THE EFFECT OF *Theobroma cacao* LEAVES ON THE BODY MASS INDEX AND BLOOD GLUCOSE LEVEL IN INDUCED-METABOLIC DISORDER RATS

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ABSTRACT – *Metabolic disorders such as obesity and diabetes are rising globally, prompting interest in alternative therapies. Theobroma cacao (T. cacao), known for its medicinal properties, contains bioactive compounds that may offer therapeutic benefits. This study evaluated the effects of T. cacao leaf extract on body weight and blood glucose levels in diet-induced metabolic disorder Sprague-Dawley rats. Thirty-six rats were randomly divided into six groups. Five groups were fed a high sodium-fat diet (HSFD) for 7 weeks to induce metabolic disorder. Treatments were then administered for 4 weeks with T. cacao leaf extract (MD CE), cocoa leaf powder (MD C), or GreenCoa (a cocoa and green tea combination, MD GC). A positive control group (MD CAM) received captopril, atorvastatin, and metformin. Body weight, BMI, adiposity index, and blood glucose levels were monitored throughout the study. After 7 weeks of HSFD, all induced groups showed a significant increase in blood glucose compared to baseline (week 0). By week 11, glucose levels declined in the MD+CAM, MD+CE, MD+C, and MD+GC groups. BMI increased in all groups by week 7 ($p<0.05$), but no significant changes were observed by week 11 following treatment. A significant difference in adiposity index was observed between the normal and HSFD-fed groups, though no significant difference was seen among the treated groups. These findings suggest T. cacao leaf extract may help modulate metabolic parameters and improve glucose regulation. Further studies are needed to clarify its mechanisms of action and therapeutic potential***.***

Keywords: Anti-obesity, anti-glycemic, adiposity index, metabolic disorder, cocoa leaves

INTRODUCTION

Metabolic disorders, including obesity and type 2 diabetes mellitus, are increasingly prevalent worldwide and pose a major burden to public health systems (WHO, 2021). These conditions are often marked by insulin resistance, elevated blood glucose levels, and excessive fat accumulation, which can lead to complications such as cardiovascular disease, neuropathy, and kidney damage (American Diabetes Association Professional Practice Committee, 2025). Although pharmacological treatments are available, presence of side effects and limited effectiveness over time, underscoring the need for safer and more sustainable therapeutic alternatives.

Theobroma cacao (*T. cacao*), commonly known as cocoa, is traditionally valued for its medicinal and nutritional properties. It is rich in bioactive compounds including flavonoids, polyphenols, and methylxanthines, which have demonstrated antioxidant, anti-inflammatory, and metabolic-regulating effects (Cura *et al*., 2021). Most of the research focused on cocoa beans, emerging evidence suggests that cocoa leaves may also possess therapeutic potential. Studies have indicated that cocoa leaf extracts may help reduce blood glucose levels, improve lipid profiles, and mitigate oxidative stress, though data remain limited (Rajasekar *et al*., 2024).

Therefore, the present study investigates the potential effects of *T. cacao* leaf on body mass index (BMI) and blood glucose levels in diet-induced metabolic disorder Sprague-Dawley rats. This study aims to expand current knowledge on the underutilized parts of the cocoa plant and explore their role as complementary agents in managing metabolic health.

MATERIALS AND METHODS

T. cocoa Tea Preparation

Ten kilograms of fresh leaf of T. cocoa was collected from Cocoa Farm at Rembau, N. Sembilan. The authentication of *T. cocoa* was provided by Malaysian Cocoa Board (MCB) (SK 2434/14). The leaves were cleaned and air-dried in the shade. Once dried, they were ground into ~~a~~ powder and stored at 4°C for further use~~d~~. Meanwhile, 100 g of *T. cocoa* leaf extract powder

and GreenCoa (combination of green tea and cocoa tea) in sachet was provided by MCB.

Animal Preparation

Thirty-six male Sprague-Dawley rats, aged 6 to 8 weeks and weighing between 180–200 g, were used in this study. The animals were housed in groups of three per cage under controlled environmental conditions (12-hour light/dark cycle, temperature 20–24°C, and humidity 40–50%). The rats were obtained from Sapphire Enterprise Sdn. Bhd. (Serdang, Selangor) and acclimatized for one week prior to the start of the experiment. During acclimatization, they were provided with standard chow pellets and had free access to water. All experimental procedures were conducted in accordance with the guidelines approved by the University of Cyberjaya Animal Care and Use Committee (Approval No.: CACUC/1/2024/3).

High Sodium Fat Diet Preparation and Metabolic Disorder Induction

The High Sodium Fat Diet (HSFD) pellets were prepared based on the method described by Mahadi et al. (2021). The HSFD formulation consisted of 57.5% commercial rat chow, 1.5% pure cholesterol, 24% egg yolk, 7% sodium chloride (NaCl), and 10% corn starch. All ingredients were thoroughly mixed to form a uniform dough, which was then shaped into pellets measuring approximately 2 cm × 1 cm. The pellets were baked at 45°C overnight until fully dried and subsequently stored in airtight containers. All rats, except normal control groups, were fed the HSFD for 7 weeks to induce metabolic disorders.

Treatment groups

Treatment started ~~w~~eek 7 till 11. Rats received 100 mL of tea daily in drinking bottle meanwhile the drug combination therapy was given via oral gavage. The grouping as shown in Table 1.

Table 1: Experimental Animal Groups and Treatment Regimens for Assessing Cocoa-Based Interventions in a Metabolic Disorder Model.

Group	Treatment
1	Normal, untreated
2	Metabolic disorder (MD)
3	Metabolic disorder + Captopril + Atorvastatin + Metformin (Drug Combination Therapy) (MD +C+A+M)
4	Metabolic disorder + Cocoa tea (MD + C tea)
5	Metabolic disorder + Cocoa extract (MD + C extract)
6	Metabolic disorder + Cocoa tea + Green tea (MD + GC Tea)

Body Weight and Body Mass Index (BMI)

The body weight was measured at week 0, week 7 and week 11. The body mass for each rat was calculated as per reported Novelli et al., (2007).

BMI (g/cm²) = Body Weight (g) / [Nose-to-Anus Length (cm)]²

Adiposity Index

The adipose tissue fats of the rats were collected from retroperitoneal, mesenteric, perirenal and epididymal area at the end of experiment. The weight was measured according to Jeyakumar et al., (2015) as calculation below.

Adiposity Index (%) = (Total Body Fat / Final Body Weight) × 100

Blood Glucose Level

The blood glucoses were measured at week 0, week 7 and week 11. The blood glucose was measured using glucometer.

RESULTS AND DISCUSSIONS

Body Weight, BMI & Adiposity Index

As shown in Figure 1, body weight significantly increased in all groups at week 7 compared to week 0 ($p < 0.05$), confirming successful induction of metabolic disorder. By week 11, a reduction in body weight was observed only in the MD + C tea group, although this decrease was not statistically significant. No other treatment groups demonstrated weight reduction, indicating that changes in body weight were relatively consistent across the experimental groups.

As shown in Figure 2, BMI increased significantly in all groups by week 7 compared to week 0 ($p < 0.05$), confirming successful induction of metabolic disorder. No significant reduction in BMI was observed in any treatment group at week 11. Instead, BMI continued to rise in MD + C tea and MD + G tea groups, although the differences between weeks 7 and 11 were not statistically significant.

Figure 3 demonstrates a significant difference in adiposity index (%) between the normal group and all other induced groups ($p < 0.05$). Among treatment groups, MD + C tea showed a notably higher adiposity index compared to MD + CAM and MD + C extract, suggesting that cocoa extract and CAM provided relatively better control of fat accumulation than cocoa tea.

Cocoa consumption has been reported for its potential role in weight management. Cocoa polyphenols may exert anti-obesity effects by increasing energy expenditure and thermogenesis, improving blood lipid profiles, and enhancing satiety (He *et al*., 2024). These mechanisms suggest that cocoa can help prevent excessive weight gain, thereby potentially slowing the progression of metabolic disorders. Previous studies have shown that cacao polyphenols, particularly flavanols and theobromine, can modulate lipid metabolism, improve insulin sensitivity, and exert anti-inflammatory effects, yet their impact on body weight remains inconsistent. A study by Jalil & Ismail (2008) demonstrated that cocoa polyphenols reduced body fat accumulation and BMI in rats fed a high-fat diet. Research by Sitarek *et al*., (2024) highlighted the potential metabolic benefits of cocoa consumption in mitigating obesity. Studies on mice fed on a high-fat diet and supplemented with cocoa revealed reduced weight gain, improved insulin sensitivity, and a lower severity of obesity-associated fatty liver disease. However, statistically significant results were observed only with daily doses under 20 g and intervention durations exceeding four weeks (Abu-Zaid et al., 2024). This reflects the result in this study that the consumption of tea is only for 4 weeks.

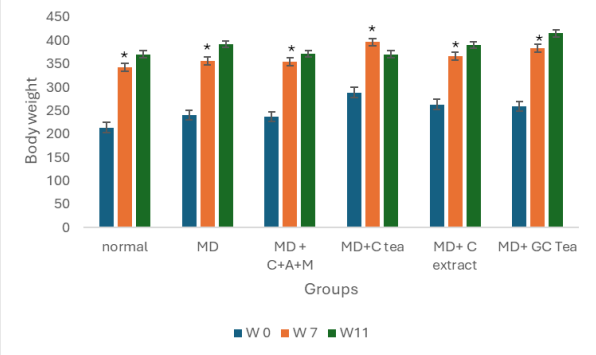

*Figure 1: Comparison of body weight level between groups at week 0, week 7 and week 11. *Body weight had significantly increased in week 7 compared to week 0 in all groups (p<0.05). Reduction of body weight was observed in MD + C tea at week 11 however no significant difference was observed.*

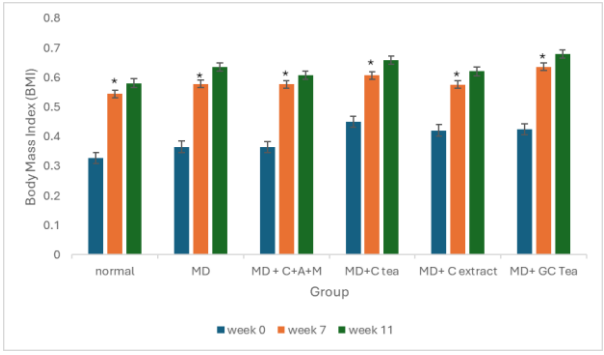

*Figure 2: Comparison of BMI between groups at week 0, week 7 and week 11. All groups showed increased BMI throughout experiment. * A significant increase in BMI was observed in week 7 in all groups (p<0.05). No reduction of BMI was observed in all treatment groups at week 11. An increase in BMI was observed between week 7 and week 11 in MD+ C tea and MD+ G Tea, however no significant difference was detected.*

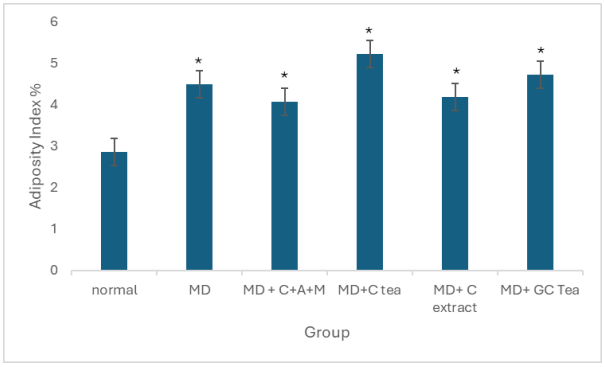

*Figure 3: Comparison of adiposity index % between groups at the end of the experiment. * A significant difference in the adiposity index % was clearly observed between normal with other groups (p<0.05). However, MD+ C tea was observed to be significantly higher compared to MD+CAM and MD+C extract.*

Blood Glucose level

As illustrated in Figure 4, blood glucose levels increased significantly in all induced groups at week 7 compared to baseline (week 0) ($p < 0.05$). A marked reduction was observed by week 11 in MD + CAM, MD + C tea, MD + C extract, and MD + GC tea groups compared to week 7 ($p < 0.05$), indicating that treatment with *T. cacao*–based preparations improved glycemic control.

Reduction of glucose level during treatment phase may have contributed for improving glycemic control as shown in Figure 4. The significant reductions in blood glucose levels at week 11 in the treatment groups suggest that *T cacao* exert beneficial effects on glycemic control. Studies have demonstrated that cocoa polyphenols can improve insulin sensitivity and

reduce blood glucose levels (Guan *et al*., 2016). *T cacao* leaves claimed to be rich in polyphenolic compounds such as catechins, epicatechin, epigallocatechin gallate (EGCG), epigallocatechin, which contribute to their antioxidant and potential therapeutic properties in lowering glucose levels and insulin sensitivity.

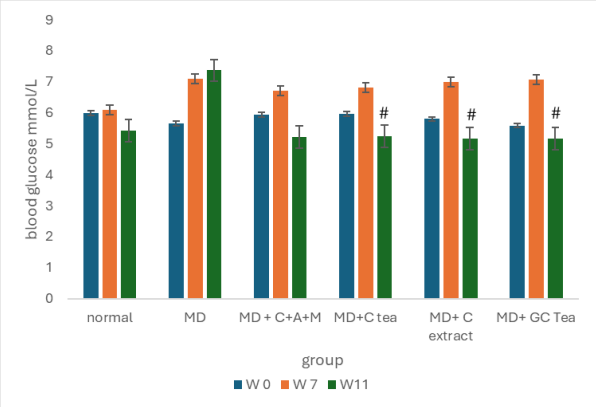

*Figure 4: Comparison of blood glucose level between groups at week 0, week 7 and week 11. *Blood glucose had significantly increased in week 7 compared to week 0 in all induce groups (p<0.05). # Reduction in blood glucose level was observed at week 11 in MD+CAM, MD+C tea, MD+C extract and MD+GC Tea as compared to week 7 (p<0.05).*

Comparison cocoa tea and cocoa extract

In addition, cocoa tea (Group 4) was prepared through aqueous infusion, which primarily extracts water-soluble compounds such as catechins, epicatechin, EGCG, theobromine, and caffeine. This preparation provides a mild to moderate effect suitable for daily consumption, with potential benefits including improved insulin sensitivity, reduced oxidative stress, and a mild lipid-lowering effect (Cura *et al*., 2021; Jalil & Ismail, 2008). However, because of its lower bioactive concentration, cocoa tea may require a longer duration of intake to exert significant metabolic improvements (Ali *et al.*, 2024).

In contrast, cocoa extract (Group 5) was produced using 100% water extraction, resulting in a more concentrated preparation containing higher levels of water-soluble compounds such as flavanols, procyanidins, catechins, and theobromine. This concentrated profile may contribute to stronger antioxidant, anti-inflammatory, glucose-lowering, and metabolic regulatory effects (Guan *et al*., 2016; Martin *et al*., 2020; Sitarek *et al*., 2024). Nevertheless, while cocoa extract demonstrates greater potency due to its higher concentration, it may also carry a higher risk of side effects at elevated doses and is less representative of a natural dietary intervention compared to cocoa tea (Abu-Zaid *et al*., 2024; Magrone *et al*., 2017).

CONCLUSIONS

In conclusion, this study highlights the potential of *Theobroma cacao* leaf preparations as a natural intervention for metabolic disorders. Treatment with T. *cacao* tea, *T. cacao* extract, and GreenCoa demonstrated comparable effects in improving body weight and blood glucose levels, while helping to maintain the adiposity index and BMI in diet-induced metabolic disorder rats. These findings suggest that *T. cacao* leaves may contain bioactive compounds beneficial for regulating metabolic and diabetic profiles. Further studies are warranted to elucidate the underlying mechanisms and therapeutic potential of these preparations.

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