NA dan EKORMIN dosis sedang 261;221 mg/kgBB), P3 (STZ-NA dan EKORMIN dosis tinggi 522;442 mg/kgBB) intervensi dilakukan selama 14 hari. Analisis data menggunakan uji statistik one way anova dan uji lanjut post hoc. Hasil, pemberian EKORMIN dengan variasi dosis dan metformin berhasil mengurangi tingkat GDP dan MDA juga menaikkan insulin ($p<0,05$) jika dibanding kontrol negatif. P2 dan P3 tidak berbeda dengan kelompok metformin (KP) ($p>0,05$). Rerata penurunan kadar GDP pada P2 dan P3 yaitu

-167,05±-2,8 dan -175,86±-1,4 mg/dL: MDA sebesar -6,32±0,33 dan -7,98±0,07 nmol/ml. Rerata penurunan tingkat insulin yaitu 121,47±3,03 dan 164,09±4,48 pg/ml. Kesimpulan, EKORMIN efektif dalam merendahkan GDP dan MDA serta menaikkan insulin pada tikus model diabetes. EKORMIN meiliki efek antidiabetes dan dapat dikembangkan dalam pengobatan diabetes mellitus tipe 2.

Kata Kunci: Abelmoschus esculentus, curcuma longa, diabetes mellitus, MDA, insulin

Introduction

Diabetes is a serious long-term condition that has a major impact on the lives and well-being of individuals, families, and communities worldwide. Diabetes is one of the top 10 causes of death and was estimated to cause four million deaths globally in 2017 (Collaborators, 2023). The prevalence of type 2 diabetes mellitus (DMT2) is estimated to be 10,5% (536,6 million people) in 2021, increasing to 12,2% (783,2 million) in 2045 worldwide (Sun et al., 2022). This global trend has made DMT2 an epidemic and accounts for 90% of the cases of diabetes mellitus worldwide (Center for Disease Control, 2020). The Ministry of Health's Basic Health Research report in 2018 showed an increase of 2% compared to 2013, 8,5% or around 20,4 million people in Indonesia affected by diabetes mellitus; therefore, special treatment is needed to reduce the incidence of type 2 diabetes mellitus.

Diabetes mellitus is a chronic metabolic disease characterized by high blood glucose levels caused by impaired insulin secretion, either in action or function, or in many cases, both (Mahan et al., 2017). Endogenous insulin levels may be normal or elevated but may not be sufficient to overcome insulin resistance, resulting in hyperglycemia. Hyperglycemia can increase oxidative stress by increasing the production of Reactive Oxygen Species (ROS) via the electron transport chain in mitochondria, with changes in glucose and the end product of lipid peroxidation, namely malondialdehyde (MDA) (Onaolapo & Olakunle, 2018).

The increase in DMT2 occurs due to various risk factors, such as the transition from traditional diets to modern diets, which tend to be high in fat, salt, and sugar, and low in nutrient density (Ahmed et al., 2020). This chronic disease is particularly common in both low- and middle-income countries, and is supported by dietary transitions worldwide by increasing the instantaneous availability of food (Grout et al.,

2022). Patients with T2DM are more prone to both short- and long-term complications, which end in early death (Prigge et al., 2022).

Natural food is a rich source of antioxidant compounds and has been widely applied in the prevention of diabetes owing to its therapeutic properties, multitarget efficacy, and low toxicity (Hasanpour et al., 2020). Flavonoids are secondary metabolites in the plant kingdom that are commonly found anywhere. Flavonoids have various benefits including anti-inflammatory, antibacterial, anticancer, and antidiabetic activities (Aditama, 2020; Hay et al., 2019). Quercetin is a flavonoid found in okra (*Abelmuschus esculentus*), and curcumin in turmeric (*Curcuma longa*). Quercetin works by activating Adenosine Monophosphate Kinase (AMPK) in skeletal muscle, which stimulates Akt and GLUT4 receptors in the cell membrane. AMPK is a signaling molecule that regulates GLUT4 expression. Glucose enters the cells by diffusion and is facilitated by GLUT4 to be metabolized in the regulation of blood glucose levels (Dhanya, 2022). Mechanistically, curcumin reduced insulin resistance, weakened the expression of inflammatory cytokines, and increased the expression of antioxidant enzymes (Shao et al., 2012).

Okra (Abelmoschus esculentus (L.) Moench) contains quercetin, a flavonoid with antioxidant activity that can suppress the production of free radicals that cause oxidative stress. The ethanol extract of okra fruit is known to reduce lipid accumulation owing to the content of quercetin glycosides (Wu et al., 2020). Administration of okra extract at a dose of 100 mg/kg/day significantly lowered fasting blood glucose levels and increased GLUT-4 levels (Kmail et al., 2019). The quercetin compound in okra shows antioxidant activity by reducing free radicals, so that free radicals are captured and cause insulin receptors on β-cells to become active and effectively make glucose usable as energy in cells, resulting in decreased gluconeogenesis and decreased fasting blood

glucose levels (Salehi et al., 2020). Regulation of carbohydrate metabolism by polyphenols is due to increased glycolysis and glucose oxidation in the body, which increase glucose homeostasis and insulin resistance (Kang et al., 2020).

Turmeric (*Curcuma domestica L.*) contains approximately 80% curcumin, desmethoxycurcumin and approximately 12% bisdemethoxycurcumin. Curcumin, also known as diferuloylmethane, is a polyphenolic compound that acts as an antioxidant and anti-inflammatory agent and is effective against ROS. Curcumin administration to rats at 100 and 200 mg/kg BW resulted in a decrease in fasting blood glucose and profillipid levels and an increase in insulin levels (Shamsi-Goushki et al., 2020). Another study conducted by Sayeli and Shenoy (2021) by administering turmeric extract to STZ-NA-induced mice showed increased beta cell function and insulin sensitivity and decreased insulin resistance. Bioactive compounds have received considerable attention because they are regularly consumed in food and are an important source of safe and effective alternative medicines. In addition, bioactive compounds affect several biological functions including sustained insulin secretion and pancreatic islet cell regeneration (Unuofin & Lebelo, 2020; Zhao et al., 2017).

Various single bioactive compounds or in combination have shown increased anti-diabetic activity (Setiawan, Kertia, Nurrochmad, & Wahyuono, 2021). The therapeutic activity of many polyphenols is enhanced when administered in combination with other polyphenols. Quercetin and curcumin are two important polyphenols with high antioxidant activity (Tanaiyo, Wiboworini, & Rahardjo, 2023). A powerful combination of antioxidants positively controls hyperglycemia by activating the production and release of insulin into the blood. The ability of anti-inflammatory and antioxidant activity obtained from curcumin can be synergistically enhanced by combining with quercetin (Güran et al., 2019). Previous in vitro studies examining the combination of quercetin (100 mg) and curcumin (300 mg) have shown significant results in reducing fasting blood glucose by inhibiting NF-κB activation in cells (Hasan et al., 2022).

Traditionally, quercetin and curcumin have been used as therapeutic agents for various ailments and as flavoring compounds. The efficacy of okra as a vegetable is known to contain quercetin and is commonly consumed by rural people; however, the efficacy of okra, which has an anti-diabetic effect, is unknown. Follow-up in vivo research will be carried out to determine the effectiveness of the combination of quercetin from okra and curcumin obtained from turmeric in reducing fasting blood sugar levels and MDA and increasing insulin in type 2 diabetes mellitus rats.

Methods

This research is a laboratory experimental study using a pretest and post-test control group design. This study was conducted from December 2021 to January 2022 at the Laboratory of the Center for Food and Nutrition Studies, Gajah Mada University, Yogyakarta, Indonesia. Male white Wistar rats (Rattus norvegicus) were 8 weeks old and weigh 150-100 grams. Mice were acclimatized to laboratory conditions, with ad libitum access to food and distilled water, room temperature ranging from to 27-29°C, humidity 60-70%, and 12 hours light-dark cycle for 7 days before the intervention.

The mice were maintained on a standard AD2 feed. The diabetic rat model was achieved after five days of intraperitoneal (i. p.) induction with a single dose combination of streptozotocin (STZ) (65 mg/kg BW) and nicotinamide (NA) (230 mg/kg ((i.p). The sample for each group was determined according to the guidelines of the Institutional Animal Care and Use Committee (IACUC) (2002). The addition of 20% for each group was to avoid dropping out, so that the number of samples in each group was seven individuals with five treatment groups.

The total sample included 35 rats using simple random sampling. KN, namely the negative control group without intervention; KP, namely the positive control group that was given the drug metformin; P1 is a group of diabetic rats given low doses of EKORMIN 130,5:110,5 mg/kgBW/day; P2 is a group of diabetic rats given moderate doses of EKORMIN 261:221 mg/kgBW/day; P3 is a group of diabetic rats with high doses of EKORMIN 522:442 mg/kgBW/day. The intervention was performed using a gastric probe for 14 days. All

experimental procedures were approved by the Ethics Committee (No. Ethical Eligibility 99/UN27.06.6.2/KEP/EC/2021), Faculty of Medicine, Sebelas Maret University.

The dose was determined based on the effectiveness of quercetin in Asian people with type 2 diabetes mellitus, which is 80 mg/day (Chen et al. 2016). After adjusting the quercetin content in okra (5,5 µg/mg) and the experimental animal conversion factor (0,018), the okra dose was 261 mg/kg BW/day. Determination of the dose of turmeric is based on the effectiveness of curcumin in type 2 diabetes mellitus, which is 300 mg/day (Na et al, 2013). From the examination of curcumin levels in turmeric (24,4 µg/mg) and the conversion factor of experimental animals, the dose of turmeric was found to be 221 mg/kg BW/day. The middle dose of EKORMIN (261:221 mg/kg BW/day) is the dose that contains quercetin and curcumin equivalent to daily requirements, whereas the low dose is determined by reducing half of the middle dose and the high dose by doubling it. The daily dose of metformin consumed by patients with T2DM was 1×100 mg. The conversion factor for humans (70 kg) to rats (200 g) was 0,018. Therefore, the daily dose of metformin administered in the present study was 1,8 mg/200 g BW/day.

Measurements were carried out quantitatively using the Enzymatic Colorimetric Test Glucose Oxidase Phenol Amino-antipyrine Peroxidase (GOD-PAP) method in units of mg/dL. Blood sampling was performed through the retroorbital sinus. MDA levels were measured using the Thiobarbituric Acid Reactive Substances (TBARs) method with samples obtained from the medial canthus sinus orbitalis. The units used are nmol/ml. Blood samples were obtained from the retro-orbital sinus and analyzed using an ELISA kit. The units used were pg/ml.

The results of the normality and homogeneity tests showed that the data were normally distributed (p>0,05) except for insulin after the intervention, and the data variations were homogeneous (p>0,05) except for GDP after the intervention. Normally distributed and homogeneous data were analyzed using the parametric statistical test One Way ANOVA Post Hoc Tukey High Significant Difference (HSD), whereas heterogeneous data were tested using the Post Hoc Games Howell test. Data that were not normally distributed were tested using the Kruskal–Wallis nonparametric test. Differences in GDP, MDA and Insulin levels before and after intervention were tested using the Paired T-Test (normal distribution) and the Wilcoxon Signed Rank Test (non-normal distribution). Results are declared significant or there is a difference if the p value is <0,05.
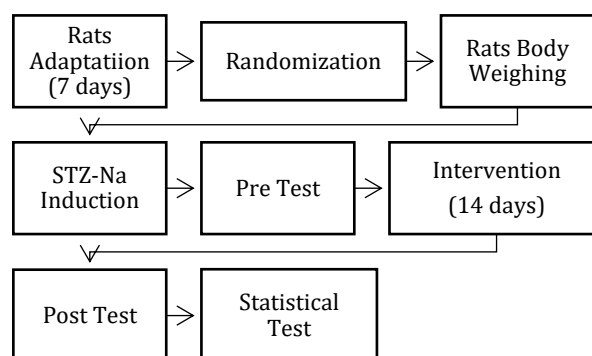

Figure 1. Research flow

Result and Discussion

Administration of low, medium, and high doses of EKORMIN for 14 days in diabetic rats affected FBG levels (Table 1). In this study, the EKORMIN group had decreased FBG levels, and there was a difference on day 14 compared to day 0 (p=0,001). The flavonoid compounds contained in okra-turmeric have antioxidant activity, which can reduce FBG levels in rats with diabetes mellitus (Table 1).

Quercetin works by inhibiting sucrase, intestinal maltase, and GLUT-2 to inhibit glucose absorption, resulting in a decrease in blood glucose (Tyagita et al., 2021). GLUT-2 plays a significant role in glucose homeostasis and is expressed in pancreatic and liver β cells. The curcumin content in turmeric is thought to work in increasing GLUT-2 expression to improve decreased GLUT-2 expression in the liver and pancreas of rats (Abd El-Aziz, Raslan, Afify, Abdelmaksoud, & El-Nesr, 2021).The decrease in blood glucose levels in this study is thought to be due to okra extract, which is rich in flavonoid hyperoside or quercetin, a flavanol glycoside compound (Hendri & Handayani, 2019; Yang et al., 2021). In addition, the okra seeds contained in okra fruit work by slowing glucose absorption or by inhibiting α-glucosidase in the rat intestine (Nguekouo et al., 2018). The curcumin content of

turmeric also acts as an antioxidant that protects cells from oxidative stress (Cas & Ghidoni, 2019).

The analysis concluded that the FBG levels on D-14 were significantly different in all treatment groups (p=0,001) where each treatment affected changes in FBG levels. Follow-up test analysis with Games-Howell's post hoc test showed no significant difference between the moderate dose (P2) and high dose (P3) EKORMIN groups and the metformin (PG) group (p>0,05). The results from the table above show that P2 and P3 were equally capable of reducing FBG levels in the DM rat model.

However, the administration of low doses of EKORMIN (P1) showed a decrease, but was not as effective as the other dose variation groups against the drug metformin (PG) (Table.2). The quercetin compounds in okra and curcumin in turmeric reduced fasting blood glucose levels due to their antioxidant content. Antioxidant enzymes (glutathione peroxidase, superoxide dismutase and catalase), as cellular mechanism, fundamentally play a significant role to protect cells from reactive free radicals. Therefore, antioxidant activity is of great relevance for the treatment of T2DM (Gulcin, 2020).

Table 1. The effect of EKORMIN on rats model DMT2

Category	Group	Median (Mean±SD)		Δ Mean±SD	p-value
		Day 0	Day 14		
Fasting Blood Glucose/FBG (mg/dL)	NG	264,96±4,61	267,36±5,23	2,4±0,62	0,005[a]*
	PG	267,29±5,28	91,86±4,18	-175,43±-1,1	0,001[a]*
	P1	264,51±4,64	116,05±4,62	-148,46±0,02	0,001[a]*
	P2	262,30±4,91	95,25±2,11	-167,05±-2,8	0,001[a]*
	P3	262,41±5,23	86,55±3,83	-175,86±-1,4	0,001[a]*
	p[b]= 0,325		p[c] = 0,001*		
Malondelhyde/MDA (nmol/ml)	NG	9,99±0,45	10,08±0,56	0,9±0,1	0,001[a]*
	PG	10,13±0,46	2,86±0,33	-7,27±0,13	0,001[a]*
	P1	10,01±0,29	5,09±0,32	-4,92±0,03	0,001[a]*
	P2	9,94±0,14	3,62±0,47	-6,32±0,33	0,001[a]*
	P3	10,28±0,31	2,30±0,24	-7,98±0,07	0,001[a]*
	p[b]= 0,416		p[b] = 0,001*		
INSULIN (pg/ml)	NG	399,02±7,84	408,58±40,65	9,56±32,81	0,001[e]*
	PG	398,57±10,42	527,63±7,84	129,06±2,58	0,001[e]*
	P1	394,02±8,77	487,59±4,49	93,57±4,28	0,001[e]*
	P2	391,14±8,93	512,61±5,90	121,47±3,03	0,001[e]*
	P3	389,17±8,31	553,26±3,45	164,09±4,48	0,001[e]*
	p[b]= 0,176		p[d] =0,001*		

Notes: NG: negative control; PG: positive control; P1: low doses of EKORMIN (130,5; 110,5) mg/kg BW; P2: moderate doses of EKORMIN (261, 221) mg/kg BW; P3: high doses of EKORMIN (522, 442) mg/kg BW; a) paired sample t-test; b) one-way ANOVA; c) one-way ANOVA post hoc Tukey test; *significant (p<0,05).

Based on Table.1, MDA levels in D-0 increased after STZ-Na induction. The results of the one-way ANOVA test showed the effect of reducing MDA levels in all groups after the intervention for 14 days, except for the NG group. MDA, which results from lipid peroxidation, is used as a biomarker of oxidative stress. The reaction between reactive oxygen species (ROS) and lipids is known as lipid peroxidation. MDA levels increase in response to oxidative stress, which is generally considered a pathological condition (Tsikas, 2017). DMT2 has been shown to increase free radical activity which is related to the development of insulin

resistance, besides that increased free radical activity will result in accumulation of lipid peroxidation which plays a role in the development of DMT2 (Barawade, Bhalerao, & Goudar, 2019). The effect of EKORMIN administration on MDA levels was due to the antioxidant compounds present in okra-curcumin (Table 1). The research conducted by Abdel et al. (2019) showed a synergistic effect of curcumin and quercetin in reducing excessive MDA production and maintaining the antioxidant capacity in tissues.

The contents of antioxidants, quercetin, and curcumin in EKORMIN have been shown to

reduce MDA levels. Based on Table 2. Further tests using post hoc Tukey 's difference (HSD), it showed that the medium- and high-dose groups (P2 and P3) did not differ in their ability to reduce MDA levels from the metformin (P2) group (p>0,05) in reducing MDA levels. The P3 group with the highest dose variation was able to reduce MDA levels by (2,30 ± 0,24 nmol/ml) when compared to metformin (2,86 ± 0,33 nmol/ml). Treatment in the P2 group showed a lower reduction in MDA levels (3,62 ± 0,47 nmol/ml) compared to the P1 group of (5,09 ± 0,32 nmol/ml). The combination of the two compounds (curcumin and quercetin) has anti-inflammatory activity against MDA as an antidote to free radicals and inhibits oxidative enzymes and oxidative metals (Setiawan et al., 2021). The phosphoinositide 3-kinase (PI3K)/protein kinase B (AKT) pathway is stimulated and the expression of nuclear factor erythroid-2 (Nrf2) is increased as part of the working mechanism of quercetin in okra. Adequate curcumin acts as an anti-apoptotic protein and regulates the PI3K/protein kinase B (AKT) signaling pathway in the liver (Liao et al., 2019; Xia et al., 2020). Other studies have shown that polysaccharides from okra extract can reduce MDA and ROS and increase GSH-Px, CAT, and SOD in the liver (Liao et al., 2019). Studies

using curcumin have also shown a decrease in MDA and recovery of GPx and SOD (the two main antioxidant enzymes), which are present in the pancreas of DM rats (Duan et al., 2022).

Based on Table 1. This shows that there was a difference (p=0,001) on D-14 compared to D-0, indicated by increased insulin levels after treatment. Administering EKORMIN to control insulin levels is due to the quercetin content in okra which has ability in reversing the dysfunction of pancreas which leads to the damaged islet cells regeneration (Majd et al., 2018; Uadia et al., 2020). Another study showed that inducing STZ in diabetic rats and feeding them an okra-based diet can lead to a significant increase in insulin secretion, where the content of quercetin in okra successfully reversed pancreatic dysfunction, which accelerated the regeneration of damaged β-cells. It is known that okra is rich in fiber and mucus which forms a thick gel to bind glucose and lipids in inhibiting absorption in the intestinal mucosa into the blood (Prabhune et al., 2017). Flavonoid compounds in turmeric have an antioxidant effect in DMT2 rats administered with curcumin for 14 days. This effect of curcumin is mediated by increased insulin receptor sensitivity and secretion (Pourmahmoudi et al., 2021).

Table 2. EKORMIN's intervention follow-up test on fasting blood glucose, MDA and insulin

	PG (-)	NG (+)	P1	P2	P3
Fasting Blood Glucose					
PG (+)	0,001*		0,001*	0,184	1,000
P1	0,001*	0,001*		0,001*	0,001*
P2	0,001*	0,184	0,001*		0,001*
P3	0,001*	1,000	0,001*	0,090	
MDA					
PG (+)	0,001*		0,001	0,050	0,172
P1	0,001*	0,001*		0,001*	0,001*
P2	0,001*	0,050	0,001*		0,001*
P3	0,001*	0,172	0,001*	0,001*	
INSULIN					
PG (+)	0,001*		0,001*	0,676	0,001*
P1	0,005*	0,001*		0,004*	0,001*
P2	0,001*	0,676	0,004*		0,001*
P3	0,001*	0,001*	0,001*	0,001*	

Notes: P1: Low doses of EKORMIN (130,5; 110,5) mg/kg/day; P2: moderate doses of EKORMIN (261; 221) mg/kg/day; P3: high doses of EKORMIN (522; 442) mg/kg/day. *) significant (p<0,05).

The increase in insulin levels is suspected to be due to the strong antioxidant potential and the quercetin content contained in EKORMIN (Table 1). Research

conducted by Wu et al., (2020) found that the high quercetin content in okra can inhibit α-glucosidase and α-amylase in counteracting metabolic changes and is

responsible for modulating insulin in DMT2 (Amadi et al., 2021).

The analysis revealed significant differences (p= 0,001) after the administration of metformin, EKORMIN P1-P3 with various doses of intervention. Insulin is essential in several tissues such as muscle, adipocytes, and liver through the redistribution of the glucose transporter (GLUT4) to regulate insulin-stimulated glucose transport in adipose tissue and skeletal muscle. Insulin sensitivity is the ability of insulin to reduce blood glucose concentrations by stimulating glucose to be used in adipose tissue and muscle, and suppressing glucose production in the liver (Yaribeygi et al., 2020). Quercetin content in okra can increase GLUT4 expression on the surface membrane of mouse skeletal muscle cells, thereby increasing insulin secretion and insulin sensitivity (Husen et al., 2019). GLUT4 expression in the skeletal muscle is stimulated by the administration of quercetin through Adenosine Monophosphate-activated Protein Kinase (AMPK) activation, which increases glucose uptake by translocating GLUT4 to cell membranes (Reckzeh & Waldmann, 2020). Research using turmeric has found that curcumin content significantly regulates GLUT4 gene expression in comparison with the diabetes control group (Rahmani et al., 2018). This study only tested the effect of the okra-turmeric combination by examining the levels of GDP, insulin, and MDA in T2DM Wistar rats. Among the limitations of this study, the toxicity test of the okra-turmeric combination was not conducted in T2DM Wistar rats.

Conclusion

Low, medium, and high doses of EKORMIN for 14 days significantly reduced FBG and MDA levels, and increased insulin levels. High-dose EKORMIN (P3) 522:442 mg/kg BW is a dose with the same strong effect in reducing FBG, MDA, and increasing insulin levels, and has comparable effectiveness with metformin (PG). Further research is needed to examine pancreatic histology and further comprehend the efficacy and safety of EKORMIN as an alternative therapy for humans.

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