**Original Research Article**

**Antihyperlipidemic and Hypolipidemic Effects of a Cocoa Liquor with High Antioxidant Properties on Wistar Rats (*Ratus norvegicus*)**

**Abstract**

Previous studies on cocoa liquor have demonstrated that a blend of raw (30%) and fermented/roasted (70%) cocoa beans yield a cocoa liquor with the desired sensory attributes for chocolate production, as well as high antioxidant potential. The main objective of the present study was to evaluate the *in vivo* hypolipidemic and anti-hyperlipidemic effects of this cocoa liquor on male Wistar rats fed with a high-fat diet. To achieve this, the cocoa liquor was incorporated into the rats' diet at a concentration of 50%. After one month of experimentation, the animals were sacrificed, blood was collected for serum extraction, and biochemical analyses were performed. The results of the hypolipidemic effect showed that consumption of this cocoa liquor led to a significant decrease in total cholesterol levels by 7.48%, LDL-C by 20.68%, triglycerides by 3.94%, and a substantial increase in HDL-C by 48.62% compared to the control group receiving no cocoa liquor, with an improvement in the atherogenic index of 37.73%. Additionally, the presence of cocoa liquor in the diet led to a decrease in ALT by 49.39% and AST by 43.87% compared to the untreated control group. Similarly, an improvement in urea and creatinine levels was observed following consumption of the cocoa liquor. Furthermore, the results of the anti-hyperlipidemic effects of the cocoa liquor demonstrated its ability to prevent the onset of hyperlipidemia. We can conclude that consumption of cocoa liquor made from raw and fermented/roasted cocoa beans (30/70) has hypolipidemic and anti-hyperlipidemic effects while protecting vital organs such as the heart, liver and kidney of Wistar rats. Therefore, it can be recommended for use in the formulation of chocolate products for overweight or obese individuals.

**Key words**:

1. **Introduction**

Cardiovascular diseases (CVDs) are the leading cause of mortality worldwide, responsible for over 17.9 million deaths annually, accounting for 31% of all deaths. More than three-quarters of CVD-related deaths occur in low- and middle-income countries [1]. About 13% of all deaths and 37% of deaths from non-communicable diseases (NCDs) in sub-Sahara Africa (SSA) are attributable to CVDs, making them the leading cause of NCDs deaths [2]. Therefore, CVDs should be a public health priority, as the World Health Organization (WHO) estimates that by 2030, CVDs will be responsible for over 23.6 million deaths worldwide, with hyperlipidemia being a major risk factor.

Hyperlipidemia, characterized by elevated triglyceride and total cholesterol levels, is a major risk factor for CVDs. It leads to endothelial dysfunction and platelet activation, which are key mechanisms underlying atherothrombosis, resulting in vasoconstriction, thrombus formation, and inflammation, ultimately increasing cardiovascular risk [3]. While there are medicinal treatments for hyperlipidemia, such as statins, fibrates, and resins, these treatments are often expensive and can have side effects [4]. Dietary changes, such as hypocaloric diets low in fat and sugar, are therefore recommended, but these can be restrictive and difficult to maintain for long-term [5].

Recent research has focused on the bioactive compounds found in plants, demonstrating that polyphenols present in foods can reduce blood lipid levels by inhibiting lipase activity, complexing and precipitating digestive proteins, or inhibiting adipocyte differentiation and adipogenesis [6]. Studies have also shown that consuming polyphenol-rich beverages, such as certain teas and wines, as well as fruits and vegetables, can increase plasma antioxidant capacity [7].

In this order of ideas, raw cocoa beans (*Theobroma cacao*) particularly rich in polyphenols have been shown to have potential health benefits, including reducing blood lipid levels [8,9]. However, to produce cocoa liquor used in chocolate industry, raw cocoa bean needs to be fermented and roasted. While these treatments improve the technological and sensory attributes of cocoa bean, they significantly reduce its polyphenol content, therefore its antioxidant potential [10]. To address this issue, a compromise was found between the desired chocolate sensory attributes and the antioxidant potential of raw cocoa beans during the production of cocoa liquor.

Indeed, Baleba *et al*., (2025) developed a cocoa liquor made of 70% fermented/roasted beans and 30% raw beans. The composite cocoa liquor was approved by experts of the Interprofessional Cocoa and Coffee Council (CICC) in terms of chocolate sensory attributes, but was also rich in polyphenols and other antioxidants compounds such as iron, selenium, and vitamin E (Baleba *et al.*, 2025). While *in vitro* tests indicated that this liquor had high antioxidant potential, questions regarding its *in vivo* efficacy on some CVDs risk factors such as hyperlipidemia remain. To answer the question, this study was set up with as main objective to investigate the effects of antioxidant-rich cocoa liquor on lipid profile (anti-hyperlipidemic and hypolipidemic tests) and liver and renal functions of Wistar rats.

1. **Materials and methods**
   1. **Production of Cocoa Liquor**

Unfermented and fermented / roasted cocoa beans were processed and blended at 30% and 70% respectively to obtain cocoa liquor as previously described by Baleba *et al*. (2025).

* 1. **Physicochemical and Phytochemical Analysis of the Samples** 
     1. ***Physicochemical characterization***

***Macronutrient and vitamin E quantification***

Moisture content was determined by drying samples at 105°C until constant weight [11]. Total ash was quantified after complete incineration of the samples in a furnace [12]. Total fat content was determined by extracting lipids from samples with hexane at high temperature for about 8 hours using the Soxhlet apparatus [13]. Soluble sugar content was determined using DNS (3,5-dinitrosalicylic acid) method [14]. Total nitrogen content was determined after mineralization of samples by Kjeldahl method and assayed using colorimetric technique [15]. The conversion factor of 6.25 was used to convert nitrogen content to protein content. The vitamin E content was quantified using CHCl3 (methylene chloride), 2,2'-Dipyridyl and absolute ethanol [16].

***Mineral content***

The mineral content (zinc, iron, selenium, and copper) was determined using flame photometry, a technique that measures the intensity of radiation emitted by excited atoms in a flame. The method involves preparing a suspension from 0.1 g of ash and 1 mL of hydrochloric acid, and then measuring the flame absorption of the suspension. The intensity of the emitted radiation is proportional to the concentration of the element in the sample, allowing for the quantification of the mineral content [17].

* + 1. ***Phytochemical characterization***

***Total Polyphenol Content***

Total polyphenols content was evaluated using Folin-Ciocalteu method based on the reduction of a phosphomolybdic-tungstic chromogen by an oxidant, resulting in a color change measured at 750 nm. A standard curve was generated using gallic acid (1 mM) and methanol. The polyphenol content was measured by adding 30 μL of sample to 1 mL of Folin-Ciocalteu reagent (0.2 N) and measuring the absorbance at 750 nm after 30 mins. The results were calculated using the equation obtained from the standard curve and expressed in mg/g equivalent gallic acid [18].

***Flavonoid Content***

Total flavonoids content was quantified using colorimetric method with aluminium chlorite. For analysis, 1 g of sample was homogenized with 20 mL of a methanol/distilled water/acetic acid (140:50:10, V/V) solvent mixture. The mixture was filtered and adjusted to a final volume with the solvent mixture. Then, 2.5 mL was transferred to a 50 mL Erlenmeyer flask and completed with distilled water to the mark. Next, 10 mL of this solution was mixed with 2 mL of distilled water and 5 mL of aluminum chloride (AlCl3) reagent, and the absorbance was read at 430 nm against a blank prepared with 10 mL of the analysis solution and 5 mL of distilled water. The flavonoid content was calculated using a rutin standard solution, and the results were expressed as mg of rutin/100g of dry matter [19].

***Condensed Tannin Content***

Condensed tannins were quantified in presence of concentrated sulfuric acid. The method involves extracting tannins from a 2 g sample with 30 ml of 80% acetone in 2% acetic acid, followed by filtration and evaporation of the solvent. The extract was then diluted and mixed with vanillin solution and HCl, and the absorbance was read at 500 nm after 15 mins. The tannin content was expressed as tannic acid equivalents using a calibration curve, and the results were calculated as the mean of triplicates, taking into account the sample mass, moisture content, and dilution factor [20].

* 1. **Animal Experimentation**
     1. ***Animals***

The experimentation was conducted in the animal house of the Laboratory of Food Biophysics, Biochemistry and Nutrition at National School of Agro-Industrial Science located in the University of Ngaoundere to investigate the impact of cocoa liquor on the lipid profile of Wistar rats. The objective was to evaluate both the antihyperlipidemic and hypolipidemic effects of cocoa liquor. To achieve this, 60 male Wistar rats (*Rattus norvegicus*) aged 10 weeks and weighing between 160-185g were utilized. After two weeks of acclimatization under standard conditions, 24 rats were randomly divided into two lots A and B, each consisting of two groups of six rats. Lot A was used to assess the antihyperlipidemic effect, while lot B was used to evaluate the hypolipidemic effect. A control group made of six rats received a standard diet throughout the experiment. The rats had unrestricted access to food and water, and their environment was maintained at ambient temperature with a natural light-dark cycle.

* + 1. ***Dietary protocol***

The obesity-inducing diet consisted of a high-fat (20-60%) diet, manufactured with lard instead of coconut oil, as used by Ngatchic *et al.* [21] with some modifications, since it is considered the most obesogenic. Indeed, saturated fatty acids, primarily derived from animal sources, are deemed more detrimental to cardiovascular health and more obesogenic (Flock *et al.*, 2014). The formulation of the diet for the rats in this study is presented in Table 1.

**Table 1**: Dietary formulation for animal experimentation [21].

|  |  |  |  |
| --- | --- | --- | --- |
| Nutrients | Ingredients | Normal Diet (g/kg BW) | Hyperlipidemic Diet (g/kg BW) |
| Proteins | Fish meal | 200 | 100 |
| Carbohydrate | Corn starch | 590 | 290 |
| Sucrose | 50 | 50 |
| Cellulose | 50 | 50 |
| Lipids | Pork fat | 0 | 150 |
| Egg yolk | 0 | 300 |
| Soybean oil | 50 | 50 |
| Other components | Minerals | 50 | 50 |
| Vitamin B complex | 10 | 10 |

BW: Body Weight

* + 1. ***Anti-Hyperlipidemic Test***

The anti-hyperlipidemic test was designed to evaluate the effect of cocoa liquor on the lipid profile of rats by administering it simultaneously with the hyperlipidemic diet for 30 days to the animals distributed as follows:

Positive Control: 100% hyper lipidic diet (PCA)

Test Group: 50% hyper lipidic diet + 50% cocoa liquor (TGA)

* + 1. ***Hypolipidemic treatment***

The hypolipidemic test was performed on rats in which hyperlipidemia had been previously induced. To achieve this, the animals were placed on a hyperlipidic diet for 28 days to induce obesity. The obese state of the rats was confirmed by calculating their Body Mass Index (BMI) and Lee Index (LI). The BMI was calculated from the weight and naso-anal length using Formula 1.

(1)

A rat was considered obese when BMI ≥ 0.68 g/cm2 [22].

The Lee Index (LI) was calculated using the cube root of the weight W (g) divided by the naso-anal length L (cm) of the rats according to Formula 2.

(2)

A rat is considered obese when LI ≥ 310 [23].

Following obesity induction, the experimental groups were assigned as follow:

Positive Control: 100% hyper lipidic diet (PCB)

Test Group: 50% hyper lipidic diet + 50% cocoa liquor (TGB)

For both anti hyper and hypolipidemic test, a negative control group (NC) was fed with 100% of normal diet.

The regimen was maintained for 30 days. To ensure *ad libitum* feeding, each group of rats received 100g of food daily at 11 am. Daily food intake was calculated by weighing leftover food at the same time each day, and the feed conversion ratio (FCR) was determined using Formula 3 [24].

(3)

Body weight and naso-anal length measurements were also recorded, following the method described by Novelli *et al.* [22]. Upon completion of the experiment, the rats were sacrificed after a 12-hour fasting period by intraperitoneal injection of ketamine (10 mg/ml) + diazepam (5 mg/ml). Blood samples were collected from the jugular vein into dry tubes for serum preparation. Additionally, the liver, kidneys, and heart were also harvested.

* 1. **Biochemical Analyses**

Blood samples were collected in centrifuge tubes and allowed to clot. The serum was then separated by centrifugation at 3000 rpm/15 mins. The collected serum was stored in Eppendorf tubes and transported to the Ngaoundere Regional Hospital for determination of biochemical parameters using enzymatic methods with commercial kits. Triglycerides were estimated using the GOP-PAP method [25], Total cholesterol was determined by the CHOD-PAP method [26], while HDL cholesterol was measured using the CHOD-PAP method [27]. Alanine Amino Transferase (ALT) and Aspartate Amino Transferase (AST) levels were measured using SBio SGPT and SGOT kits respectively, following the method of Bergmeyer & Hørder [28]. Urea levels were determined using the enzymatic method of Talke & Schubert [29]. Creatinine was measured using the colorimetric Jaffé method with SGM creatinine LR kits [21].

* 1. **Statistical Analysis**

Each essay was performed in triplicate and the results expressed as mean ± standard deviation using Excel 2016 software. The histograms were drawn using the same software. Data were tested for normality, and then submitted to analysis of variance (ANOVA) for significance difference (p<0.05) check using Statgraphics centurion XVI.I software. The Duncan’s multiple range test was investigated to accomplish the separation of means.

1. **Results and discussion**
   1. **Physicochemical and Phytochemical characteristics of the cocoa liquor produced**

Table 2 presents the nutrients and bioactive content of the cocoa liquor produced. The liquor has a water content of approximately 6.87%, which is beneficial for its conservation. A water content below 10% is known to result in a longer shelf life, due to the inactivation of microorganisms and the decrease of metabolic reactions [31]. This result is close to the one found by Baleba et al. [8] for a cocoa liquor produced by blending 70% of fermented/roasted cocoa beans with 30% of raw ones. The liquor has an ash content of approximately 2%, suggesting a significant mineral content. This was confirmed by quantifying some minerals in the liquor sample, with interesting contents of zinc (6.91±0.11 mg/100 g DW), iron (37.32±0.53 mg/100 g DW), and copper (1.96±0.01 mg/100 g DW). Given that these minerals act as cofactors in many antioxidants and immune reactions in the body [32], this result could predict a high antioxidant activity for cocoa liquor produced, similar to the one reported by Baleba *et al*. [8]. The vitamin E content in the cocoa liquor is 1.52 mg/100 g DW, an interesting level. Vitamin E is a powerful antioxidant that protects cellular membranes from oxidation [33]. As for bioactive compounds, the cocoa liquor contains interesting levels of total polyphenols (47.14±0.31 mg EAG/g DW), flavonoids (10.70±0.13 mg ER/g DW), and condensed tannins (0.41±0.01 mg EAT/g DW), which are beneficial for human health. Indeed, polyphenols are recognized to have anti-inflammatory, antioxidant, antihypertensive, and anti-diabetic properties [34]. Flavonoids, a particular class of polyphenols, have been shown to protect the cardiovascular system [35]. Condensed tannins (proanthocyanidins) contribute to preventing or managing cardiovascular diseases, cancer, high blood pressure, hyperlipidemia, and diabetes [36].

**Table 2**: Physicochemical characteristics of cocoa liquor produced

|  |  |
| --- | --- |
| Parameters | Values |
| Water content (%) | 6.87±0.23 |
| Ash content (%) | 2.03±0.12 |
| Total fat (g/100g DW) | 45.07±0.27 |
| Soluble sugar (g/100 g DW) | 12.31±0.30 |
| Crude protein (g/100 g DW) | 3.57±0.18 |
| Vitamin E (mg/100 g DW) | 1.52±0.01 |
| Iron (mg/100 g DW) | 37.32±0.53 |
| Zinc (mg/100 g DW) | 6.91±0.11 |
| Copper (mg/100 g DW) | 1.96±0.01 |
| Selenium (mg/100 g DW) | 0.011±0.00 |
| Total polyphenols (mg EAG/g DW) | 47.14±0.31 |
| Flavonoids (mg ER/g DW) | 10.70±0.13 |
| Condensed tannins (mg EAT/g DW) | 0.41±0.01 |

* 1. **Induction of obesity**

Table 3 presents the body mass index (BMI) and Lee index (LI) used in this study to evaluate the nutritional status of rats. It appears that at the end of the experiments, with a BMI ≥ 0.68 and an LI ≥ 310, all rats in batch B (hypolipidemic test) were obese, both in the positive control group (PCB) and the test group (TGB). However, it is noted that the BMI and LI values of the test group that consumed cocoa liquor (TCB) were significantly lower than those of the positive control group fed with 100% hyperlipidemic diet (PGB). For batch A (antihyperlipidemic test), rats in the positive control group (PCA) fed exclusively with hyperlipidemic diet were obese at the end of the experiment, while rats in the test group (TGA) that received 50% cocoa liquor had a normal nutritional status. These results indicate that for the antihyperlipidemic test, consumption of cocoa liquor in association with a hyperlipidemic diet by normal rat limits weight gain, while for the hypolipidemic test, consumption of cocoa liquor with a hyperlipidemic diet by obese rats contributes to reducing rat weight. However, given its richness in fat, which would be primarily composed of long-chain saturated fatty acids, consumption of cocoa liquor would be expected to promote weight gain in rats. The opposite effect observed can be attributed to the polyphenols present in significant quantities in cocoa liquor, as indicated in Table 2. Indeed, numerous studies have shown that consumption of foods rich in polyphenols contributes to limiting fat mass gain and improving nutritional status [37-39].

**Table 3:** Body measurement parameters of experimental rats

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Start** | | **End** | |
| **Groups** | **BMI (g/Cm2)** | **LI (g/Cm)** | **BMI (g/Cm2)** | **LI (g/Cm)** |
| **NC** | 0.48±0.02b | 285.07±1.98c | 0.62±0.02b | 289.34±2.68d |
| **PCA** | 0.53±0.01a | 304.66±1.87a | 0.70±0.02a | 318.07±3.13a |
| **TGA** | 0.48±0.03b | 293.05±3.56b | 0.63±0.03b | 301.15±2.52c |
| **PCB** | 0.53±0.03a | 304.26±1.24a | 0.69±0.01a | 317.09±1.29a |
| **TGB** | 0.53±0.01a | 306.10±1.71a | 0.69±0.01a | 311.31±2.26b |

**A:** Antihyperlipidemic test; **B:** Hypolipidemic test; **NC:** Negative control (Normal diet); **PC:** Positive Control (High fat diet); **TG:** Test Group (High fat diet + cocoa liquor); **BMI**: Body Mass Index; **LI**: Lee Index; Different letters in superscript within the same column indicate significant differences between means (p<0.05)

* + 1. **Blood biochemical parameters**
    2. **Lipid profile**

Figure 1 presents the lipid profile of rats for the anti-hyperlipidemic (A) and hypolipidemic (B) tests. It appears that for both tests, the levels of triglycerides, total cholesterol, and LDL are higher in the rats of the positive control group that consumed 100% of a hyperlipidemic diet. However, when cocoa liquor is introduced into their diet, a significant decrease in these levels is observed, along with a significant increase in HDL cholesterol levels in the test group rats. Notably, the cocoa liquor added contains nearly 50% lipids (Table 2), and this fat would be primarily composed of long-chain saturated fatty acids, given the very firm texture of the produced cocoa liquor. Previous studies have shown that lipids rich in long-chain saturated fatty acids are very firm at room temperature [40]. With a significant lipid intake from the cocoa liquor, one would expect the levels of total cholesterol, LDL cholesterol, and triglycerides to increase in the test groups, along with a decrease in HDL cholesterol levels. However, the opposite effect was observed, revealing the anti-hyperlipidemic and hypolipidemic effects of cocoa liquor, which in one case prevented the increase in hyperlipidemia biomarkers (anti-hyperlipidemic), and in the other case decreased the levels of these biomarkers in obese rats (hypolipidemic). These effects of cocoa liquor on rat lipidemia can be attributed to its high content of total polyphenols and flavonoids (Table 2). Indeed, numerous studies have shown that polyphenols can reduce lipidemia through several mechanisms of action. Firstly, polyphenols inhibit pancreatic and intestinal lipases, limiting lipid digestion and absorption. The proportion of lipids that are not digested is excreted in the feces, contributing to reduced lipidemia [41,42]. Secondly, polyphenols intervene in cholesterol metabolism by inhibiting the action of HMG-CoA reductase, which prevents cholesterol synthesis and reduces cholesterolemia or by Inhibiting the Transport and Expression of Niemann–Pick C1-Like 1 [43,44]. Furthermore, the decrease in LDL cholesterol levels by cocoa liquor helps limit the risk of atherosclerosis. Indeed, LDL cholesterol can be oxidized in arteries and deposited on the inner wall, forming atherosclerotic plaques that lead to atherosclerosis, a starting point for cardiovascular diseases [45]. The anti-hyperlipidemic and hypolipidemic properties of cocoa liquor can be valued in the production of chocolate products for individuals with pathologies such as obesity, type 2 diabetes, and cardiovascular diseases, all of which have hyperlipidemia as a common risk f

actor.

TC: Total cholesterol; HDL-c: HDL cholesterol; LDL-c: LDL Cholesterol; TG: Triglycerides; Different letters above histograms reveal significant differences (p < 0.05). In this case, we have indicated with the same letter style, the data to be compared with each other.

**Figure 1**: Lipid level in rats’ serum (A: Antihyperlipidemic test; B: Hypolipidemic test)

* + 1. **Effect of cocoa liquor on hepatic, heart and kidney functions**

To assess the potential adverse effects of consuming cocoa liquor on liver, heart, and kidney functions in rats, serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), urea, and creatinine were determined, and the results are presented in Figures 2 and 3. Figure 2 shows lower serum AST and ALT levels in the test groups that consumed cocoa liquor compared to the positive control group on a hyperlipidemic diet, both in the anti-hyperlipidemic (Fig. 2A) and hypolipidemic (Fig. 2B) tests. ALT and AST are both used to evaluate hepatic disorders. An increase in the activities of these enzymes in the blood may be primarily due to their leakage from the liver cytosol into the bloodstream. Several studies have shown that elevated AST and ALT levels are a key indicator of liver dysfunction, reflecting disturbances in enzyme biosynthesis and alterations in hepatic membrane permeability [46]. These results suggest that consuming cocoa liquor for 30 days did not have adverse effects on the heart and liver of rats but rather improved the functioning of these organs. Regarding kidney function, Figure 3 shows significantly lower serum urea and creatinine levels in rats that consumed cocoa liquor for 30 days compared to the positive control group on a hyperlipidemic diet, both in the anti-hyper (Fig. 3A) and hypolipidemic (Fig. 3B) tests. This result indicates that cocoa liquor improved kidney function in rats, as low serum urea and creatinine levels are indicators of healthy kidneys [47]. Previous studies have shown that high-fat diets (HFD) can cause kidney damage through various mechanisms, including altered lipid metabolism, lipogenic enzyme stimulation, and impaired autophagic flux [48]. This can lead to renal injury, characterized by glomerulosclerosis, interstitial fibrosis, and albuminuria [49]. Overall, high-fat diets appear to have multiple pathways to induce kidney damage. Another theory is that a higher body mass index causes blood pressure to rise, which causes adverse kidney effects and changes that lead to increased tubular secretions, which in turn raise blood levels of urea, creatinine, and uric acid [50,51]. The beneficial effects of cocoa liquor on vital organs in rats may be attributed to its richness in polyphenols, consistent with previous studies highlighting the protective role of antioxidants such as polyphenols, flavonoids, and pro-anthocyanidins on the heart, liver, and kidneys of rats by protecting their cells from oxidation by free radicals and reactive oxygen species (ROS) [52-54].

a

AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; Different letters above histograms reveal significant differences (p < 0.05). In this case, we have indicated with the same letter style, the data to be compared with each other.

**Figure 2:** Transaminase level in rat serum (A: Antihyperlipidemic test; B: Hypolipidemic test)

a

The letters appearing above the histograms reveal significant differences between treatments after analysis of variance (p < 0.05). In this case, we have indicated with the same letter style, the data to be compared with each other.

**Figure 3:** Urea and creatinine level in rat’s serum (A: Antihyperlipidemic test; B: Hypolipidemic test)

**Conclusion**

This study demonstrates that a cocoa liquor fraction composed of 20% non-fermented and 80% fermented cocoa, rich in antioxidants, effectively mitigates diet-induced hyperlipidemia in Wistar rats, achieving its intended purpose. The cocoa liquor produced exhibits a favorable nutritional profile, with a low water content, significant mineral content, and interesting levels of bioactive compounds such as polyphenols, flavonoids, and condensed tannins. These compounds have been shown to have various health benefits, including antioxidant, anti-inflammatory, and cardiovascular protective effects. The results suggest that the cocoa liquor produced could be a valuable ingredient for the development of functional foods and beverages with potential health benefits. Furthermore, the antioxidant and anti-hyperlipidemic properties of the cocoa liquor make it a promising candidate for the prevention and management of chronic diseases such as cardiovascular disease and diabetes.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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