

Purple Eggplant Infusion and Maceration As A Valuable Functional Food

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Abstract In Côte d'Ivoire, purple eggplant is commonly used in food preparation. It contains valuable nutrients and has antioxidant potential, offering benefits for metabolic diseases. However, the cooking process results in nutrient losses. To address this, infusion and maceration were proposed as alternative methods. This study aimed to evaluate the impact of eggplant maceration and infusion on glycemia and hypercholesterolemia. Physicochemical parameters, phytochemical compound content, and antioxidant activity were determined. The glycemic response of macerated and infused eggplants was assessed using the blood sugar response method, and lipid content was measured in Wistar rats. The results showed that macerated eggplant had higher protein ($0.13 \pm 0.02\%$), fat ($0.06 \pm 0.0\%$), fiber ($0.08 \pm 0.01\%$), and ash ($0.03 \pm 0.003\%$) contents, while the infusion was richer in total carbohydrates ($0.29 \pm 0.05\%$), total sugars (2.17 ± 0.06 mg/100g), and reducing sugars (0.88 ± 0.04 mg/100g). Phenolic compound content and antioxidant activity were higher in the infused eggplant compared to the macerated eggplant. The antioxidant inhibitory concentration of 50% (IC₅₀) for DPPH activity was 0.05 mg/mL for infused eggplant, compared to 0.17 mg/mL for macerated eggplant. These IC₅₀ values indicate strong antioxidant activity, with respective anti-radical powers of 2000.00 and 588.24 μ mol of reduced DPPH/mg of sample. Normal glycemic values after the ingestion of macerated and infused eggplants were reached at 90 minutes, with 104.5 mg/dL and 94 mg/dL, respectively, and remained stable until the end of the experiment (240 minutes). Normal blood sugar levels range between 50.5 and 110.5 mg/dL. Both macerated and infused eggplants increased HDL cholesterol levels compared to the control. A significant difference ($P < 0.05$) was observed between the macerated and infused eggplant samples for all parameters investigated. Based on phenolic compound content, antioxidant activity, the ability to decrease hyperglycemia, and increase HDL cholesterol, macerated and infused eggplants may be beneficial for the prevention of diabetes and hypercholesterolemia.

Keywords: Macerate eggplant, infusion eggplant, diabetes, hypercholesterolemia

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1. Introduction

Eggplant (*Solanum melongena* L.) is the fifth most widely consumed vegetable in the world, with an estimated annual production of 56.6 million tons (Mt) [1]. Since eggplant is typically grown two to three times per year, it is available in the market year-round. Due to its nutritional composition, which includes low calories and beneficial minerals such as potassium, calcium, magnesium, sodium, and iron, as well as phytochemicals like phenolic compounds (e.g., caffeine and chlorogenic acid) and flavonoids, eggplant is highly nutritious and has been used for medicinal purposes [2]. The primary dietary sources of phenolic compounds for humans are fruits and vegetables, with flavonoids and phenolic acids being the most abundant [2]. According to Azizuddin *et al.* [3],

eggplant offers various health benefits. Phenolic compounds in eggplant possess antioxidant properties that contribute to human health by helping regulate blood sugar levels and controlling the absorption of glucose from food. Additionally, eggplant is rich in dietary fiber, which promotes the absorption of blood cholesterol by the liver for bile production. As one of the richest sources of dietary fiber, eggplant plays a vital role in maintaining gastrointestinal health [4].

However, like many vegetables, eggplant is typically cooked before consumption. Cooking enhances food palatability and digestibility but also leads to nutrient losses. To minimize this, cooking time or method can be adjusted. For example, eggplant can be steamed for no more than 10 minutes instead of boiling to preserve its nutrients [5]. Additionally, processes such as infusion and maceration can be used to retain the full nutritional and therapeutic potential of eggplant. Infusion has been

reported as an effective method for extracting biologically active compounds, which, in their dissolved form, are more easily absorbed by the body [6]. Alves-Silva et al. [7] demonstrated that the traditional use of *Thymra capitata* infusion in the Algarve region of Portugal improved its anti-inflammatory, wound-healing, and anti-aging properties. Furthermore, both maceration and infusion processes have been reported in several studies as effective methods for optimizing the extraction of bioactive compounds [6].

This study aims to evaluate the biochemical and antioxidant properties of purple eggplant infusion and macerate. It also examines their effects on glycemia and cholesterol levels in Wistar rats.

2. Materials and Methods

2.1. Materials

The purple eggplant samples were harvested from an experimental field in Guitry, a town in western Ivory Coast (5° 31' 08" N, 5° 14' 24" W) in April 2022. A nursery was established, and 4 weeks after sowing, the plants were transplanted with the following spacing: 0.7 m between rows and 0.5 m between plants within rows. Watering was carried out in the morning and evening for two weeks after transplanting, and subsequently as needed.

Sixteen Wistar albino rats (*Mus musculus*), 12 weeks old and weighing an average of 100 g, were used to assess in vivo biochemical parameters. The animals were purchased and treated according to the ethical guidelines of the Botany and Plant Diversity Valorization Laboratory of Nangui Abrogoua University (Côte d'Ivoire). The rats were acclimated for one week to the laboratory conditions, which included 65% humidity, an average room temperature of 28 °C, and a 12-hour light/dark photoperiod. Their primary food source was commercial pellets produced by Ivograin Abidjan (Ivory Coast).

2.2. Methods

2.2.1. Sampling

On the field, eggplants were harvested early in the morning at maturity, 105 days after transplanting. They were then transported to the laboratory for analysis, where they were cleaned and washed under running water.

The animals were divided into 4 groups, with 4 rats per group, and assigned as follows: 1 control group (receiving only distilled water by gavage), 1 group receiving glibenclamide (Daonil 5 mg), the reference hypoglycemic substance, 1 group receiving eggplant infusion, and 1 group receiving eggplant macerate.

2.2.2. Purple Eggplant Infusion Process

A quantity of 2 kg of fresh purple eggplants (*Solanum melongena* L.) was carefully washed under running water, cut into thin strips, and dried in an oven at 45°C. The dried eggplants were then ground using a blender (SMART) to obtain eggplant powder. This powder was subsequently infused for 5 minutes in boiling water at 100°C.

2.2.3. Purple Eggplant Maceration Process

Approximately 2 kg of fresh purple eggplant (*Solanum melongena* L.) were carefully washed under running water and cut into thin strips. Next, 500 g of the eggplant were weighed and soaked in 5 L of cold water for 24 hours at room temperature. The mixture was then filtered to obtain the maceration water.

2.2.4. Physicochemical Properties Assessment

The physicochemical properties of the samples, including pH, titratable acidity, moisture, fat, protein, fiber, and ash content, were assessed according to the AOAC method [8]. The energy values and carbohydrate content were calculated based on the contents of other biochemical compounds. Water-soluble carbohydrates were determined using the phenol-sulfuric acid method, as described by Dubois et al. [9], and total reducing sugars were quantified using the dinitrosalicylic acid method described by Bernfeld [10]. Mineral content was determined according to the method of Kularatne and Freitas [11] using atomic absorption spectrophotometry.

2.2.5. Phytochemical Analyses

Total polyphenol content was analyzed using the Folin-Ciocalteu colorimetric method [12]. Total flavonoids were determined using the modified method of Hariri et al. [13]. The determination of condensed tannins in the various extracts was carried out according to Heimler et al. [14]. The concentrations of condensed tannins were derived from calibration curves established with catechin (0-300 µg/mL) and are expressed as µg of catechin equivalents per mg of extract.

2.2.6. Free radical Scavenging Activities and Anti-Radical Power Determination

The free radical scavenging activity of the extracts was measured using the DPPH method [15]. This test evaluates the capacity of the extract to neutralize the DPPH free radical by measuring the decrease in color at 517 nm. Vitamin C (100 µg/mL) was used as a standard. The sample concentration required to inhibit 50% of DPPH (IC₅₀) was determined from the graph and used to express the anti-radical activity. This value was then used to calculate the anti-radical power [16], as follows:

$$ARP = \frac{\text{DPPH solution concentration } (\mu\text{mol of reduced DPPH})}{IC_{50} \times 10^{-3} (\mu\text{g/ml})}$$

ARP: anti-radical power

DPPH: 2,2-diphenyl-1-picrylhydrazyl

IC₅₀: Sample concentration which inhibit 50% of DPPH

2.2.7. Assessment of Glycemic Response of Purple Eggplant Infusion and Macerate Ingestion by Wistar Rats

All animals were fasted starting from the previous day. A blood sample was taken, and 30 minutes later, hyperglycemia was induced orally in all rats using an anhydrous glucose solution (250 mg/mL) (Gharras et al., 1999) [17]. Another blood sample was taken 30 minutes after the induction of hyperglycemia, and the animals were then treated immediately by gavage with 2 mL per

100 g of body weight of either water, glibenclamide, eggplant infusion, or eggplant macerate, according to their respective groups.

Blood samples were finally collected at 60 min (T60), 120 min (T120), 180 min (T180), and 240 min (T240) to assess the effect of the different treatments on hyperglycemia. Glycemia was measured directly using an Accu-Chek® glucometer (Roche Diagnostics) according to the glucose oxidase method (Tietz, 1995) [18].

2.2.8 Cholesterols and Triglycerides Assessment

For the analysis of total cholesterol, HDL-cholesterol, and triglycerides, a blood sample was taken from the tails of the rats at the beginning and at the end of the one-month experiment. Approximately 3 mL of blood was collected into red-top tubes. The blood was centrifuged at 3,000 rpm for 10 minutes at 4°C. Serum was separated and stored at -20°C for biochemical analysis using an automatic multiparameter analyzer (Hitachi 902, Germany). The rats were sacrificed at the end of the study.

2.2.9. Statistical Analyses

R.301 software was used. A one-way ANOVA was performed, and means were separated using Tukey test ($p \leq 0.05$). Graph Pad Prism 5.0 (Microsoft U.S.A) were used for antioxidant activity representation.

3. Results

3.1. Physicochemical and Biochemical Composition of Purple Eggplant Macerates and Infusions

Table 1. Physicochemical and biochemical composition of purple eggplant maceration and infusion

Parameters	Purple eggplant extract	
	Macerate	Infusion
pH	5.07 ± 0.05 ^a	4.80 ± 0.02 ^b
Titrateable Acidity (meq g/L)	0.40 ± 0.01 ^a	0.60 ± 0.04 ^b
Dry matter (%)	0.34 ± 0.01 ^a	0.29 ± 0.01 ^b
Moisture (%)	99.66 ± 0.01 ^a	99.71 ± 0.01 ^a
Ash (%)	0.07 ± 0.001 ^a	0.03 ± 0.003 ^b
Proteins (%)	0.13 ± 0.02 ^a	0.05 ± 0.01 ^b
Fat (%)	0.06 ± 0.0 ^a	0.03 ± 0.05 ^b
Carbohydrates (%)	0.09 ± 0.10 ^a	0.29 ± 0.05 ^b
Fibers (%)	0.08 ± 0.01 ^a	0.06 ± 0.05 ^b
Total sugar (g/L)	0.82 ± 0.30 ^a	2.17 ± 0.06 ^b
Reducing sugar (g/L)	0.30 ± 0.02 ^a	± 0.04 ^b

Mean values with the same letter in a row are not significantly different (Tukey's test, $P > 0.05$).

Table 1 shows the physicochemical and biochemical parameters of purple eggplant extracts: macerate and infusion. The macerate was characterized by higher protein ($0.125 \pm 0.02\%$), fat ($0.055 \pm 0.00\%$), fiber ($0.08 \pm 0.01\%$), and ash ($0.032 \pm 0.003\%$) content. In contrast, the infusion, which was acidic ($pH = 0.4 \pm 0.01\%$), was characterized by higher levels of total carbohydrates ($0.285 \pm 0.05\%$), total sugars ($2.165 \pm 0.06\%$), and reducing sugars ($0.879 \pm 0.04\%$). Overall, there was a

statistically significant difference ($P < 0.05$) between the purple eggplant macerate and infusion.

3.2. Phytochemical Composition of Purple Eggplant Macerate and Infusion

The phenolic compound contents in eggplant infusion and eggplant macerate are shown in Table 2. The infusion had the highest total phenolic compound contents, including 5.43 ± 0.15 mg EGA/g DM for polyphenols, 0.51 ± 0.02 mg EQ/g for flavonoids, and 1.13 ± 0.28 mg EC/g DM for condensed tannins. Statistical analysis also showed a significant difference ($P < 0.05$) between the macerate and eggplant infusion samples.

Table 2. Phenolic compounds content of macerate and infusion of purple eggplant

Eggplant extract	Phenolic compounds		
	PT (mg EGA/gDM)	FT (mg EQ /gDM)	TC (mgEC/gDM)
Macerate	0.39 ± 0.003^b	0.01 ± 0.001^b	0.48 ± 0.002^b
Infusion	5.43 ± 0.150^a	0.51 ± 0.02^a	1.14 ± 0.28^a

PT: total polyphenols; FT: total flavonoids; TC: condensed tannins. Mean values with a different letter in a column are significantly different (Tukey's test, $P > 0.05$).

3.3. Antioxidant Activity of Purple Eggplant Macerate and Infusion

Figure 1 shows the anti-radical activity of purple eggplant macerate and infusion. The infusion IC_{50} (0.05 mg/mL) is closer to that of the reference, vitamin C (0.04 mg/mL). This corresponds to an anti-radical power (ARP) of 2,000 μ mol reduced DPPH (Table 3). However, the macerate IC_{50} was about 0.17 mg/mL and indicated an anti-reducing power (ARP) of 588.24 μ mol reduced DPPH.

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Table 3. IC_{50} and anti-radical power of purple eggplant infusion and macerate

	Infusion	Macerate	Vitamin C
IC_{50} mg/ml	0.05 ± 0.001	0.17 ± 0.05	0.04 ± 0
ARP (μ mol reduced DPPH / mg)	2000 ± 0.001	588.24 ± 0.05	$2,857.14 \pm 0$

IC_{50} (50% inhibitory concentration). ARP: anti-radical power (μ mol reduced DPPH / mg).

3.5. Wistar Rats' Postprandial Hyperglycemia

The results showed that after ingestion of anhydrous glucose, the glycemic response increased in all rat groups.

However, when receiving the treatment solution (glibenclamide, infusion, and macerate), glycemia decreased after 30 minutes for glibenclamide and infusion, from 173.25 to 45.25 mg/dL and from 154.5 to 83.5 mg/dL at 240 minutes, respectively. For the macerate, the decrease began at 60 minutes, reaching 45.76 mg/dL at 240 minutes. Normal glycemia was reached after ingestion of glibenclamide at 60 minutes (108.5 mg/dL), while normal glycemia values for macerate and infusion were reached at 90 minutes, at approximately 104.5 mg/dL and 94 mg/dL, respectively (Figure 2).

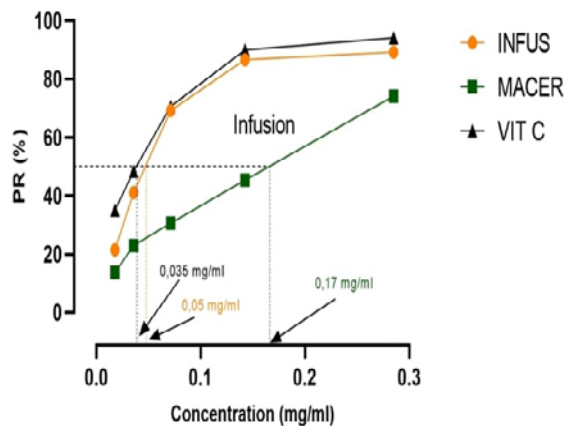


Figure 1. DPPH inhibition rate of purple eggplant infusion and macerate

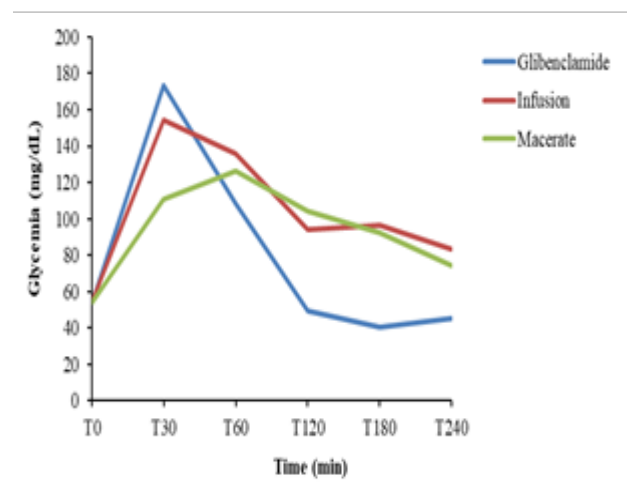


Figure 2. Blood sugar responses after ingestion of glucose, glibenclamide, eggplant macerate and eggplant infusion

3.6. Effects of Purple Eggplant Macerate and Infusion Eggplant on in Wistar Rat and Atherogenic Index

After one month of treatment, cholesterol, HDL-cholesterol, and triglycerides were analyzed in the blood of Wistar rats (Figure 3). In the rat groups that received any beverage, the total cholesterol level was approximately 2.39 g/L, HDL-cholesterol was about 0.55 g/L, and triglycerides were around 0.65 g/L. In the rat groups that received water, infusion, and macerate, the total cholesterol levels decreased by approximately 1.41, 2.41, and 2.32 g/L, respectively. Triglycerides also decreased by about 0.71, 0.50, and 0.51 g/L, respectively.

However, HDL-cholesterol increased, with the highest level observed in the rat group that received infusion (2.09 g/L), which was higher than in the other groups. Figure 4 shows the atherogenic index, or cholesterol/HDL ratio, for the different Wistar rat groups. The cholesterol/HDL ratio ranged from 4.38 in the group that received any beverage. However, it was about 1.15 for the rats receiving eggplant infusion and 1.33 for those receiving eggplant macerate. All these values were below the normal threshold of 5. Thus, consumption of purple eggplant macerate and infusion contributed to a decrease in the atherogenic index. Overall, a statistically significant difference ($P < 0.05$) was observed between the samples.

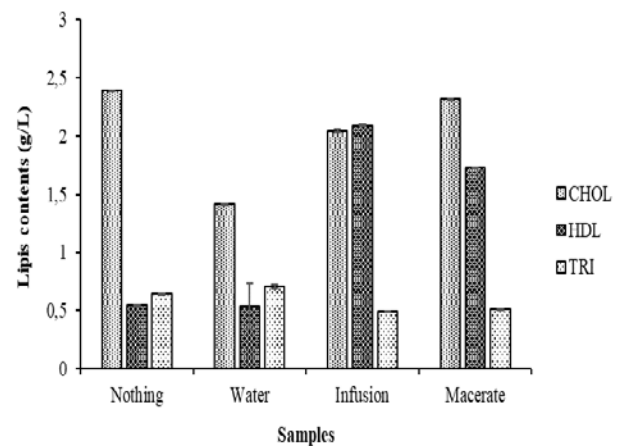


Figure 3. Cholesterol, HDL-cholesterol and triglycerides analyzed on Wistar rats

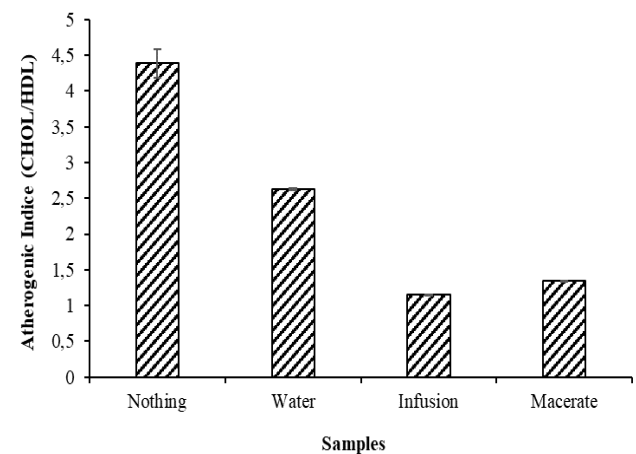


Figure 4. Atherogenic index or cholesterol/HDL ratio of the different Wistar rats' batches

4. Discussion

Purple eggplant contains important nutrients that can contribute to good health. Regarding the physicochemical composition of the macerate and infusion, eggplant infusion is more acidic than the macerate. This could be due to the hot water used in the infusion process, which may have favored the extraction of organic components, leading to a more acidic solution. These results are consistent with those of Prasain *et al.* [19] and Erdemgil *et al.* [20], who reported that the pH of infused green tea

leaves varies between 4.2 and 6.0.

The presence of proteins, lipids, carbohydrates, fibers, ash, and total sugars in both purple eggplant infusion and macerate gives them notable nutritional properties. However, the differences observed can be explained by the preparation method. Specifically, some compounds, such as proteins, are more abundant in the skin of the eggplant than in the flesh, which may explain the higher concentrations of proteins in the macerate compared to the infusion. Proteins present in the infusion and macerate may have roles as building and defense molecules against certain diseases, potentially supporting cell growth in children and cell regeneration in adults [21].

Additionally, the low lipid content in both eggplant infusion and macerate has been reported by several authors. Itoua *et al.* [22] highlighted that vegetables typically contain very little lipids. This low lipid content may be due to the fact that lipids are poorly soluble in water [23].

The nutritional value of purple eggplant infusion and macerate is also reflected in their fiber and ash content. The fibers in both the infusion and macerate may help improve digestive health, reduce the risk of high blood pressure, constipation, diabetes, and colon cancer [24]. The highest fiber content was observed in the eggplant infusion compared to the macerate. This could be due to the fact that eggplant fibers are highly water-soluble, and during the infusion process, eggplant powder is diluted in hot water, enhancing fiber solubility. In contrast, the macerate involves eggplant pieces soaked in water, which may not extract as many soluble fibers. The importance of fibers for the body has also been emphasized by Vodouhé *et al.* [25], who noted their role in the digestive tract and in preventing hypercholesterolemia. Indeed, numerous studies have linked high dietary fiber intake to a reduced risk of cardiovascular diseases [26].

Ash content indicates the mineral content in eggplant, with higher levels observed in the macerate compared to the infusion. This is likely due to the hot water used in the infusion process, which may have caused the loss of some minerals. These minerals can help reduce the risk of mineral deficiencies and cardiovascular disease [27].

Phenolic compound levels were higher in the purple eggplant infusion than in the macerate. This can be explained by the fact that the infusion was made from whole raw dried eggplant powder (including both pulp and skin), while the macerate was prepared from fresh eggplant soaked in water. According to Seyar [28], the skin of purple eggplant is rich in polyphenols (anthocyanins) with high antioxidant potential. Dranca and Oroian [29] reported that phenolic compounds in eggplant are concentrated in the peel, with levels ranging from 80 to 850 mg/kg, depending on agronomic, genetic, light, temperature, processing, and storage factors. This richness in polyphenols may help neutralize free radicals in the body, which are associated with various metabolic diseases. Consequently, flavonoid content was also higher in the infusion. Flavonoids explain the anti-inflammatory properties of purple eggplant and its ability to modulate immune system function [30]. These results align with those of Elekofehinti *et al.* [31], who showed that African eggplant (*Solanum anguivi*) contains high levels of flavonoids such as rutin and quercetin. Furthermore,

flavonoids are effective scavengers of pro-oxidant free radicals, particularly those involved in lipid peroxidation, similar to α -tocopherol. Tannin content was also higher in the infusion, which could contribute to protection against cardiovascular and metabolic diseases [32], as they are involved in antioxidant activity [33,34].

Both macerate and infusion exhibited significant antioxidant potential, with the infusion showing a higher antioxidant capacity, as evidenced by its lower IC₅₀ value and greater anti-radical power. According to Halvorsen *et al.* [35], cooking in water, and thus the addition of hot water, promotes the increase of antioxidant activity. Therefore, the different extracts, particularly the eggplant infusion, which presented the highest antioxidant power, could be beneficial for individuals suffering from metabolic diseases such as diabetes.

The impact of purple eggplant infusion and macerate on glycemia and hypercholesterolemia was evaluated in Wistar rats. The results from the postprandial glycemia assessment showed that glucose levels decreased in rats treated with glibenclamide (positive control), as well as in those treated with eggplant macerate and infusion. This could be attributed to the low reducing sugar content and high fiber content in both the infusion and macerate. Fibers help regulate blood sugar levels by controlling glucose absorption from food [3]. They also help maintain the integrity of cell walls during mastication and digestion, slowing the breakdown of plant tissues and, to a lesser extent, attenuating postprandial spikes in glycemia [36].

Purple eggplant macerate and infusion also reduced total cholesterol and triglyceride levels while increasing HDL-cholesterol levels. This is particularly important for metabolic diseases, especially cardiovascular conditions. According to Naeem and Ugur [37], eggplant plays a key role in reducing cardiovascular problems. These properties may be attributed to the phenolic compounds that help prevent metabolic diseases. Specifically, anthocyanins appear to reduce LDL (low-density lipoprotein) oxidation, enhance blood antioxidant capacity, and contribute to cardiovascular disease and hyperlipidemia prevention. Basuny *et al.* [38] noted that anthocyanins' ability to increase HDL-cholesterol levels makes purple eggplant peel a valuable medicinal ingredient. Furthermore, the low atherogenic index of the eggplant macerate and infusion, compared to the control and water groups, suggests the important role that eggplant may play in the prevention of metabolic diseases.

5. Conclusion

Eggplant is an important agronomic and economic crop that contains bioactive compounds with potential benefits for disease prevention. Purple eggplant infusion is rich in phenolic compounds and exhibits strong antioxidant potential, while the macerate has the highest fiber content. Both purple eggplant infusion and macerate help reduce glycemia and improve HDL-cholesterol levels. Therefore, the consumption of purple eggplant infusion and macerate may be beneficial for preventing diabetes and cardiovascular diseases.

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Conflict of Interest

Authors have no conflict of interest regarding the publication of this paper.

Authors Contribution

All authors have contributed equally during the manuscript preparation.

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