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EVALUATING THE EFFECT OF A COMBINATION OF BLACKBERRY AND STRAWBERRY JUICES ON STZ-INDUCED OXIDATIVE STRESS OF DIABETIC RATS

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ABSTRACT

This investigation aims to examine the effect of a newly combination of blackberry and strawberry juice on diabetic rats. Fifty rats were used and divided into five groups, 10 rats for each group. The groups were divided as follows: The first groups a control group (NC), The second groups a group that took a combination of blackberry and strawberry juices (B+S) only, and a third group injected with streptozotocin (STZ): the fourth and fifth groups of diabetic rats were treated with a combination of juices (STZ+B+S) and metformin (STZ+Met), respectively. The experiment lasted 56 days; estimates were made on serum, liver homogenate, and histological examination of liver tissues at the end. The results showed that diabetic rats had significantly higher levels of glucose metabolism enzymes, tumor necrosis factor-alpha (TNF-α), interleukin 6 (IL-6), and significantly lower levels of hepatic antioxidants. Compared to the STZ group, diabetic rats given a combination of juices showed significant improvements in glucose metabolism enzymes, IL-6, and TNF-α levels, as well as significant increases in antioxidant enzyme activity. The results indicate that a combination of blackberry and strawberry juices can be a functional food that helps reduce diabetes complications.

Key words: blackberry, strawberry, streptozotocin, IL-6, and TNF-α

INTRODUCTION

Hyperglycemia, brought on by the lack of or insufficient insulin incorporation, alters glucose synthesis and is a hallmark of diabetes mellitus. Evidence from the past suggests that insulin's ability to enhance glycolysis is crucial for maintaining glucose homeostasis and facilitating normal plasma levels (**Ono ,2008**). Similar insulin decreases and glucose levels were also observed in STZ-induced diabetic rats (**Ajiboye *et al.,* 2018**). Hyperglycemia caused by defects in insulin action, insulin secretion, or both typifies the metabolic disease known collectively as diabetes mellitus. Epidemic levels of diabetes have made it one of the world's leading health concerns (**Lin *et al.,* 2020**). Patients with diabetes are at an increased risk of developing rapid atherosclerotic micro- and macro-vascular disease due to hyperglycemia (**Wright *et al.,*2006**). These side effects strain society and the economy in the long run due to diabetes, and they're the main cause of death from the disease **(King *et al*., 2010).** Diabetes impairs two main processes: insulin action and secretion, and hyperglycemia exacerbates this impairment by increasing oxidative stress. In addition, oxidative stress may be exacerbated because diabetic patients have impaired antioxidant mechanisms (**Rains and Jain, 2011).** There is mounting evidence that oxidative stress contributes to the etiology of diabetes and its complications (**Brownlee, 2001**).

There is a growing request for diet supplements that are now made using different fruits, veggies, and herbs to provide natural curative and preventive methods for combating diseases and poor health (**Abbas *et al.,* 2015**). Humans have consumed fruits and fresh vegetables for centuries. They have low energy content and are an important method of obtaining sugars, minerals, amino acids, fiber, vitamins, and antioxidants (**Bressy *et al.,* 2013**). **Oyebode *et al.,* (2014)** proved that increased consumption of fruits and vegetables is known to reduce cases of cancers, inflammatory, immunomodulatory effects, and cardiovascular mortality. They may contain phytochemicals such as polyphenols, coumarins, carotenoids, alkaloids, vitamins, and minerals. Antioxidants play a crucial role in inhibiting hydrolytic and oxidative digestive enzymes, providing anti-inflammatory effects, and participating in other natural or medicinal activities, including scavenging dangerous reactive oxygen species (**Sachdeva *et al*., 2014**).

The current study aimed to evaluate the potential of a combination of blackberry and strawberry juice as an antioxidant, anti-inflammatory, and anti-hyperglycemic agent.

MATERIAL AND METHODS

2.1. Strawberry and blackberry juice preparation

Blackberries and strawberries were purchased from Minia-Egypt. Fruits were rinsed and blended separately in an electric blender (Philips, China), filtrated by a piece of double layer gauze, and immediately diluted with distilled water to a volume of 1:1 then filtered twice using a double layer gauze to eliminate cellular material and produce a clear natural juice, and stored at -20°C until use.

2.2. Experimental Animals

Fifty male albino rats weighing (150±5 g) of eight weeks old were housed in well-ventilated plastic cages in the animal house of the Faculty of Agriculture, Minia University. A constant light/dark cycle of 12 hours was used with all the rats. One week was used to acclimate the rats to their environment before they were treated. All the animals were fed a commercially available diet and given access to water at will. The experiment was carried out according to the Ethical Committee at Faculty of Agriculture, Minia University (Ethics approval number 0.0.6.1.2.2).

2.2.1. Diabetes induction and experimental protocol

By injecting 50 mg/k_g of freshly prepared STZ (0.09 M cold citrate buffer, pH 4.8) intraperitoneally (IP), we induced diabetes in rats that had fasted overnight. After injecting STZ into the rats, we gave them a 5% glucose solution (10 ml/rat) for 24 hours to prevent their initial death from hypoglycemia. In the control group, rats were injected intraperitoneally with a vehicle solution of the same volume (0.5 ml per rat) (0.1 M citrate buffer, pH 4.5). Following STZ administration, rats were evaluated at 2, 5, and 7 days to determine if diabetes had been successfully induced. The glucometer readings were based on blood samples from tail veins (Bionime GM300). To qualify as diabetic, the blood glucose level in these rats had to be over 250 mg/dl.

Rats were randomly assigned into five experimental groups (n = 10). The treatment protocol was lasted for 56 days and was as follows:

NC group: Rats received a single injection of 0.5 ml of 0.1 M citrate buffer and 0.5 ml of saline once daily for 56 days.

B+S group: Rats received a combination juices (B+S, 4.5 mL +4.5 mL/ Kg. b. wt); respectively once daily by an oral tube for 56 days **(Ismail *et al.*,2014).**

STZ group: Rats were given a single (IP) injection of 50 mg/kg. b. wt of STZ in citrate buffer.

STZ +B+S group: diabetic rats received a combination juices (4.5 mL+4.5 mL mg/Kg. b. wt, respectively) orally by an oral tube for 56 days.

STZ +Met group: diabetic animals received Metformin (500 mg/ Kg. b. wt) by an oral tube for 56 days **(Luo *et al.*,2020).**

At the end of the study (56 days), the rats were allowed to fast overnight before being sacrificed. A rat's retro-orbital vein plexus was used to get blood samples. The blood was left to coagulate and then centrifuged for 15 minutes at 3000 g to separate the serum. The serum was taken and kept at -4°C until it could be analyzed biochemically. Then, rats were euthanized, and liver was removed and cleaned with filter paper.

2.2.2. Blood glucose

The blood glucose level of rats was measured using a one-touch glucometer (Accu check Roche, Germany).

2.2.3. Biochemical analyses

Serum liver enzymes alanine amino transferase (ALT) and aspartate amino transferase (AST) levels were chemically determined according to the methods of **(Reitman and Frankel ,1975).** Serum protein, albumin levels were determined according to the methods of **(Trinder ,1969).** Serum globulin was calculated **(Friedewald *et al.*,1972)** Serum total lipids **(Zöllner and Kirsch, 1962)**, triglycerides (TG) **(Friedewald *et al.*, 1972),** total cholesterol (TC) **(Fossati and Prencipe, 1982)** and high-density lipoprotein (HDL) (**Lopes-Virella *et al.* 1977a**) were chemically determined. Very low-density lipoprotein (VLDL) (**Lopes-Virella *et al.* 1977b**) and Low-density lipoprotein (LDL) were calculated (**Fossati and Prencipe, 1982).**

2.2.4. Estimation of liver biochemical parameters:

A portion of liver tissue was homogenized in phosphate-buffered saline (PBS) (pH 7.4). By centrifugation (1000 rpm for 20 min at 4 °C), supernatant was obtained, according to **Hasona *et al.* (2017).** It used homogenates to measure the levels of malondialdehyde (MDA), catalase (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GPx) were measured using assay kits according to the manufacturer's instructions.

Glucose-6-phosphatase activity, insulin level, hepatic glycogen content, and glucokinase activity were estimated using the methods of **Brandstrup *et al.* (1957)**, **Ojo *et al.* (2017), Harper (1959), Roe and Dailey (1966),** respectively, in the liver homogenate.

The levels of pro-inflammatory cellular tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) were measured by following the manufacturer's instructions using a test reagent kit (CUSABIO Company, 7505 Fannin St 610-312, Houston, TX 77054, USA) in liver homogenate.

2.2.5. Histopathology

Another part of the liver was fixed in a 10% neutral buffered formalin solution for at least 24 hours, after which they were dehydrated in a series of ethanol concentrations, cleared in xylene, and finally embedded in paraffin. The tissue was sectioned to a thickness of 5 µm. Histopathological changes were analyzed using a light microscope after being stained with hematoxylin and eosin (H&E), as described by **Suvarna *et al.* (2019).**

2.3. Statistical analysis

Statistical analysis was performed using the SPSS statistical software (version 17, SPSS Inc. Chicago, IL, USA), and the results were expressed as the mean ± standard error (SE). Using one-way ANOVA, the data were analyzed. Differences between the groups were statically significant at $p < 0.05$.

RESULTS AND DISCUSSION:

The body cannot function normally without the help of the foods we eat and the nutrients they contain. Several chronic disorders, including colon cancer, obesity, diabetes, and diverticulosis, can be prevented with proper nutrition. Some success in treating and controlling these long-term conditions has also been described (**D'Archivio *et al.*, 2010**).

This study aimed to investigate the effect of using a combination of blackberry and strawberries on blood lipids, liver lipid peroxidation (LPO) parameters, antioxidant enzyme activities, and inflammatory markers in diabetic rats.

3.1. Effect of a combination of blackberry and strawberry juices supplementation on Liver function in diabetic rats

Fig. 1 shows liver parameters in diabetic rats. It was observed that the untreated diabetic rats (STZ group) had a significant increase ($p < 0.05$) in ALT, total protein, albumin, AST, and globulin compared to the NC group. As reported by **Sharma *et al.* (2013),** similar results were found with increased levels of ALT and AST in diabetic rats compared to control rats.

The results revealed that rats with diabetes treated with a combination of strawberry and blueberry juice had a significant decrease ($p < 0.05$) in levels of ALT, total protein, albumin, AST, and globulin compared to the STZ group (Fig. 1). This improvement may be due to the high amount of phenolic and flavonoid compounds in the juice, which protect liver cells from damage.

3.2. Effect of hyperlipidemia in diabetic rats' supplementation on hyperlipidemia in diabetic rats:

As shown in Fig (2), streptozotocin-injected rats had significantly higher serum levels of total lipid, TG, TC, LDL-c, and VLDL-c significantly ($p < 0.05$) when compared to the NC group. In contrast to the STZ group, diabetic rats with oxidative stress who received a combination of strawberry and blackberry juice experienced a significant ($P < 0.05$) decrease in serum total lipids, TG, TC, VLDL-c, and LDL levels, and a rise in serum HDL as compared to the STZ group, as shown in Fig (2).

Our results showed that STZ induced hyperlipidemia. These findings are consistent with earlier research by **Atwaa *et al.* (2022). Ibrahim *et al.* (2018)** appeared that STZ increased TG, TC, LDL-c, and VLDL-c levels and reduced HDL-c levels in rats. Insulin deficiency promotes lipogenesis and reduces lipoprotein lipase activity, both of which impede the hydrolysis of triglycerides. This finding may explain why diabetic rats have higher than normal lipid levels.

Administration of blackberry and strawberry combination juices to diabetic rats elicited hypolipidemic activity. This improvement may be attributable to a juice ingredient that can normalize triglyceride levels and total lipids in diabetic rats. **Mroz *et al.* (2011)** stated that strawberry extract lowered LDL-c, VLDL-c, TG, and TC in rats fed fructose-enriched diets. The hypoglycemic and hypolipidemic impacts after receiving blackberry and strawberry juice are due to its content of polyphenols that stop the work of digestive enzymes (**McDougall *et al.*,2009 and Sandhu *et al.*,2015).**

3.3. Effect of a combination of blackberry and strawberries supplementation on hyperglycemia in diabetic rats:

According to Fig 3, diabetic rats that STZ induced had significantly elevated glucose levels in their blood compared to the NC group ($p <0.05$). Compared to untreated STZ-induced diabetic rats, the blood glucose levels of diabetic rats given a combination of blackberry and strawberries decreased significantly ($p <0.05$), as shown in Fig 3. Also, metformin treatment resulted in a statistically significant lower blood glucose level in the Met + STZ group compared to STZ group ($p<0.05$). But when the rats were given a combination of blackberry and strawberries, they showed greatly improved blood glucose and insulin levels.

Also, Fig. 3 showed that diabetic animals had significantly ($p < 0.05$) lower insulin, glucokinase, and glycogen levels than the control group. When diabetic rats were given a combination of blackberry and strawberries for 56 days, their insulin, glucokinase, and glycogen levels increased significantly ($p < 0.05$). In contrast, glucose-6-phosphatase levels were significantly ($p < 0.05$) higher in diabetic rats than in the control group. When diabetic rats were given a combination of blackberry and strawberry juice, their glucose-6-phosphatase levels returned to normal (Fig. 3). Reactive oxygen species are present in the liver since it is a key organ for metabolism and has undergone oxidative damage from diabetes mellitus (DM) (**Al-Ania *et al.*,2017)**.

Glucose is used as fuel by every cell and organ in the body, but an excess of it can have serious consequences. Blood glucose levels are controlled to prevent a wide range of complications that arise from hyperglycemia. Rats with diabetes induced by STZ respond favorably to oral administration of a combination of blackberry and strawberry juice, which reduces blood glucose levels. The high concentration of alkaloids, flavonoids, and saponins in the juice may have contributed to their potent antihyperglycemic activity in diabetic rats (**Gad-Elkareem *et al.*, 2019**). These compounds may have acted synergistically or independently as insulin release stimulants or by inhibiting glucose absorption in the intestine after the juice repaired pancreatic β-cells.

Glucose is stored in the human body in the form of glycogen. Therefore, the glycogen level in the liver is a direct indicator of insulin activity. This is due to the role of insulin in stimulating glycogen synthase and inhibiting glycogen phosphorylase, which promote intracellular glycogen deposition (**Ajiboye *et al.*, 2018**). The current study reports a significant decrease in liver glycogen levels in diabetic rats due to insufficient insulin secretion. In contrast, diabetic rats given a combination of blackberry and strawberry juice showed an improvement in glycogen levels due to increased insulin secretion.

Naik (2010) suggested that insulin stimulates the liver to store glucose as glycogen by inhibiting the activity of glucose- 6-phosphatase. Glucose-6-phosphatase is an important key enzyme involved in glycogenolysis and gluconeogenesis. Therefore, increased gluconeogenesis during diabetes mellitus may account for the uptick in glucose-6-phosphatase activity in diabetic rats **(Ajiboye *et al.*, 2018).**

3.4. Effect of a combination of blackberry and strawberries supplementation on lipid peroxidation and antioxidant enzymes activities in diabetic rats:

Figure 4 showed that the activity of the superoxide dismutase (SOD) decreased significantly ($P < 0.05$) in diabetic animals compared to the NC group. Rats with diabetes may have lower SOD activity because they produce more reactive oxygen radicals, which can slow down the activity of this enzyme (**Wohaieb and Godin, 1987**). SOD is a vital defense enzyme that turns superoxide into H_2O_2. A decrease in the activity of this enzyme in diabetic rats may have serious consequences. In contrast, diabetic rats given the juice (STZ + B + S group) had significantly higher SOD levels compared to untreated diabetic rats (STZ group), indicating that these higher levels are indicative of protection against tissues damage. Thus, this mixture of juices can help prevent complications related to diabetes.

The results presented in Figure 4 showed that the levels of CAT were higher in normal control rats and the combination juice group, while they were lower in the STZ group. The treatment diabetic rat with juice increased CAT levels comparing with STZ group.

Fig 4 showed also that the glutathione peroxidase (GPX) levels in diabetic rats were significantly lower compared to the normal control group. Compared to the diabetes control group, GPX levels were significantly higher in diabetic rats treated with a combination of blackberry and strawberry juice (STZ) (Fig. 4). The concentration of malondialdehyde (MDA) significantly ($P<0.05$) increased in diabetic rats compared to the normal control group. When compared to diabetic rats (STZ group), diabetic rats given a combination of blackberry and strawberries had lower MDA levels ($P < 0.05$), as shown in Fig 4.

The MDA can be used as an index of LPO **(Naik, 2010).** Our results agree with the results of **Rigoulet *et al.* (2011)**, who showed that the level of MDA was higher in diabetic mice compared to the control group. The high MDA level in DM may indicate the peroxidative reactions in lipids caused by high blood sugar **(Hunkar *et al.*, 2002).** Fruits support the body's natural defenses against damage from free radicals by making antioxidant enzymes work better, lowering lipid peroxide levels, and protecting the liver and kidneys from the bad effects of oxidative stress. The polyphenolic constituents in blackberry and strawberry juice may have antioxidant effects that reduce MDA levels and recover the liver from diabetic oxidative stress. The supplementation of blackberry and strawberries juices have been shown to reduce MDA levels. The findings are consistent with those of **(Ramos, 2007),** who suggested that dietary polyphenols play a role in mitigating the damaging effects of reactive oxygen species (ROS) on cancer by reducing MDA levels.

The results showed that CAT, GPx, and SOD activities were decreased in diabetic rats. In the present experiment, the severe reduction in liver CAT, GPx, and SOD activities is likely due to the enforced production of free radicals, which exceeds the scavenging potency of enzymatic antioxidants in diabetic rats. Diabetic rats that were given a combination of blackberry and strawberry juice for 56 days had much higher levels of antioxidant enzymes in their livers. This could be because polyphenols in blackberry and strawberries have antioxidant properties and may have a solid ability to eliminate free radicals. Thus, the present findings suggest that a combination of blackberry and strawberries might be beneficial for decreasing the oxidative stress associated with diabetes.

3.5. Effect of a combination of blackberry and strawberries on the production of TNF-α and IL-6 in diabetic rats:

Fig. 5 shows that streptozotocin (STZ) significantly increased the production of pro-inflammatory markers TNF-α and IL-6 in the liver compared to normal control rats ($P < 0.05$). Meanwhile, treatment with a combination of blackberry and strawberry juice was found to substantially lower these pro-inflammatory cytokine levels compared to the STZ group ($P < 0.05$). Results indicate that juice supplementation reduced inflammatory cytokine levels in rats with diabetes induced by STZ. The polyphenols in the combination of strawberry and blackberry juice have been shown to have anti-inflammatory effects by preventing oxidative stress and mitochondrial damage **(Marimoutou *et al.*, 2015)** and by scavenging free radicals, which enhances antioxidant enzyme activity. When NF-kB activity is suppressed, antioxidant effects are altered, making it more difficult for inflammatory cytokines to be expressed **(Yaman *et al.*, 2017).**

3.6.Histopathological examination of liver:

The livers of the rats in the control group showed typical histoarchitecture under a microscope (Fig. 6A). Furthermore, rats given a combination of blackberry and strawberry juice showed no histological abnormalities in their livers (Fig. 6B). In contrast, the livers of the rats in the STZ group showed signs of portal edema, necrosis in sporadic hepatocytes, vacuolar degeneration, activation of Kupffer cells, and thickening of the bile duct wall (as indicated by arrows in Fig. 6C). On the other hand, the livers of diabetic rats receiving metformin showed no histological changes (Fig. 6E), except for small vacuolation in a few hepatocytes in a few sections (as indicated by arrows in Fig. 6E). Additionally, the livers of diabetic rats given the juice combination showed only minor activation of Kupffer cells (as indicated by arrows in Fig. 6D).

Histopathological results in previous STZ-induced diabetes studies have shown necrosis in hepatocytes, infiltration of inflammatory cells, lipidosis, dilation of sinusoids, and disruptions in portal intervals **(Ahmed *et al.*, 2014)**. This investigation's rats in the DM group showed similar results. However, these outcomes were greatly diminished in the STZ+B+S and STZ+Met treatment groups. The livers of the rats in the STZ+B+S group were found to be comparable to those of the control group rats. These findings suggest that a combination of blackberries and strawberries may significantly reduce hepatocyte necrosis, degeneration, and infiltration of inflammatory cells, which are associated with the onset of diabetes mellitus.

CONCLUSION:

The results of the study indicate that the combination of blackberry and strawberries juices has clear and effective therapeutic and preventive effects on diabetic rats. This is because all evaluated biochemical parameters showed improvement compared to the control group, indicating that the combination has anti-inflammatory, antioxidant, and anti-hyperglycemic properties. As a result, the new combination can be relied upon as a food supplement with preventive capabilities, offering an alternative solution to the problem of high drug prices and unavailability in the market.

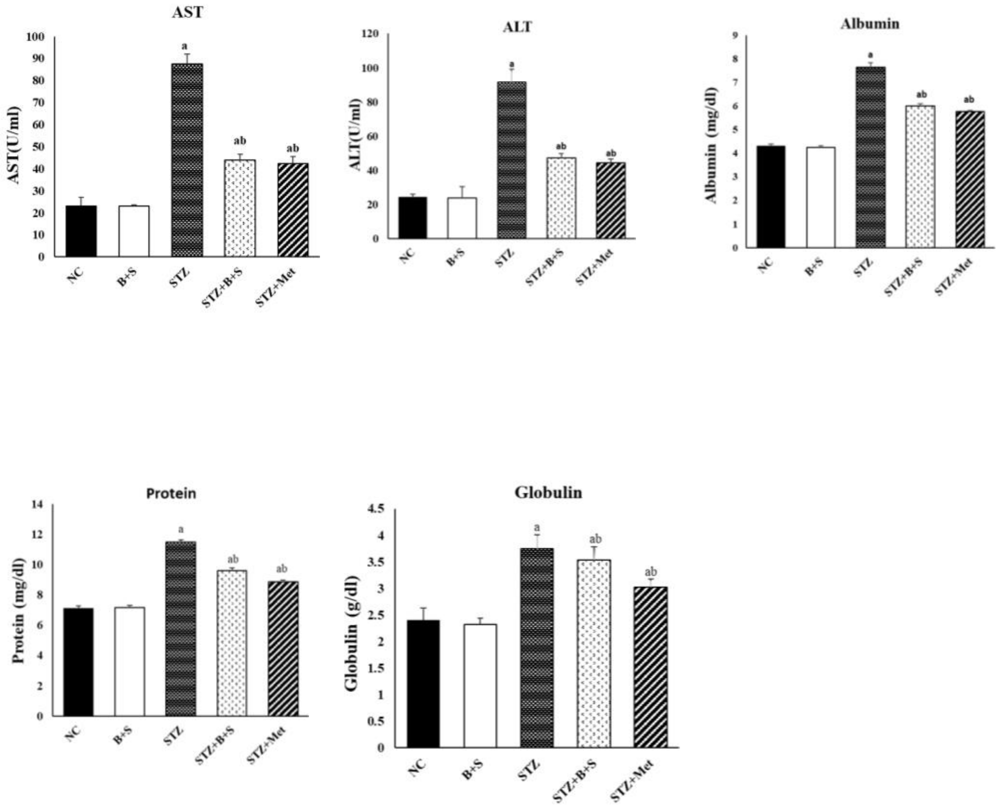

Fig 1: Liver function enzymes of the control and experimental groups.

Values are expressed as mean ± SE, n=10, [a] and [b] are significant at $p < 0.05$ in comparison of groups with normal and diabetic control groups, respectively. ***NC****: normal control* ***S+B****: Strawberry and blackberry,* ***Met****: Metformin.*

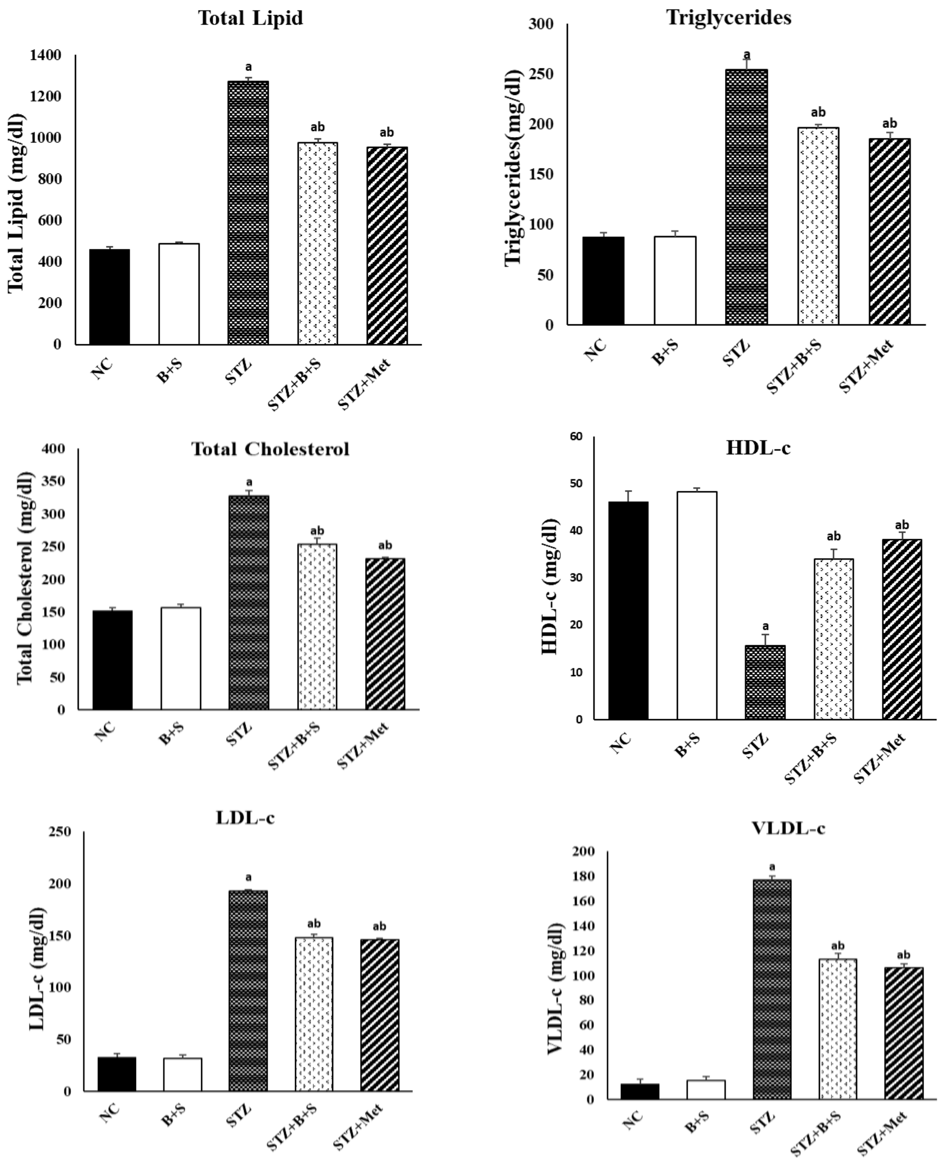

Fig (2): Lipid profile of the control and experimental groups.

*Values are expressed as mean ± SE, n=10, [a] and [b] are significant at $p < 0.05$ in comparison of groups with normal and diabetic control groups, respectively.**NC**: normal control **S+B**: Strawberry and blackberry, **Met**: Metformin.*

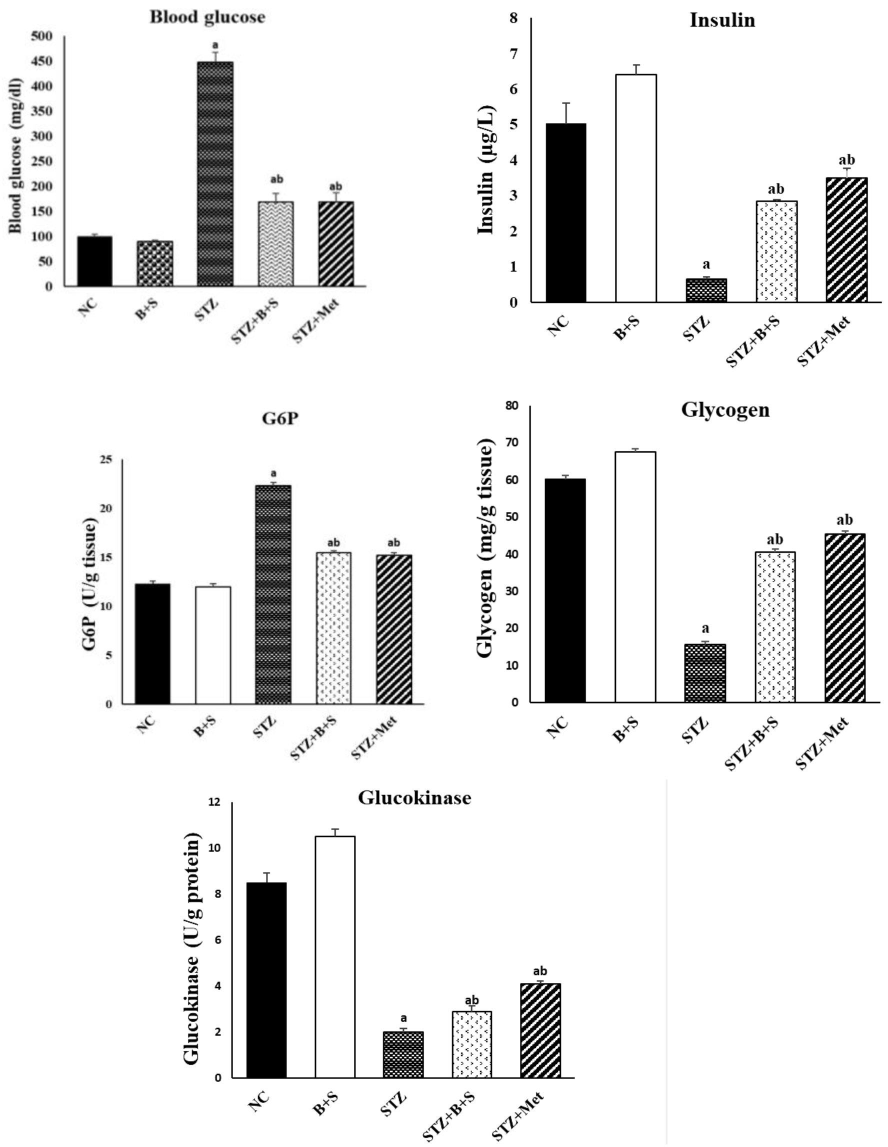

Fig (3): Glucose metabolism of the control and experimental groups.
*Values are expressed as mean ± SE, n=10, [a] and [b] are significant at $p < 0.05$ in comparison of groups with normal and diabetic control groups, respectively.**NC**: normal control **S+B**: Strawberry and blackberry, **Met**: Metformin.*

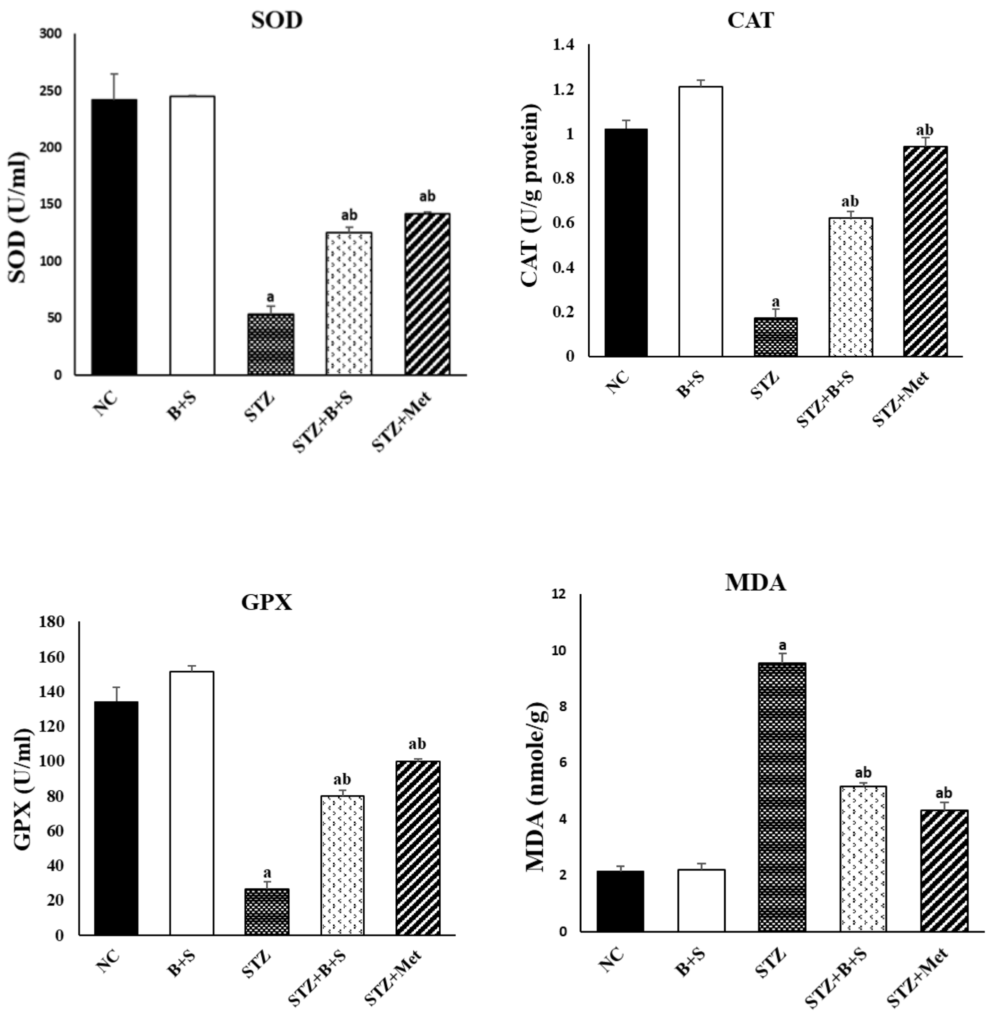

Fig (4): Lipid peroxidation and antioxidant enzymes activities of the control and experimental groups.

*Values are expressed as mean ± SE, n=10, [a] and [b] are significant at $p < 0.05$ in comparison of groups with normal and diabetic control groups, respectively.**NC**: normal control **S+B**: Strawberry and blackberry, **Met**: Metformin.*

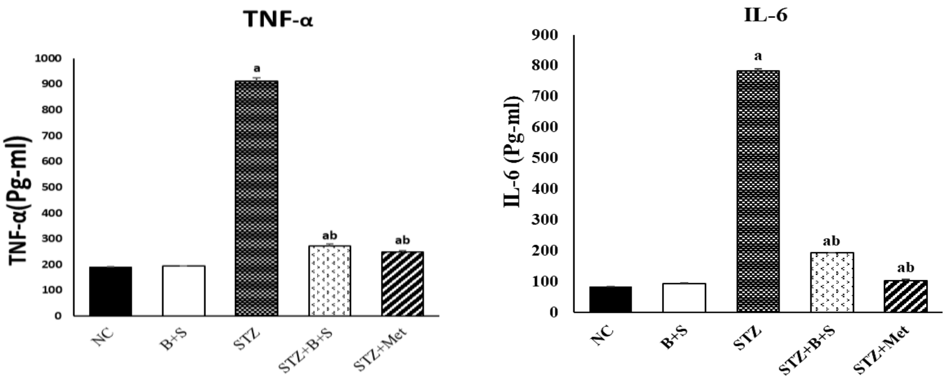

Fig (5): Effect of a combination of blackberry and strawberries on the production of TNF-α and IL-6 in control and experimental groups.

*Values are expressed as mean ± SE, n=10, [a] and [b] are significant at $p < 0.05$ in comparison of groups with normal and diabetic control groups, respectively.**NC**: normal control **S+B**: Strawberry and blackberry, **Met**: Metformi*

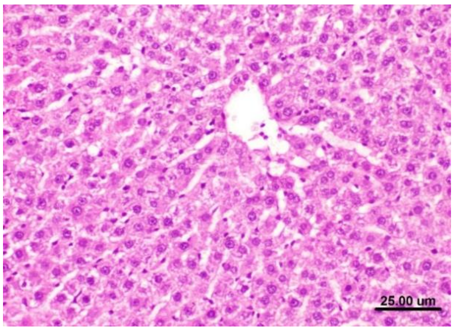

Fig. (6A): Photomicrograph of liver of rat from group normal control showing no histopathological lesions (H & E X 400, scale bar 25µm).

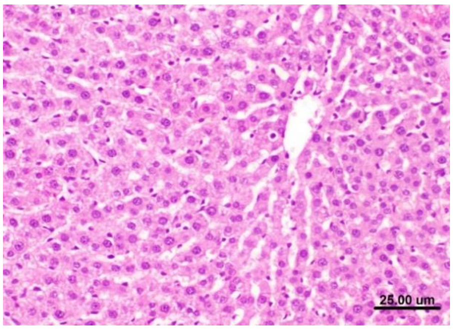

Fig. (6B): Photomicrograph of liver of rat from group B+S showing no histopathological lesions (H & E X 400, scale bar 25µm).

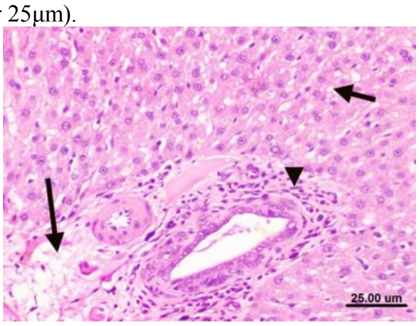

Fig. (6C): Photomicrograph of liver of rat from group STZ showing hepatocellular vacuolar degeneration, portal edema and thickening in the wall of bile duct (H & E X 400, scale bar 25µm).

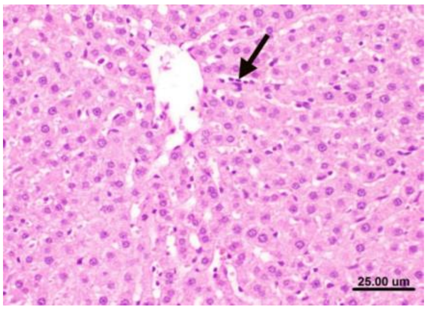

Fig. (6D): Photomicrograph of liver of rat from group STZ+B+S showing slight Kupffer cells activation (H & E X 400, scale bar 25µm).

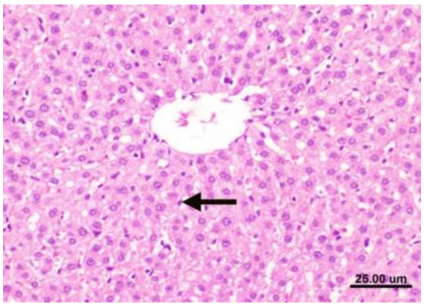

Fig. (6E): Photomicrograph of liver of rat from group STZ+ Met showing slight Kupffer cells activation (H & E X 400, scale bar 25µm).

Fig (6): Histopathological examination of liver

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الملخص العربي

تقييم تأثير مزيج من عصير التوت الاسود والفراولة على الإجهاد التأكسدي الناجم عن STZ للفئران المصابة بداء السكري

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يوجد العديد من الأشخاص المصابون بمرض السكرى الذي يسبب آثارا ضارة على صحة الإنسان. ثبت أن مرض البول السكرى يمارس آثاره على النظم البيولوجية من خلال توليد أو زيادة أنواع الجهد التأكسدي. الذي يسهم في العديد من الآثار البيولوجية. أشارت بعض الدراسات إلى أن مضادات الأكسدة منعت الآثار الضارة لهذه العوامل المدمرة على الجسم من خلال تدمير و / أو تقليل الجذور الحرة. التوت والفراولة هي مدمرة قوية للجذور الحرة.

يهدف هذا التحقيق إلى فحص تأثير مزيج حديث من عصير التوت الأسود مع الفراولة على الفئران المصابة بداء السكري. تم استخدام خمسين جرذاً وقسمت إلى خمس مجموعات بواقع 10 جرذ لكل مجموعة. تم تقسيم المجموعات على النحو التالي: المجموعة الضابطة (NC)، المجموعة التي تناولت خليط عصائر التوت والفراواة (B + S) فقط، والمجموعة الثالثة المحقونة بمادة STZ, المجموعة الرابعة والخامسة من الفئران المصابة بداء السكري عولجت بـ خليط العصائر (STZ + B + S) والميتفورمين (STZ + Met) ، على التوالي. استمرت التجربة 56 يومًا. تم عمل تقديرات على مصل الدم، تجانس الكبد، والفحص النسيجي لأنسجة الكبد في النهاية. أظهرت النتائج أن الفئران المصابة بداء السكري لديها مستويات أعلى بشكل ملحوظ من إنزيمات استقلاب الجلوكوز وعامل نخر الورم ألفا (TNF- α) والإنترلوكين 6 (IL-6) ومستويات أقل بكثير من مضادات الأكسدة الكبدية. مقارنةً بمجموعة STZ، أظهرت الفئران المصابة بداء السكري التي أعطيت خليط العصائر تحسنًا كبيرًا في إنزيمات استقلاب الجلوكوز، ومستويات IL-6، وTNF، بالإضافة إلى زيادات كبيرة في نشاط إنزيم مضادات الأكسدة. تشير النتائج إلى أن خليط العصائر يمكن أن يكون غذاءً وظيفيًا يساعد في تقليل مضاعفات مرض السكري.

كما تشير النتائج إلى أن التأثيرات العلاجية والوقائية لخليط العصائر على الفئران المصابة بداء السكري كانت واضحة وعملية. أظهرت نتائج هذه الدراسة أن خليط العصائر لها خصائص مضادة للالتهابات ومضادة للأكسدة ومضادة لفرط سكر الدم لأن جميع المعلمات البيوكيميائية المقيمة قد تحسنت مقارنة بالمجموعة المعاملة بمادة STZ. نتيجة لذلك، يمكننا الاعتماد على خليط العصائر كمكمل غذائي مع وظيفة وقائية، ويمكن استخدام التركيبة الجديدة كبديل لحل مشكلة ارتفاع أسعار الأدوية وعدم توفرها في السوق.