

Evaluation of the antioxidant, hypoglycemic, and anti-hyperglycemic potential of a fermented drink made from tamarind, ginger, and turmeric in rabbits

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ABSTRACT: Beverages are important in the diet because they help humans stay hydrated. However, they are implicated in the development of metabolic diseases due to their variable sugar content. A study was therefore conducted to develop and evaluate the antioxidant and hypoglycemic properties of a drink made from tamarind, turmeric and ginger, given the nutritional potential of these foods. For this, turmeric and ginger were added to tamarind in a ratio of 10%. The drinks were fermented spontaneously for 36 hours. The analyses were on pH, total polyphenols, and antioxidant activity according to DPPH determination. These beverages were then administered to healthy 2-month-old rabbits to assess their impact on blood sugar levels. Results revealed that beverages pH remained acidic and below 3 during fermentation. The combination of tamarind (90%), turmeric (5%), and ginger (5%) increased polyphenol content from 1.498 to 1.514 mg GAE/g. Fermented tamarind-turmeric and tamarind-turmeric-ginger drinks DPPH inhibitory concentrations (IC₅₀) were 2.14 and 2.23 µg/ml respectively, revealing respective anti-radical powers of 37.74 and 44.84 µmol of reduced DPPH. Combination of tamarind (90%), turmeric (5%), and ginger (5%) also led to a decrease in blood sugar levels 2.5 hours after glucose induction from 126.6±15.30 to 112.8±5.63 (mg/dL) and from 121±9.72 to 112.6±6.65 (mg/dL), respectively. The anti-hyperglycemia test revealed a decrease in blood glucose levels for all beverages. Beverages made from tamarind, turmeric, and ginger have good antioxidant properties that promote lower blood sugar levels, contributing to fight against metabolic diseases.

KEYWORDS: tamarind, ginger, turmeric, fermentation, antioxidant, blood sugar.

1 INTRODUCTION

Hyperglycemia is a real health problem that is part of the metabolic syndrome, resulting in high blood sugar levels, very often caused by oxidative stress but also by poor eating habits such as excessive consumption of sugary drinks [1]. However, the amount of sugar added to these drinks is not always controlled by the manufacturer [2], [3]. So, population is increasingly turning to a healthy, so-called functional diet based on fruits and vegetables rich in phytonutrients. These Phytonutrients, found in plant-based foods, are attracting considerable interest in the fight against metabolic diseases [4].

To address the resurgence of metabolic diseases, it would be beneficial to boost the potential of tamarind by adding antioxidant spices, particularly ginger and turmeric, and by using the process of spontaneous lactic fermentation. Indeed, lactic acid fermentation is a biological process that transforms food through the action of lactic acid bacteria. This age-old process is used for preservation, to improve flavor, taste, and nutritional value of food, to increase the bioavailability of bioactive compounds, and to promote the production of metabolites beneficial to health [5].

Furthermore, fermented foods and beverages, rich in probiotics and bioactive compounds, are generating increasing interest due to their potential positive effects on health and nutrients (phenolic compounds, B vitamins, essential amino acids,

etc.) improvement [6]. In addition, spices with antioxidant properties have the ability to eliminate free radicals, which are the basis of oxidative stress. Indeed, [7] in her study has shown that adding ginger and turmeric to tamarind increased also antioxidant potential without fermentation. But, a hepatoprotective effect of fermented turmeric rhizome was observed in rats and, during plant fermentation, lactic acid bacteria are able to hydrolyze phenolic compounds present in polymer form, thus releasing bioactive molecules and increasing their bioavailability [8].

However, these studies did not assess the impact of these nutrient- and antioxidant-dense beverages on metabolic diseases, particularly hyperglycemia. This study therefore aims to evaluate the antioxidant, hypoglycemic, and antihyperglycemic effects of fermented beverages based on tamarind, ginger, and/or turmeric in rabbits.

2 MATERIALS AND METHODS

2.1 BIOLOGICAL MATERIAL

Plant materials used in this study were tamarind pods (*Tamarindus indica*), turmeric (*Curcuma longa* L.), and ginger (*Zingiber officinale*). Tamarind pods were harvested in Lagnonkaha, a village in Korhogo department of the PORO region, located in northern Côte d'Ivoire, approximately at 600 kilometers from Abidjan, the economic capital. Turmeric and ginger rhizomes were collected in Divo, in the LÔH-DJIBOUA region, in southwestern Côte d'Ivoire, at approximately 187.9 km from Abidjan.

Animal materials consisted of 30 Hyplus rabbits, aged two months, with body weights ranging from 600 to 1800 grams. The rabbits were acclimatized for one week in cages and received daily water and pellets (IVO-GRAINS). They were divided into 10 groups of 3 rabbits and received treatments over a period of 28 days. All rabbits were used for *in vivo* tests, and the experimental protocol and animal handling procedures were conducted in accordance with the guidelines of the Ethics Committee of Nangui ABROGOUA University (Côte d'Ivoire).

2.2 BEVERAGE FERMENTATION

Tamarind beverage was prepared by adding 800 mL of water to 250 g of tamarind. Tamarind-turmeric and tamarind- ginger beverages were prepared by mixing 800 mL of water with 90% tamarind (225 g) and 10% turmeric or ginger (25g), respectively. The tamarind-turmeric-ginger beverage was prepared by mixing 800 mL of water with 90% tamarind, 5% turmeric, and 5% ginger. The mixtures were transferred into sterilized glass jars, sealed hermetically, and 10 g of salt was added as a preservative and as a nutrient for bacterial growth. Samples of each beverage were taken at time 0 (T0H), representing the non-fermented beverages. The remaining mixtures underwent spontaneous fermentation for 36 hours at 37°C, maintaining a pH below 3 for each beverage. Samples were then taken every 12 hours for analysis. However, for *in vivo* analysis, only T0H and T36H samples were used.

2.3 BLOOD SAMPLING

Blood samples were collected using a glucometer with test strips (One Call Vivid) via puncture of the marginal vein of the ear. Samples were taken before force-feeding at T0min, then at 30, 60, 90, and 150 min after induction of hyperglycemia.

2.4 DETERMINATION OF PH, PHENOLIC COMPOUNDS AND ANTIOXIDANT ACTIVITY

The pH was determined using the [9] method, and total polyphenols were determined using the [10] method. Antioxidant activity according to DPPH was determined using the method of [11]. The IC₅₀ was determined on the graph and used to calculate the anti-radical power using [12] method according to the following equation:

$$\text{ARP} = \frac{\text{Concentration of DPPH solution (mg sample / } \mu\text{mol DPPH)}}{\text{CI}_{50} \times 10^{-3} (\mu\text{g/ml)}} \quad (1)$$

2.5 EVALUATION OF HYPOGLYCEMIC AND ANTIHYPERGLYCEMIC EFFECT

2.5.1 INDUCTION OF HYPERGLYCEMIA

Hyperglycemia was induced using anhydrous glucose in solution at a concentration of 4 g.l⁻¹ via an intubation cannula. The volume administered was 0.2 ml of glucose per 20 g of body weight (bw), 10 mg/kg bw [13]; [14]. Rabbits that had been fasting for 12 hours were used for the tests [15].

2.5.2 EVALUATION OF THE HYPOGLYCEMIC EFFECT

Thirty minutes after the induction of hyperglycemia by anhydrous glucose (10 mg/kg bw), rabbits from batches 3, 4, 5, 6, 7, 8, 9, and 10 received extracts of fermented or unfermented beverages. Those in groups 1 and 2 received water and glybenclamide, respectively, after induction of hyperglycemia. Blood glucose levels were monitored at 0, 30, 60, 90, and 150 min.

2.5.3 EVALUATION OF THE ANTI-HYPERGLYCEMIC EFFECT

For this test, rabbits from different groups were given water, glybenclamide, and 2 ml per 100 g of fermented or unfermented beverage extract (groups 3, 4, 5, 6, 7, 8, 9, and 10) via gavage. Thirty minutes later, hyperglycemia was induced by administering anhydrous glucose (10mg/kg bw). Blood glucose levels were monitored at 0, 30, 60, 90, and 150 minutes.

2.6 STATISTICAL ANALYSIS

The results statistical analysis was processed using XLSTAT 2016 and Statistica7.1 software. An ANOVA followed by Tukey and Newman-Keuls post hoc tests were used to compare the means at a significance level of 5% ($p=0.05$).

3 RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 EVOLUTION OF PH DURING FERMENTATION

Table 1 shows beverages pH values during fermentation. From T0h to T36h, the pH of the beverages varied but remained acidic and below 3. However, the pH of the TC10 beverage fluctuated between 2.78 and 2.52. The pH remained stable from T24h to T36h. However, TG10, TCG10, and T100 beverages pH increased from T0h to T36h, rising from 2.38 to 2.48 for the TG10 beverage, from 2.27 to 2.47 for the TCG10 beverage, and from 2.1 to 2.42 for the T100 beverage.

Table 1. Evolution of pH during fermentation

Time	Beverages			
	T100	TC10	TG10	TCG10
T0H	2,1±0,02 ^a	2,78±0,02 ^c	2,38±0,01 ^a	2,27±0,02 ^a
T12H	2,25±0,01 ^b	2,52±0,1 ^b	2,42±0,01 ^a	2,56±0,1 ^c
T24H	2,2±0,02 ^b	2,62±0,1 ^b	2,43±0,01 ^a	2,43±0,01 ^b
T36H	2,42±0,01 ^c	2,62±0,1 ^b	2,48±0,01 ^c	2,47±0,01 ^b

T100: drink made with 100% Tamarind. TC10: drink made with 90% Tamarind and 10% Turmeric; TG10: drink made with 90% Tamarind and 10% Ginger; TCG10: drink made with 90% Tamarind, 5% Turmeric and 5% Ginger. Values followed by the same letter in line do not differ significantly, Newman keul ($p=0.05$).

3.1.2 CHANGES IN PHENOLIC COMPOUNDS IN FERMENTED AND NON-FERMENTED BEVERAGES

Figure 1 shows the total phenolic compound content generally increased between T0h and T36h during beverage fermentation. In fact, total phenolic compounds increased from 1.431 to 1.528 mg GAE/g DM (in T100 beverage) and from 1.305 to 2.011 mg GAE/g DM (in TC10 beverage). However, peaks were observed at T12H for TG10 beverage (1,326 mg GAE/g DM) and for TCG10 beverage (1.12 to 1,514 mg GAE/g DM).

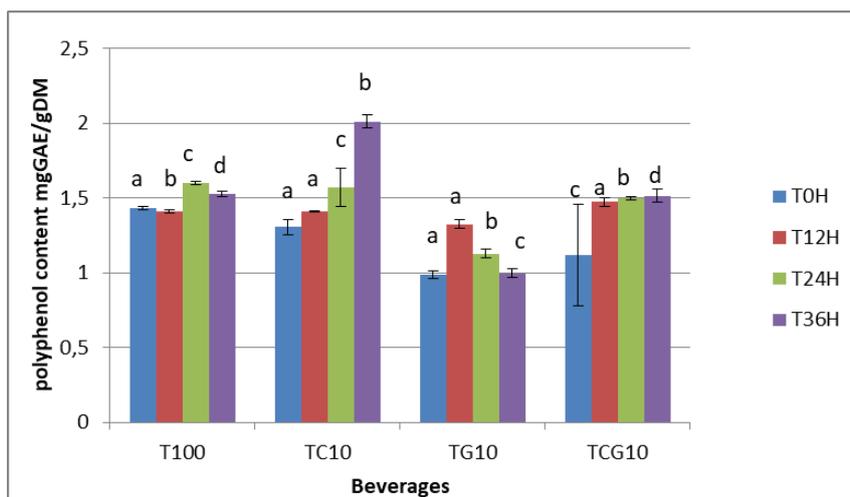


Fig. 1. Changes in total polyphenols during beverage fermentation

T100: drink made with 100% Tamarind. TC10: drink made with 90% Tamarind and 10% Turmeric; TG10: drink made with 90% Tamarind and 10% Ginger; TCG10: drink made with 90% Tamarind, 5% Turmeric and 5% Ginger; Values followed by the same letter in line do not differ significantly, Newman keul ($p=0.05$).

3.1.3 EVOLUTION OF TANNINS IN FERMENTED AND NON-FERMENTED BEVERAGES

Figure 2 shows the evolution of tannins during fermentation of the different beverages from T0h to T36H. These values decrease for TC10 and TG10 beverages, ranging from 0.497 to 0.481mg TAE/l for TC10 beverage, and from 0.749 to 0.591mg TAE/l for TG10 beverage. However, there was an increase in TCG10 and T100 beverages from T0h to T24h and then a decrease until T36h. The variation rank from 0.509 to 0.665mg TAE/l for TCG10 beverage, and from 0.471 to 0.553mg TAE/l for T100.

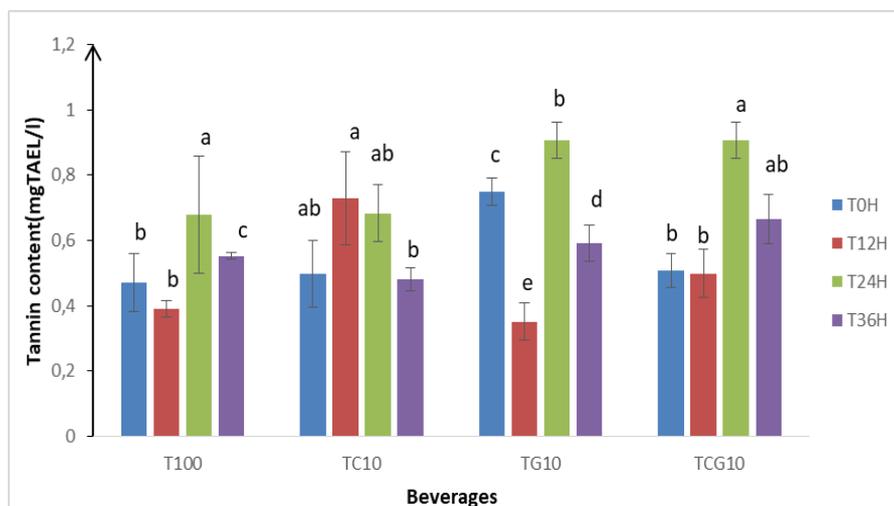


Fig. 2. Evolution of tannins

T100: drink made with 100% Tamarind. TC10: drink made with 90% Tamarind and 10% Turmeric; TG10: drink made with 90% Tamarind and 10% Ginger; TCG10: drink made with 90% Tamarind, 5% Turmeric and 5% Ginger; Values followed by the same letter in line do not differ significantly, Newman keul $p=0.05$

3.1.4 EVOLUTION OF ANTIOXIDANT ACTIVITY

Beverages' antioxidant activity evolution during fermentation is presented in figure 3. In general, this antioxidant activity increases with concentration. Moreover, tables 2 and 3 show IC_{50} and free radical scavenging capacity. Vitamin C (standard) IC_{50} is about 1.61 $\mu\text{g/ml}$, revealing a free radical scavenging capacity of 62.11 mg of sample/ μmol of reduced DPPH. Only

Tamarind-Turmeric (TC10) beverage IC_{50} at T0h (1.82 $\mu\text{g/ml}$) is close to that of vitamin C (Table 2). From T0h to T36h, there is an increase in antioxidant activity for the TG10 and TCG10 beverages. This increase is marked by a decrease of IC_{50} from 4.86 to 3.5 $\mu\text{g/ml}$ and from 2.65 to 2.23 $\mu\text{g/ml}$, respectively (Table 2), and an increase in free radical scavenging capacity from 20.58 to 28.57 and from 37.74 to 44.84 $\text{mg}/\mu\text{mol}$ of reduced DPPH, respectively (Table 3). However, the TC10 beverage has the highest free radical scavenging capacity, at 54.95 $\text{mg}/\mu\text{mol}$ of reduced DPPH. But this free radical scavenging capacity decreases to 46.73 $\text{mg}/\mu\text{mol}$ of reduced DPPH after 36 hours of fermentation.

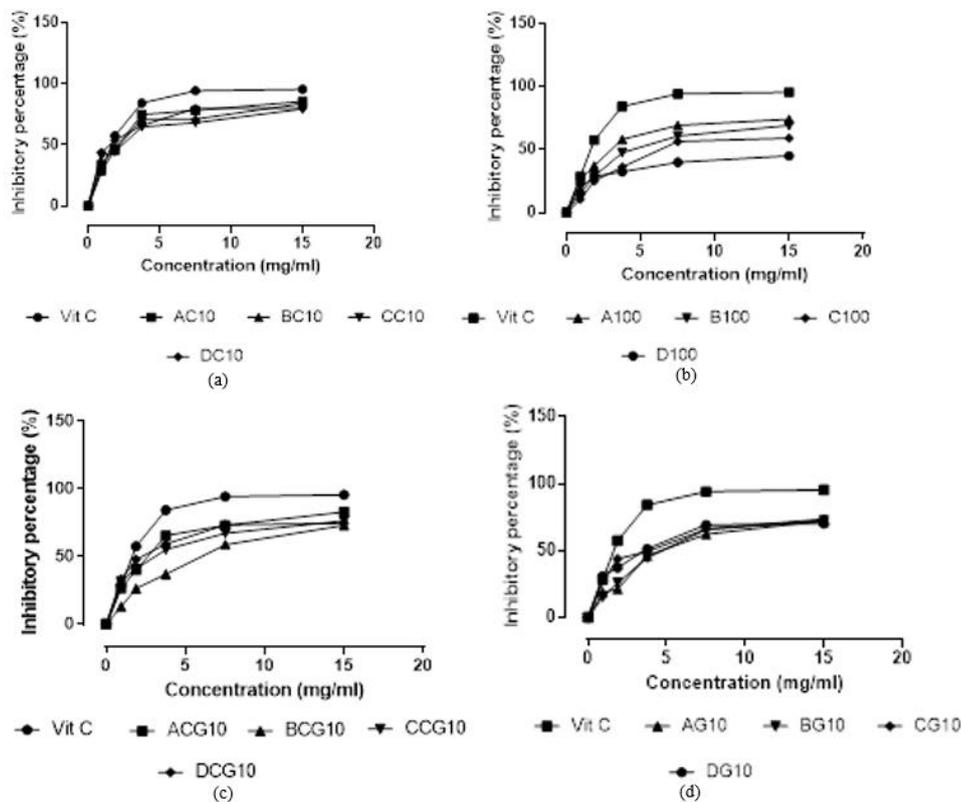


Fig. 3. Evolution of the Percentage of Inhibition of Beverages and Vitamin C as a Function of Concentration: (a) tamarind-based beverage, (b) tamarind-turmeric beverage, (c) tamarind-ginger beverage, (d) tamarind-turmeric-ginger beverage

A100: Tamarind at T0; B100: Tamarind at T12; C100: Tamarind at T24; D100: Tamarind at T36; AC10: Tamarind-turmeric at T0; BC10: Tamarind-turmeric at T12; CC10: Tamarind-turmeric at T24; DC10: Tamarind-turmeric at T36; AG10: Tamarind-ginger at T0; BG10: Tamarind-ginger at T12; CG10: Tamarind-ginger at T24; DG10: Tamarind-ginger at T36; ACG10: Tamarind-turmeric-ginger at T0; BCG10: Tamarind-turmeric-ginger at T12; CCG10: Tamarind-turmeric-ginger at T24; DCG10: Tamarind-turmeric-ginger at T36.

Table 2. Inhibitory concentration (IC_{50}) of non-fermented and fermented beverages

Time	IC_{50} ($\mu\text{g/ml}$)				
	Vitamin C	T100	TC10	TG10	TCG10
T 0H	1.61	3.11 \pm 0.1 ^a	1.82 \pm 0.1 ^a	4.86 \pm 0.2 ^c	2.65 \pm 0.1 ^b
T 12H	1.61	4.51 \pm 0.1 ^c	2.32 \pm 0.2 ^c	4.86 \pm 0.2 ^c	6.08 \pm 0.2 ^e
T 24H	1.61	6.35 \pm 0.2 ^j	2.46 \pm 0.2 ^j	4.07 \pm 0.2 ^b	3.18 \pm 0.2 ^j
T 36H	1.61	6.3 \pm 0.2 ^j	2.14 \pm 0.1 ^b	3.5 \pm 0.2 ^a	2.23 \pm 0.1 ^a

T100: drink made with 100% Tamarind. TC10: drink made with 90% Tamarind and 10% Turmeric; TG10: drink made with 90% Tamarind and 10% Ginger; TCG10: drink made with 90% Tamarind, 5% Turmeric and 5% Ginger. Values followed by the same letter in line do not differ significantly, Newman keul ($p=0.05$).

Table 3. Evolution of anti-radical power in non-fermented and fermented beverages

Time	ARP (μmol. ml/μg)				
	Vitamine C	Beverages			
		T100	TC10	TG10	TCG10
T0H	62.11±0.2 ^a	32.15±0.2 ^d	54.95±0.2 ^e	20.58±0.1 ^a	37.74±0.2 ^d
T12H	62.11±0.2 ^a	22.17±0.1 ^b	43.10±0.1 ^c	20.58±0.1 ^a	16.45±0.1 ^a
T24H	62.11±0.2 ^a	15.75±0.1 ^a	40.65±0.1 ^b	24.57±0.2 ^c	31.45±0.1 ^b
T36H	62.11±0.1 ^a	15.87±0.1 ^a	46.73±0.2 ^d	28.57±0.2 ^d	44.84±0.2 ^e

T100: beverage prepared from 100% tamarind; TC10: beverage prepared from 90% tamarind and 10% turmeric; TG10: beverage prepared from 90% tamarind and 10% ginger; TCG10: beverage prepared from 90% tamarind, 5% turmeric, and 5% ginger. Note: In any given column, values followed by the same letter do not differ significantly at the $p = 0.05$ level, according to Dunnett's test.

3.1.5 ASSESSMENT OF BEVERAGES GLYCEMIC PARAMETERS

3.1.5.1 ASSESSMENT OF BEVERAGES HYPOGLYCEMIC POTENTIALITIES

Figure 4 shows the hypoglycemic effect of fermented and unfermented beverages over time (T0 to T150 min) on rabbits' blood glucose levels after oral administration of anhydrous glucose. At T0, i.e., before treatment of the rabbits, fasting blood glucose levels showed significant differences among the 10 experimental groups. Group 2 (150 ± 0.33 mg/dL) had the highest fasting blood glucose level, and the lowest was observed in group 5 (93.4 ± 5.27 mg/dL). Anhydrous glucose was administered after the fasting blood glucose level was measured, resulting in an exponential variation between T0 and T30, with 305.8 ± 52.52 mg/dL being the maximum observed blood glucose value for these different rabbit groups. Furthermore, after treatment of the experimental rabbit groups with the studied extracts and glibenclamide, particularly at times T30 and T150, a significant and very significant decrease in blood glucose was observed in these groups compared to the control group that received distilled water. However, in rabbits that received glibenclamide and those in groups 7 and 10, the blood glucose value at T150 was lower than the starting blood glucose, namely 84.6 ± 12.58 mg/dL, 110.2 ± 81.76 mg/dL, 112.8 ± 5.63 mg/dL, and 112.6 ± 6.65 mg/dL at T150 versus 124 ± 1.58 mg/dL, 115 ± 5.45 mg/dL, 126.6 ± 10.06 mg/dL and 126.6 ± 15.30 mg/dL at T0.

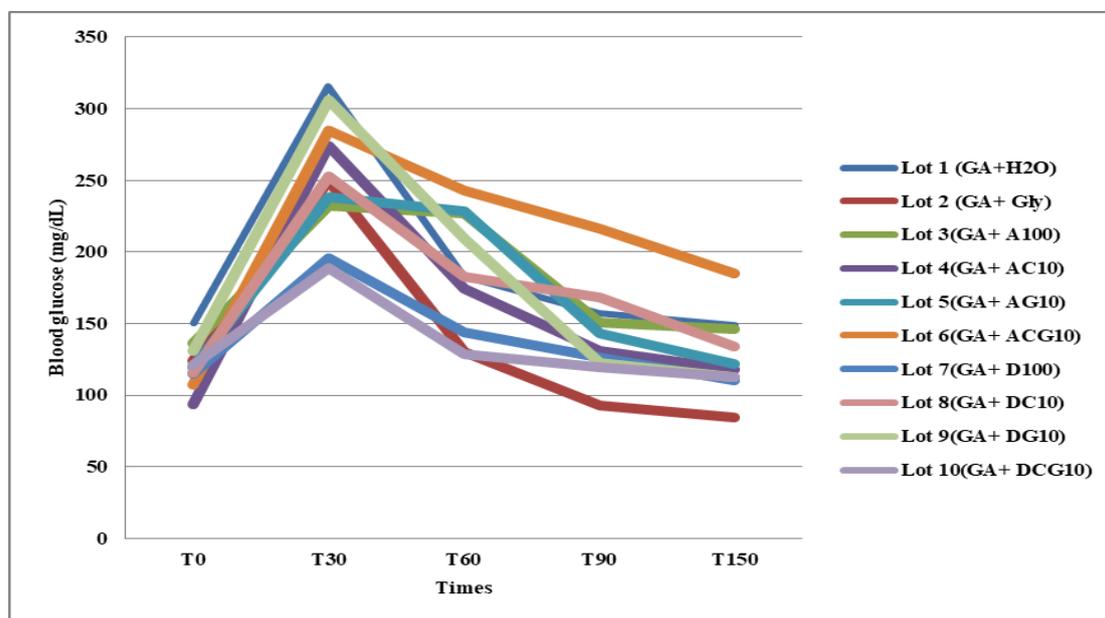


Fig. 4. Hypoglycemic effect of fermented and unfermented beverages

AC10: beverage composed of 90% tamarind and 10% turmeric T0H, AG10: beverage composed of 90% tamarind and 10% ginger T0H; ACG10: beverage composed of 90% tamarind, 5% turmeric, and 5% ginger T0H; A100: beverage composed of 100% tamarind T0H DC10: beverage composed of 90% tamarind and 10% turmeric T36H, DG10: beverage composed of 90% tamarind and 10% ginger T36H; DCG10: drink composed of 90% tamarind, 5% turmeric, and 5% ginger T36H; D100: drink composed of 100% tamarind T36H, GLY (glibenclamide), GA (anhydrous glucose), H₂O (water).

3.1.5.2 EVALUATION OF BEVERAGES ANTI-HYPERGLYCEMIC POTENTIAL

Figure 5 shows the antihyperglycemic effect of the beverages on the blood glucose levels of rabbits after oral administration of unfermented and fermented beverages followed by anhydrous glucose. Fasting blood glucose levels ranged from 103.4 ± 5.18 mg/dL to 152 ± 5.15 mg/dL. For this test, the beverages and glibenclamide were administered by gavage before the introduction of anhydrous glucose at T30, i.e., 30 minutes after. Analysis of the results revealed a significant decrease in blood glucose levels between T0 and T30 for all 10 groups except the control group. However, at T150, only a significant decrease in blood glucose was observed in the rabbits treated with glibenclamide and the extracts compared to the control group that received only distilled water. In rabbits that received water and pure unfermented tamarind juice, blood glucose levels increased up to T60 before decreasing at T150, although still higher than blood glucose levels at T0. However, in rabbits that received glibenclamide and in those from groups 4 to 10, i.e. those that received the drinks enriched with unfermented turmeric and ginger and those that received the fermented drinks, blood glucose increases at T30 and decreases at T90.

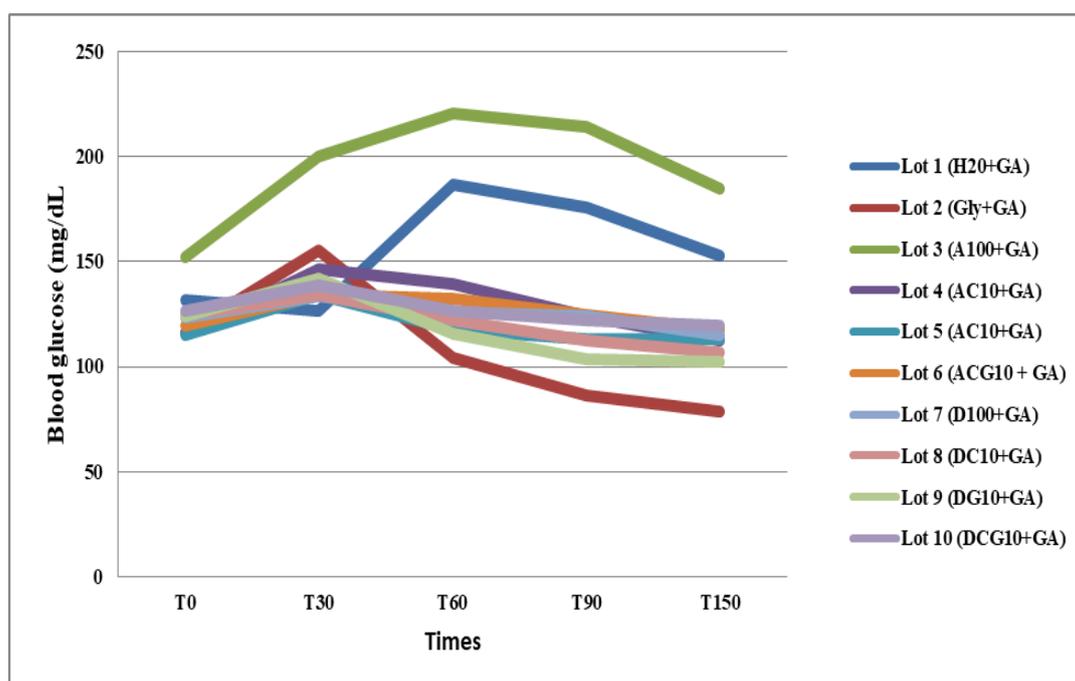


Fig. 5. Evolution of the anti-hyperglycemic effect of unfermented and fermented drinks

AC10: unfermented beverage composed of 90% tamarind and 10% turmeric; AG10: unfermented beverage composed of 90% tamarind and 10% ginger; ACG10: unfermented beverage composed of 90% tamarind, 5% turmeric, and 5% ginger; A100: unfermented beverage composed of 100% tamarind DC10: fermented beverage composed of 90% tamarind and 10% turmeric, DG10: fermented beverage composed of 90% tamarind and 10% ginger; DCG10: fermented beverage composed of 90% tamarind, 5% turmeric, and 5% ginger; D100: fermented beverage composed of 100% tamarind, GLY (glibenclamide), GA (anhydrous glucose), H2O (water).

3.2 DISCUSSION

The study results showed that the beverages pH remained acidic throughout the fermentation process. This could be explained by the production of lactic acid bacteria during the fermentation process [16]. However, [17] showed a decrease in pH from 6.13 before fermentation to 3.9 after 72 hours of fermentation in fermented kale juice. These results are higher than the values obtained during fermentation and differ from those found by [18] in pineapple wine, where the pH was around 4.5.

Regarding the evolution of total polyphenols during fermentation, an increase in polyphenols was observed in the T100%, TC10%, and TCG10% beverages. According to [19], microorganisms are thought to be the cause of this increase, which could be due to the release of phenolic compounds during fermentation. However, it would depend on the species or strain of bacteria present in the beverage during fermentation [20]. Furthermore, [21]; [22] also found an increase in total polyphenols in fermented kale juice. This result is consistent with that obtained for fermented beverages. However, a decrease in

polyphenols was observed in the TG10% beverage. This could be due to different interactions between polyphenols and nutrients. Indeed, according to [23], the interaction between polyphenols and proteins makes polyphenols less extractable.

According to [24], the lower the IC₅₀, the greater the antioxidant capacity of the food. This is the case for the 10% TC fermented beverage compared to other fermented beverages after 36 hours of fermentation. This decrease confirms the greater antioxidant activity of this beverage. These results are consistent with those of [25], who demonstrated an increase in the antioxidant activity of lemon juice after fermentation. They also corroborate the findings of [26], who reported an increase in IC₅₀ after kambuncha fermentation ranging from 9 to 21 µg/mL. The decrease of antinutritional factors rate during fermentation, particularly tannins, can be explained either by the hydrolysis of polyphenolic compounds into simple compounds by polyphenol oxidase, or by the degradation of tannin complexes (tannin-protein, tannin-starch, tannin-iron), [27].

Regarding the evaluation of the hypoglycemic effect of beverages, analysis of the results showed an increase in blood glucose levels after administration of anhydrous glucose to rabbits via gavage. However, this increase was followed by a rapid decrease after the drinks and glibenclamide were administered. According to [28], the hypoglycemic effect of the drinks is likely linked to their polyphenol and flavonoid composition. Indeed, flavonoids reduce the risk of diabetes, probably due to their strong inhibition of α -amylase and α -glucosidase, thereby decreasing glycogen breakdown. This potential mechanism is similar to that of hypoglycemic biguanides (metformin), which inhibit glucose absorption in the small intestine and thus decrease gluconeogenesis in the liver [29]. These beverages could therefore act via this same mechanism to reduce blood glucose levels in consumers or patients with diabetes. Furthermore, in the evolution of the hypoglycemic effect, consumption of the DCG10% and DG10% beverages led to a decrease in blood glucose levels, ultimately reaching a value below the baseline blood glucose level (T0h).

The fermented beverages DCG10 and DG10 thus promoted blood glucose regulation blood glucose levels by inhibiting the enzymes responsible for glucose absorption, thereby stimulating insulin production [30]. These results corroborate those of [31], who demonstrated the hypoglycemic effect of the ethanoic extract of *Anthocleista djalensis* roots after administration at doses of 37 to 111 mg/kg in rabbits made diabetic by alloxan. With regard to the anti-hyperglycemic effect of the beverages produced, analysis of the results revealed a significant decrease in blood glucose levels in rabbits treated with glibenclamide and in those fed with the beverages produced between T60 and T150. These results would suggest that the beverages had an antihyperglycemic effect in rabbits. For 2 and a half hours, they regulated blood glucose levels in rabbits fed a high concentration of anhydrous glucose. These beverages could therefore correct orally induced hyperglycemia in rabbits thanks to certain phytochemical compounds contained in tamarind, turmeric and ginger.

Indeed, according to [32] and [33], turmeric and ginger have good antioxidant potential, partly due to their phenolic compounds. However, [34] revealed that the hypoglycemic effect of wild olive leaves on blood sugar levels in rabbits was due to oleuropein, a powerful antioxidant contained in these leaves. The antioxidant activity generated by phenolic compounds could also have an impact on blood sugar levels. Indeed, in a study conducted by [35], it was reported that fruits may contain several active components that effectively regulate blood glucose levels in hyperglycemic rats and rabbits. These constituents may exert their effect by potentiating insulin secretion from residual insulin-producing cells or by increasing the cells' capacity to maintain glucose, including insulinotropic and protective and/or regenerative effects on pancreatic β -cell mass.

4 CONCLUSION

This study reveals that tamarind drinks enriched with ginger and turmeric contain phenolic compounds, giving them significant antioxidant potential. Furthermore, these drinks have a hypoglycemic effect on postprandial blood glucose and a pronounced antihyperglycemic effect when fermented. Evaluation of the antihyperglycemic potential of these drinks in rabbits showed very low oral glucose tolerance activity compared to the hypoglycemic test. In other words, the consumption of tamarind drinks enriched with ginger and turmeric would help restore blood glucose levels to normal within 2.5 hours in cases of food-induced hyperglycemia. The results for the drinks fermented at 36 hours (T36H) open the door to further investigation of the effect of fermentation time on blood glucose regulation in hypoglycemic and hyperglycemic situations.

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