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Angela Mumbua Musyoka^a, Grace Akinyi Odongo^b, Erick Nyakundi Ondari^c, Sarah Nwozo^{a,d}, Michael Musembi Muteti^{e,f}, Ilembayo Victor Fasogbon^a, Josiah E. Ifie^a, Andrew Kisakye^a, Pastori Mujinya^a, Stellamaris Kembabazi^a, Solomon Mbina^a, Ibrahim Babangida Abubakar^a, Olubukola Sinbad Olorunnisola^a, Shehu Dayyabu^a and Patrick Maduabuchi Aja^{a,g}

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ABSTRACT

Background: Hyperkalemia is a medical condition characterized by excess potassium in the blood. Overindulgence in foods high in potassium can also result in hyperkalemia, particularly in individuals with severe kidney disease..

Aim of the study: In this study, hyperkalemia was assessed in Wistar albino rats administered with *M. acuminata*.

Material and Methods: Thirty-six rats underwent various treatments over three months after being randomly divided into groups of six. Standard medications administered included Lisinopril and kayaxalate. The proximate and mineral content of raw banana (RB) and normal rat pellets (NRP) were compared and evaluated with that of cooked banana (CB). The rats' serum and urine calcium and potassium levels were measured using established protocols.

Results: In comparison to RB, CB was found to have significantly higher levels of nutrients (proteins and fats) and minerals (calcium, sodium, and potassium). Administration of CB markedly significantly increased serum potassium levels however, kayaxalate decreased urine potassium levels; the treatment of kayaxalate plus lisinopril markedly decreased urine Ca concentration ($p < 0.05$).

Conclusions: Cooked banana has a higher mineral and nutritional content than raw banana. Continuous and daily consumption of cooked bananas led to hyperkalemia in Wistar rats as evidenced by elevated serum potassium levels.

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KEYWORDS

Hyperkalemia; *M. acuminata*; potassium; chronic; administration

1. Introduction

According to St-Jules et al. [1], hyperkalemia is a disorder marked by elevated potassium levels in the blood. It can also be defined as serum potassium higher than 5 mmol/L. Hyperkalemia can further be subdivided into mild (5.6–6.0) mmol/L, moderate (6.1–7.0) mmol/L, and severe (>7.0) mmol/L [2]. The normal adult's blood potassium level is between 3.5 and 5.0 mmol/L. Hyperkalemia occurs when it is greater than 5.5 mmol/L [3]. Studies have indicated that potassium concentrations greater than 6.5 mmol/L may interfere with cardiac function, necessitating immediate medical attention [4]. Additionally, this may result in significant metabolic problems, which may then cause electrophysiological issues with serious clinical consequences, including the possibility of mortality [5]. Patients suffering from hyperkalemia can be managed with Kayexalate

an ion exchanger. It works by serving as an exchange resin in the large intestine, specifically, between potassium and sodium ions, increasing the rate at which potassium ions are eliminated through the stool [6]. Potassium is filtered out of the blood by a healthy kidney [7]. This is how the body uses urine to get rid of the extra potassium load [7]. When a person has hyperkalemia, blood potassium levels rise because the body contains too much potassium for the kidneys to effectively filter [8]

According to Betts et al. [9], the prevalence of hyperkalemia in the general population in the United States is 1.55%, but it is 6.35% among patients with kidney disease. Research conducted in Uganda by Wismayer [10] found that hyperkalemia developed in 7.7% of the hospitalized patients. In Uganda, the incidence of chronic kidney disease varies from 2% to

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7% and 15% among individuals who are HIV-positive and have high blood pressure [11–13]. In sub-Saharan Africa, the prevalence of acute renal illness is between 10% and 13% [11]. Kidney illness is one of the top 10 causes of death in Uganda, accounting for 21% of all deaths, and its cases are on the rise [11]. According to research conducted in April 2017 in Uganda, 45.3% of children had acute renal damage, and 21.5% of them still had acute kidney injury that needed to be addressed [14]. This acute kidney disease is found to be more common in Eastern Uganda [14].

According to Paul et al. [15], banana, also known as matoke in Uganda, is a staple meal and the main source of starch in Uganda. Uganda is one of the top-producing nations in the world for matoke or cooking bananas. Furthermore, Uganda is ranked #1 in Sub-Saharan Africa with an estimated 9.5 million tons of matoke output. This produces 26.4% of the matoke produced worldwide, with 72% of farmers thought to be involved in its cultivation. Since Uganda is reported to have the highest rate of banana (matoke) consumption per capita – an estimated 191 kg annually – banana planting and consumption are firmly ingrained in Ugandan society [16].

The high consumption of bananas could be attributed to their availability as a staple food in East Africa especially in Uganda [17].

Eating a meal high in potassium can cause hyperkalemia, thus it's important to keep blood potassium levels in check [18,19]. Research has shown that banana has higher potassium content than other foods, fruits, and vegetables [20,21]. According to earlier research, one banana can provide about 23% of the daily potassium requirements for an individual

[22,23]. With 100 g of weight, the ordinary “Cooking Banana,” or *Musa paradisiaca* as it is scientifically termed, can provide about 487 mg of potassium [21]. Therefore, when the amount of potassium consumed exceeds the kidney's capacity to excrete it, potassium accumulates and levels become excessive, which in turn increases the likelihood of hyperkalemia. Nevertheless, prior research has hinted that healthy individuals with regularly functioning kidneys are also susceptible to hyperkalemia following aberrant eating of foods high in potassium [24,25]. This puts patients with renal impairments at risk as well. According to a prior study, there is no difference in the severity of hyperkalemia between patients with kidney disease and those with normal kidney function [24]. This study investigated the correlation between cooked banana consumption and hyperkalemia.

2. Materials and methods

2.1. Study area

This research was done at Kampala International University – Western Campus (KIU-WC) laboratories.

2.2. Analysis of Matoke's content

2.2.1. Collection and authentication of plant materials

Samples of Matoke, including both the green fruit and leaves, were gathered from the Bassajabalaba market (GPS Coordinates $-0.54117, 30.17741$) in the Bushenyi district of Uganda as shown in Figure 1. Subsequently, they were transported to the laboratory

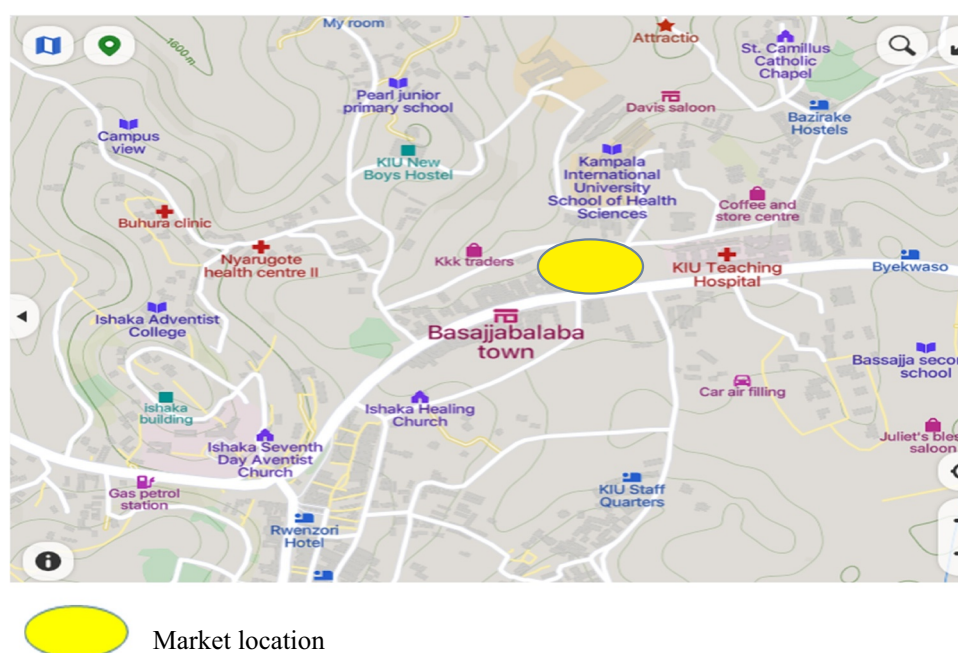


Figure 1. The location of Bassajabalaba market (GPS coordinates $-0.54117, 30.17741$) in the Bushenyi district of Uganda (<https://uganda.worldplaces.me/schools-in-bushenyi/31364050-basajjabalaba-s-s-ishaka-bushenyi.html>).

for analysis. Afterward, selected samples were chosen and transported for identification by a plant taxonomist at the Botany Department at Mbarara University of Science and Technology (MUST), Uganda who identified them to be of the *M. acuminata* species.

2.2.2. Preparation of matoke feed

The method for preparing the cooked banana (CB) was outlined by Akankwasa et al. [16]. After that, they were finely grated into tiny bits and properly dried in an oven set to 50°C for a full day. The dried matoke was packed in a clearly labeled airtight paper bag to avoid microbial spoiling.

2.2.3. Determination of potassium, calcium, magnesium, and sodium content in the normal rat pellets, the raw banana, and the cooked banana

The potassium, calcium, magnesium, and sodium contents of the raw banana, cooked banana, and normal rat pellets were determined using flame photometry, method.

2.2.4. Proximate compositions

The proximate compositions (carbohydrates, proteins, ash content, crude fiber, moisture content, and lipid content) of raw and cooked bananas, as well as normal rat pellets were determined according to the methods of the Association of Analytical Chemists (AOAC) and Matin et al. [26].

2.2.5. Research animals

Before the study, ethical approval was obtained from the Bishop Stuart University Research and Ethics Committee under the reference number BSU-REC- 140. The study used 36 healthy male Wistar rats weighing between 50 and 70 g. This sample size was determined using the resource equation method [27]. The animals were purchased from the breeding unit of Kampala International University Animal House after which they were randomly distributed into six groups of 6 animals each. They were housed in a well-ventilated animal house in stainless steel cages measuring 16 by 9 inches, or 144 inches. Before the trials began, they were allowed to acclimatize for seven days in a well-lit, room-temperature laboratory setting (12 hours of light and dark cycle). Water and

normal rat feed were available to all animals at all times. After the acclimatization, the animals were given different treatments as shown in table 1 for three months.

The study was an experimental research design. This is because a set of procedures was put in place to provide answers to the research question which was the association between *Musa acuminata* consumption (independent/exposure variable) and hyperkalemia (dependent/outcome variable). Wistar albino rats were given different treatments and compared with a control group, that is, after acclimatization for one weeks, the rats were randomly distributed into 6 groups containing male rats each and they were given different treatments for 90 days [28]. In the course of the trial, two deaths were recorded, one each in groups 1 and 5 respectively.

The lisinopril and the kayexalate dosages were calculated using the human equivalent dose to the animal dose. The drugs were administered by oral gavage once a day between 2–4 pm for 3 months.

2.2.6. Sample collection

After 90 days of treatment, urine samples were collected. The animals were then euthanized using diethyl ether anesthesia, and blood was extracted using the heart puncture technique. The blood was drawn into sterile vacuum-sealed containers using five (5) milliliter syringes, and it was allowed to stand for a short while to facilitate clotting. Using a chilled centrifuge, the blood was centrifuged for precisely ten minutes at a speed of three thousand revolutions per minute. After that, the serum was cautiously transferred into Eppendorf tubes and kept at 4°C in the refrigerator.

2.2.7. Potassium and calcium content analysis

2.2.7.1. Determination of serum and urinary potassium content. The levels of potassium in both serum and urine were assayed using the Humalyte plus 3 following a procedure described by Woyesa et al. [29].

2.2.7.2. Determination of serum and urinary calcium content. The levels of calcium both in serum and

Table 1. The different groups and their treatments.

Group	Treatment
1	Cooked banana(CB) + de-ionized water +1.029 mg/kg/day ACE inhibitor (Lisinopril)
2	CB + de-ionized water +5000 mg/kg/day kayexalate
3	CB + de-ionized water
4	Normal rat pellets (NRP) + de-ionized water 1.029 mg/kg/day of ACE inhibitor (Lisinopril)
5	NRP + de-ionized water +5000 mg/kg/day drug kayexalate
6	NRP + distilled water

Cooked banana, (CB).

Normal rat pellets, (NRP).

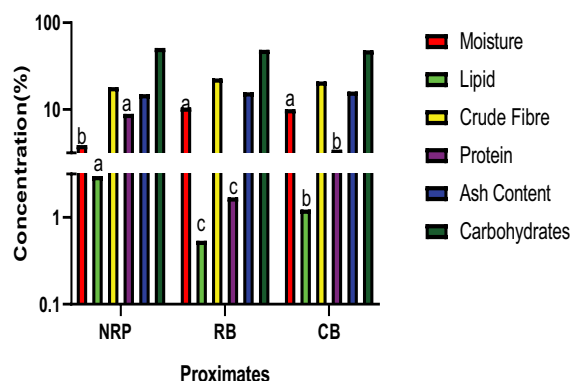


Figure 2. Proximate compositions of NRP, RB, and CB. Data are shown as mean $\pm$ S.D ($n = 3$). Mean values with different alphabets across the row on different proximate (Bartlett test) showed significant differences at $p < 0.05$. Normal rat pellet (NRP), raw banana (RB), and cooked banana (CB).

urine were assayed using a Chemistry analyzer following a procedure described by Dupuy et al. [30].

2.2.7.3. Data analysis using graph pad prism. Data was then expressed as mean $\pm$ SD. One-way analysis of variance (ANOVA) and Dunnett's multiple comparisons test were done using Graph pad Prism version 8.0 and a p value ≤ 0.05 was considered significant. Mean values of various groups were compared to the normal rat pellet (NRP) or cooked banana (CB) + lisinopril using Dunnett's multiple comparisons test with significant differences at $p < 0.05$.

3. Results

3.1. Proximate composition of normal rat pellet (NRP), raw banana (RB), and cooked banana (CB)

The proximate analysis revealed that NRP's percentage moisture content was significantly ($p < 0.05$) lower at 3.90 ± 0.00 than that of RB ($16.54 \pm$

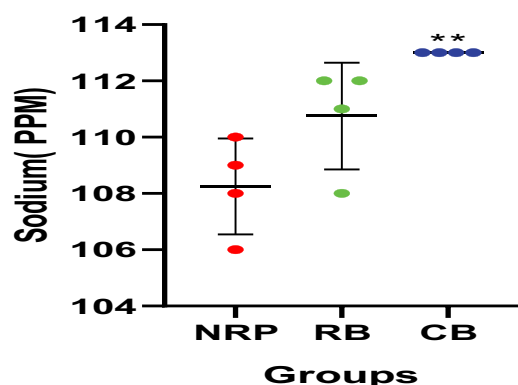


Figure 3. Sodium concentrations in NRP, RB, and CB. The data is displayed as mean $\pm$ standard deviation ($n = 4$). Mean values of various groups were compared to the NRP using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP), raw banana (RB), and cooked banana (CB).

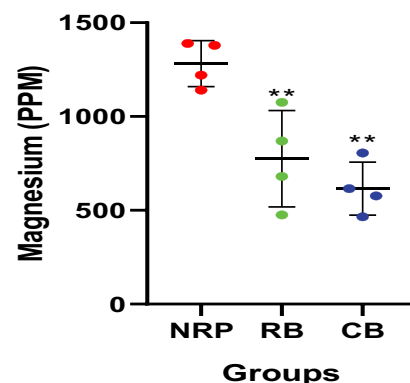


Figure 4. Magnesium concentrations in NRP, RB, and CB. The data is displayed as mean $\pm$ standard deviation ($n = 4$). Mean values of various groups were compared to the NRP using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP), raw banana (RB), and cooked banana (CB).

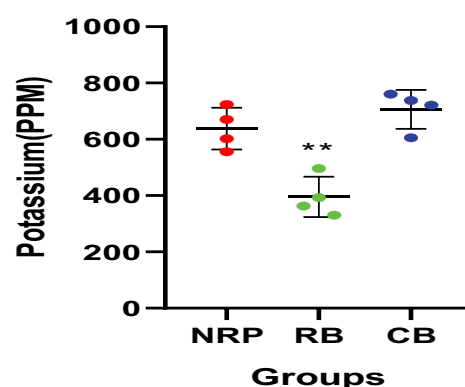


Figure 5. Potassium concentrations in NRP, RB, and CB. The data is displayed as mean $\pm$ standard deviation ($n = 4$). Mean values of various groups were compared to the NRP using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP), raw banana (RB), and cooked banana (CB).

0.00%) and CB ($16.12 \pm 0.00\%$), respectively (Figure 2). The findings also demonstrated that NRP had a significantly ($p < 0.05$) higher lipid content ($3.00 \pm 0.00\%$) in comparison to CB ($1.23 \pm 0.00\%$) and RB ($0.55 \pm 0.00\%$), and that NRP had a significantly ($p < 0.05$) higher protein content ($8.90 \pm 0.00\%$) in comparison to CB ($3.45 \pm 0.00\%$) and RB ($1.70 \pm 0.00\%$) (Figure 2).

3.2. Sodium, magnesium, potassium, and calcium compositions of normal rat pellet (NRP), raw banana (RB), and cooked banana (CB)

As compared to NRP (108.30 ± 1.71 PPM), the results of the mineral analysis revealed a significant ($p < 0.05$) high concentration of Na in CB (113.00 ± 0.00 PPM), but no significant ($p > 0.05$) Na concentration was found in RB (110.80 ± 1.89 PPM) (Figure 3). In comparison to the concentration in NRP (1282.00 ± 122.30

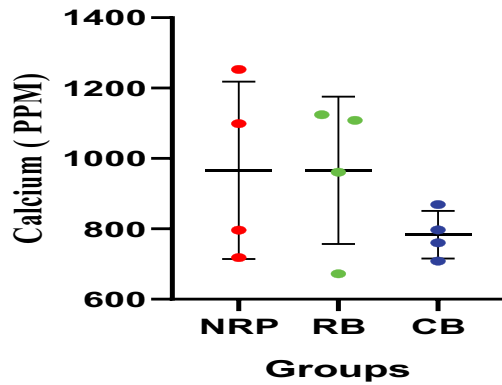


Figure 6. Calcium concentrations in NRP, RB, and CB. The data is displayed as mean $\pm$ standard deviation ($n = 4$). Mean values of various groups were compared to the NRP using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP), raw banana (RB), and cooked banana (CB).

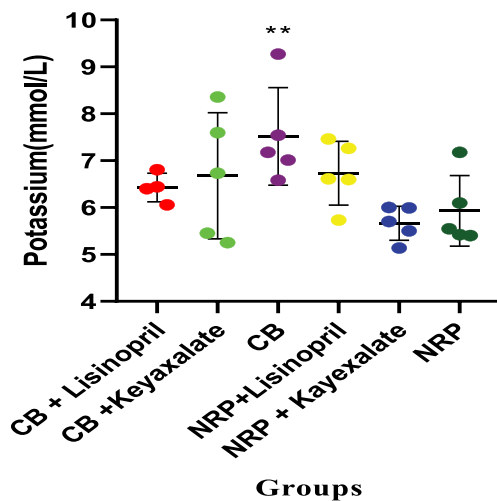


Figure 7. Effect of cooked banana (CB) on serum K⁺ concentration in Wistar albino rats. Data is presented in the format of mean $\pm$ standard deviation ($n = 5$). The mean values of various groups were compared against those of the CB + lisinopril using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP) and cooked banana (CB).

PPM), the Mg concentrations in RB (775.30 ± 226.80 PPM) and CB (615.80 ± 141.10 PPM) were significantly ($p < 0.05$) lower (Figure 4). As illustrated in Figures 5 and 6, there was no significant ($p > 0.05$) difference in the concentration of Ca between RB (966.30 ± 209.40 PPM) and CB (783.50 ± 67.69 PPM) and NRP (966.50 ± 252.00). However, there was a significant ($p < 0.05$) lower concentration of K in RB (395.50 ± 71.77)

3.3. Effect of cooked banana (CB) on serum and urine K and Ca concentration in Wistar albino rats

When compared to the NRP group (5.75 ± 0.81 mmol/L), the administration of CB to rats

significantly ($p < 0.05$) increased the serum level of K (7.29 ± 1.08 mmol/L), whereas the administration of kayexalate to rats markedly decreased the urine level of K (31.99 ± 23.78 mmol/L) compared to the NRP group (63.32 ± 21.28 mmol/L) (Figures 7 & 8). It's interesting to note that, in comparison to the NRP Group (1.36 ± 0.39 mmol/L), the administration of CB, kayexalate, and lisinopril considerably ($p < 0.005$) lowers the urine Ca content (Figures 9 & 10).

4. Discussion

The proximate analysis showed that NRP's percentage moisture content was significantly RB and CM respectively (Figure 2). This present study's report is in line with Popkin et al. [31] which revealed the moisture content of raw bananas (RB) and cooked bananas (CB) to be 16.54 ± 0.00 and $16.12 \pm 0.00\%$ respectively. The findings also demonstrated that NRP had a significantly ($p < 0.05$) higher lipid content ($3.00 \pm 0.00\%$) in comparison to CB ($1.23 \pm 0.00\%$) and RB ($0.55 \pm 0.00\%$), and that NRP had a significantly ($p < 0.05$) higher protein content ($8.90 \pm 0.00\%$) in comparison to CB ($3.45 \pm 0.00\%$) and RB ($1.70 \pm 0.00\%$) (Figure 2). This result is in correlation with the previous studies which indicate that *M. acuminata* contains very low levels of lipids and proteins [31,32]. The low levels of lipids in CB ($1.23 \pm 0.00\%$) and RB ($0.55 \pm 0.00\%$) and the low levels of proteins in CB ($3.45 \pm 0.00\%$) and RB ($1.70 \pm 0.00\%$) are generally consistent with their findings. The difference in nutrients between raw bananas and cooked bananas agrees with a previous study that reported that steaming increases the nutritional composition of food [33].

A previous study found that cooking using the steaming method increases the content of sodium and magnesium significantly while the content of potassium and calcium increases but the increase is less significant than the sodium and magnesium [34]. In contrast, the significantly low concentrations of Mg in RB (775.30 ± 226.80 PPM) and CB (615.80 ± 141.10 PPM) disagree. The significantly high levels of sodium in CB (113.00 ± 0.00 PPM) and the significantly lower concentration of K in RB (395.50 ± 71.77) and K and sodium levels in RB agree.

Based on the proximate and elemental analysis, cooked bananas were selected for the study over raw bananas because they reflected the genuine form of the staple food consumed in Uganda and contained higher amounts of nutrients and minerals.

After kayexalate was administered, the potassium concentration in the urine decreased to 31.99 ± 23.78 mmol/L. This could be explained by the way kayexalate works, which involves binding potassium from the digestive system and excreting it while it's bound in the feces. As a result, the kidneys filter out

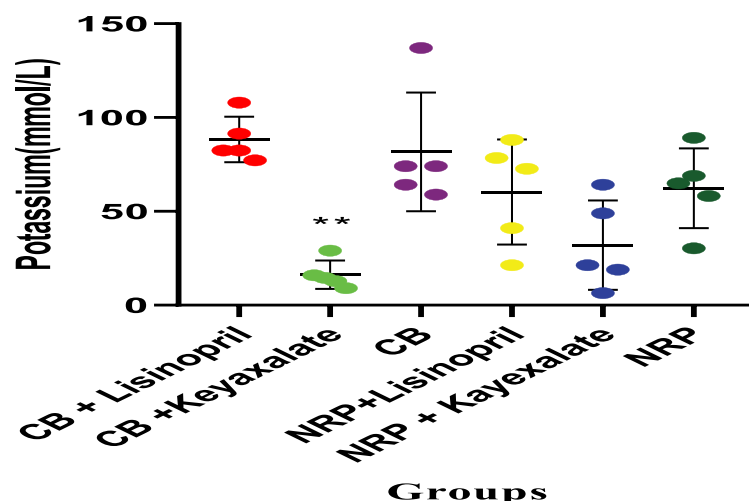


Figure 8. Effect of CB on urine K⁺ concentrations in Wistar albino rats. Data is presented in the format of mean $\pm$ standard deviation ($n = 5$). The mean values of various groups were compared against those of the CB + lisinopril using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP) and cooked banana (CB).

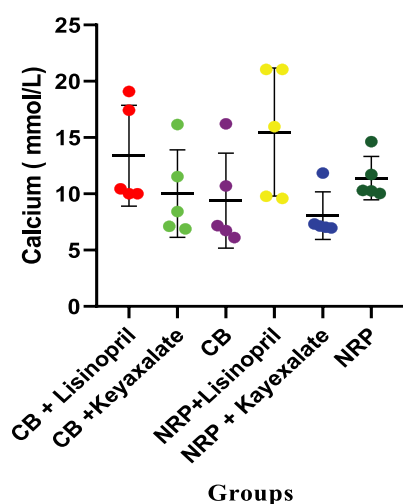


Figure 9. Effect of CB on serum Ca²⁺ concentrations in Wistar albino rats. Data is presented in the format of mean $\pm$ standard deviation ($n = 5$). The mean values of various groups were compared against those of the CB + lisinopril using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP) and cooked banana (CB).

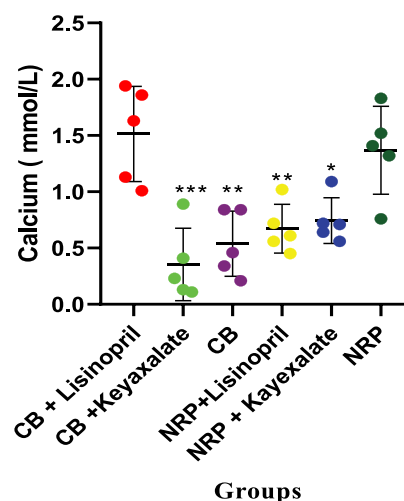


Figure 10. Effect of CB on urine Ca²⁺ concentrations in Wistar albino rats. Data is presented in the format of mean $\pm$ standard deviation ($n = 5$). The mean values of various groups were compared against those of the CB + lisinopril using Dunnett's multiple comparisons test with significant differences at $p < 0.05$. Normal rat pellet (NRP) and cooked banana (CB).

less potassium to be expelled in urine, lowering the potassium level in the blood [35,36]. The increase in serum potassium in CB (7.29 ± 1.08 mmol/L) is consistent with a previous study carried out by te Dorsthorst et al. [24] that showed increased consumption of high-potassium food can cause hyperkalemia even in those whose kidneys are functioning normally.

Remarkably, the administration of CB, kayexalate, and lisinopril considerably ($p < 0.05$) decreased the amount of calcium in the urine as compared to the NRP Group (1.36 ± 0.39 mmol/L). The injection of kayexalate decreased the levels of calcium. This may be because it has been previously documented that kayexalate is not entirely selective for potassium and

that, while binding potassium, it can also bind some calcium, hence lowering the levels of calcium [36]. The drop in calcium levels in the urine among the Lisinopril-treated group defies earlier research suggesting that angiotensin-converting enzyme inhibitors, like Lisinopril, did not affect urine calcium levels [37]. On the other hand, the experimental groups' use of de-ionized water may have contributed to the drop in urine calcium levels. The lower calcium levels in the urine of the group fed CB are consistent with other research [38,39] suggesting that higher dietary consumption of potassium lowers urine calcium levels.

4.1. Recommendation

Individuals with kidney disease should be advised to reduce the consumption of cooked bananas. This is because hyperkalemia in a person with kidney disease can set on easily with daily consumption of potassium-high food. The dieticians and caretakers of hospitalized patients should be advised not to serve cooked bananas to patients with kidney problems.

4.2. Limitations of the study

In this study, there are some limitations which included the duration of the study being extended to 6 months and rodents with kidney diseases included in the study.

5. Conclusion

According to the study's findings, cooked banana has a higher mineral and nutritional content than raw banana. Continuous and daily consumption of cooked bananas led to hyperkalemia in Wistar rats with normal functioning kidneys as evidenced by elevated serum potassium levels.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

No funding was received for the conduct of this study.

Notes on contributors

Angela Mumbua Musyoka holds a First-Class Honours Bachelor's degree in Laboratory Science and Technology and a Master's degree in Biochemistry. Her master's research explored the biochemical association between *Musa acuminata* consumption and hyperkalemia in a Wistar albino rat model, contributing to the understanding of dietary impacts on potassium regulation. Currently, she serves as an Assistant Lecturer at Kampala International University, where she combines her passion for teaching and research to mentor students in biochemistry.

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Oxidative Stress Biomarkers, Toxicity, Mutagenicity, Mycotoxins, Aflatoxin, and Toxicology

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Data availability statement

Data supporting the findings of this study are available from the corresponding author [MAM] on request.

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