

STUDY OF THE FRUIT PULP OF WILD *RAPHIA SESE* (Arecaceae): NUTRITIONAL VALUE AND PHYSIOLOGICAL EFFECTS ON BLOOD GLUCOSE REGULATION

ABSTRACT

Introduction

The use of medicinal plants is very common in Africa, particularly in the Democratic Republic of the Congo, where the pulp of the fruit of *Raphia sese* De Wild. is used for nutritional and curative purposes.

Objective

The general objective of this research is to evaluate the nutritional composition and the physiological effect of the pulp of the fruit of *Raphia sese* De Wild (Arecaceae) on the regulation of blood glucose levels.

Materials and Methods

To achieve this objective, two types of study were carried out: the first involved analysing the nutritional composition of the pulp of the *Raphia sese* De Wild fruit, whilst the second was a laboratory experiment conducted on Swiss mice, with the aim of observing the physiological effect of this pulp on the regulation of blood glucose levels.

The nutritional composition analysis determined several parameters, such as moisture, total fibre, fat, crude protein, carbohydrates, total ash, mineral elements and the phytochemical profile (alkaloids, saponins, polyphenols including catechin and gallic tannins, flavonoids and quinones).

The experimental study involved measuring blood glucose levels at specific time intervals following the administration of the total extract of the powder of the pulp under study and of glibenclamide. The animals were divided into different groups according to the dose administered.

Results

The results of the nutritional analysis showed that the pulp of the fruit under study contains appreciable amounts of water, proteins, ash, carbohydrates, and, in particular, total fibre and lipids. It is also rich in mineral salts such as copper, iron, zinc, chromium, sodium, calcium and magnesium. Identification of phytochemicals revealed an abundance of alkaloids, saponins and catechinic tannins, as well as lower concentrations of polyphenols including flavonoids, anthocyanins and quinones, suggesting that this pulp is both nutritious and therapeutic.

The results of the experimental study in Swiss mice showed that blood glucose levels vary according to the dose of the substance administered and the time elapsed after ingestion. The higher the dose of *R. sese* De Wild pulp, the lower the blood glucose level, with significant results observed after 180 minutes of experimentation.

These results partly confirm our hypothesis that the pulp of *R. sese* De Wild, consumed by the Congolese population, may contain essential nutrients for regulating blood sugar, helping to prevent sudden fluctuations in blood sugar levels.

Conclusion

In conclusion, we found that consuming this pulp in high doses effectively reduces blood sugar levels.

Keywords: *Raphia sese* De Wild, blood glucose, diabetes, nutritional value

INTRODUCTION

Type 1 diabetes (insulin-dependent, ‘thin’ diabetes or juvenile diabetes) and type 2 diabetes (non-insulin-dependent, ‘obese’ diabetes or ‘age-related’ diabetes) remain metabolic disorders affecting approximately 90 per cent of adults aged between 20 and 79 worldwide, which amounts to nearly 537 million people. In Kinshasa, the prevalence of type 2 diabetes in hospital settings is estimated at nearly 12.9 per cent, with risk factors such as high blood pressure. (International Diabetes Federation, 2021). The cause of this condition remains a disruption in carbohydrate metabolism, associated with a reduction in blood insulin levels (Ripsin et al., 2009).

Despite significant advances in the fight against this condition, research into new antidiabetic treatments continues, as many synthetic drugs have shown their limitations. Herbal therapy for diabetes is among the recommended treatments. It currently presents an attractive option due to the gradual discovery of plant extracts that are effective in the management of type 2 diabetes (Zhang et al., 2000; Katembo et al., 2012).

The plant *R. sese* De Wild belongs to the Arecaceae family. Its fruits are edible and prized for their fat content. According to ethnobotanical research, a large proportion of the population in the Democratic Republic of the Congo (DRC) uses this plant not only as food, but also for its recognised medicinal properties, such as its anti-diabetic and anti-inflammatory effects (Lathan and Konda, 2006). It is generally known by the names Makeke or Nteke (Equateur), Masendé (Bas-Congo, now Kongo Central), Balempâ or Bankulu (Kinshasa and Bandundu), and Libondo (north-east and south-east of the DRC). Phytochemical analysis of the plant’s fruit has revealed the presence of polyphenols, saponins, alkaloids and terpenoids. Measurements of the glycaemic index and glycaemic load revealed very low values, and its aqueous extract demonstrated, through *in vivo* studies on mice, significant anti-hyperglycaemic activity (Mpiana et al., 2013).

The pulp of this fruit under study, which has a bitter taste, is widely appreciated and consumed by the inhabitants of the Gungu territory, located in Kwilu Province (in Greater Bandundu), in the DRC. Within this community, this food plays a crucial role in preventive and even therapeutic practices for certain conditions such as diabetes (Mangala J., 2010).

MATERIALS AND METHODS

STUDY MATERIALS

Fruit pulp of *R. sese* De Wild

The samples of this fruit's pulp from the town of Gungu (Kwilu Province) used in this study were purchased at the BITABE market in the commune of Masina, in the city-province of Kinshasa, in the DRC. *R. sese* De Wild is listed under accession number 33138 in the eFlore / Tela Botanica database published by Emile Laurent in 1905.

Laboratory animals

A total of 30 Swiss mice, equally divided between males and females, all aged 10 weeks and weighing between 20 and 25 g, were obtained and used for an experiment at the INRB (National Institute for Biomedical Research, Kinshasa) laboratory. They were housed in plastic cages lined with wood shavings at the bottom, topped with a metal mesh lid allowing them access to their water bottle and food. The average temperature in the rearing facility was 25°C and the photoperiod (days and nights/light and darkness) was normally maintained.

Blood glucose meter

Blood glucose levels were measured using a *One Touch Ultra Plus Reflect* glucometer on blood samples obtained by pricking the animal's tail following ingestion of the fruit pulp extract under investigation: 30 minutes, one hour, two hours and three hours after administration.

METHODS

Two studies were carried out, namely: an analysis of the nutritional composition and an experiment involving the fruit pulp under investigation in laboratory animals.

First study: Analysis of the nutritional composition of the fruit pulp of *R. sese* De Wild.

To carry out this study, we utilised the analytical methods and procedures employed at the microbiology laboratory of the Faculty of Pharmaceutical Sciences at the University of Kinshasa, in order to determine the following chemical parameters: moisture content using the thermogravimetric method, total fibre using the KURSCHNER method, lipids by the centrifugation method, crude protein by the Kjeldahl method, carbohydrates by the Degroote method, total ash by muffle furnace incineration, mineral elements by plasma-source atomic emission spectrophotometry, and chemical screening of the aqueous extract, which enabled us to identify secondary metabolites.

Second study: Experiments on laboratory animals

The Swiss mice were first fasted for 16 hours and then weighed before blood glucose levels were measured. They were divided into five groups of six mice each.

The first group received 250 mg/kg body weight of the pulp extract. The second group received 500 mg/kg, and the third 1,000 mg/kg of the same extract. The fourth group was treated with 0.5 ml/kg body weight of solvent (80% ethanol) as a negative control, while the fifth group received 5 mg/kg body weight of glibenclamide, used as a positive control.

Thirty minutes after administration of the various treatments, an oral glucose load (4 g/kg body weight) was administered to all animals. Blood glucose levels were then measured at intervals of 30 minutes, 1 hour, 2 hours and 3 hours after the glucose load.

Preparation of the extract

We air-dried the sample at laboratory temperature ($\pm 27^{\circ}\text{C}$); we then ground it to obtain a powder, which we used to prepare the extract by maceration in 80% ethanol. The extract obtained after maceration with ethanol was finally dried in an oven at 45°C .

The inhibition percentages of the various mean blood glucose levels in the control group by the other samples tested were calculated as a function of time (%GI) using the following formula (Anwar et al., 2010):

$$\% IG = \left(G_{tn} - \frac{G_x}{G_{eau}} \right) \times 100$$

Caption:

G_{tn} = mean blood glucose levels in the control group at different time points;

G_x = blood glucose level at a given time x (in minutes) after administration of the test samples (extract or glibenclamide).

RESULTS

1. RESULTS OF THE NUTRITIONAL ANALYSIS

Nutritional composition of the dried pulp of *R. sese* De Wild

The results regarding the nutrient composition of the fruit pulp powder under study are set out in Table I below.

Table I: Content per 100 g of dry and wet matter in the fruit pulp of *R. sese* De Wild

Analysed components	Contents per 100g DM	Contents per 100g FM
Moisture		9.70 ± 0.23
Total ash	3.62 ± 0.2	3.13 ± 0.15
Crude fibre	29.7 ± 0.1	26.75 ± 0.19
Total fat	23.9 ± 0.3	21.51 ± 0.02
Total protein	9.6 ± 0.2	8.36 ± 0.25
Total carbohydrates	33.18 ± 0.2	29.60 ± 0.61
Energy (in kcal)	347.81 ± 0.7	347.81 ± 0.7

Key:

DM: Dry Matter

FM: Fresh Matter

This table shows that 100g of the dry sample of the fruit pulp under study contains 3.62% total ash, 29.7% crude fibre, 23.9% total lipids, 9.6% total protein, 33.18 per cent total carbohydrates and provide 347.81 kcal of energy. Similarly, 100 g of the wet sample contains

9.70 per cent moisture, 3.13 per cent total ash, 26.75 per cent crude fibre; 21.51 per cent total lipids, 8.36 per cent total protein and 29.60 per cent total carbohydrates, and 347.81 kcal of energy.

Mineral content of the fruit pulp of *R. sese* De Wild

The results regarding the mineral composition of the powder made from this pulp are set out in Table II below:

Table II: Average mineral content of the fruit pulp of *R. sese* De Wild

Elements analysed	Content (in mg)
Calcium	931.50 ± 1.50
Magnesium	574.33 ± 1.15
Sodium	74.34 ± 0.41
Copper	7.18 ± 0.24
Manganese	8.39 ± 0.25
Selenium	2.74 ± 0.01
Iron	17.46 ± 0.01
Zinc	17.46 ± 0.03
Cobalt	0.25 ± 0.04
Chromium	11.79 ± 0.08

Table II shows that the pulp powder under study contains significant levels of calcium, magnesium, sodium, iron, zinc, chromium, copper and manganese, but low levels of selenium and cobalt.

Results of the phytochemical screening of the pulp of *R. sese* De Wild fruit

The results of the phytochemical screening of the fruit pulp under investigation are set out in Table III below:

Table III: Results of the phytochemical screening of the fruit pulp of *R. sese* De Wild

Chemical groups	Results
Alkaloids	++
Polyphenols	+
Catechin tannins	+++
Gallic tannins	-

Flavonoids	+
Anthocyanins	-
Quinones	-
Saponins	++

Key:

+:lower;

++:high;

+++:veryhigh;

- : Not present

The results in Table III relating to the phytochemical screening of this pulp show that it contains very high levels of catechin tannins, as well as high levels of alkaloids and saponins, whilst polyphenols – including flavonoids – are present in low concentrations. A complete absence of gallic tannins, anthocyanins and quinones was observed.

2. RESULTS OF EXPERIMENTS ON LABORATORY ANIMALS

Table I: Distribution of subjects according to the different doses of the products administered

Doses (mg)	Sample size (n=30)	Percentage
0	12	40
250	6	20
500	6	20
1,000	6	20

Table I shows that 40 per cent of respondents were in the group of subjects who had not received any dose of the powder made from the pulp of the fruit under study, compared with 20 per cent of those who had received 250 mg, followed by 500 mg and 1,000 mg respectively.

Table II: Changes in blood glucose levels over time and according to the doses of the products administered

Doses (mg/kg)	Blood glucose at T ₃₀	Blood glucose at T ₆₀	Blood glucose at T ₁₂₀	Blood glucose at T ₁₈₀
250	18.4	12.7	14.2	48.1
500	29.5	28.8	41.6	59.1
1,000	30.4	44.9	51.9	62.7
GLI	40.5	66.0	71.5	79.0

Table II shows that the anti-hyperglycaemic activity of glibenclamide, the reference antidiabetic agent used, remains higher than that of the plant's total extract.

Table III: Average changes in blood glucose levels over time and across study groups

Time experimental	Study groups	Sample size (n=30)	Mean $\pm$ Standard deviation Type	p-value
T ₃₀	Intervention group	18	203.39 $\pm$ 26.473	0.412
	Control group	12	219.50 $\pm$ 62.317	
T ₆₀	Intervention group	18	185.67 $\pm$ 39.192	0.697
	Control group	12	174.67 $\pm$ 90.373	
T ₁₂₀	Intervention group	18	138.56 $\pm$ 37.392	0.989
	Control group	12	138.92 $\pm$ 81.519	
T ₁₈₀	Intervention group	18	87.22 $\pm$ 16.805	0.150
	Control group	12	130.08 $\pm$ 95.158	

Table III shows that blood glucose levels do not differ across the various time points in the study subjects. This means that the administration of *R. sese* De Wild does not lead to a reduction in blood glucose levels in mice that consumed *R. sese* De Wild powder ($p > 0.05$). It is also noted that blood glucose levels decrease to the same extent in both groups.

Table IV: Average changes in blood glucose levels according to the treatment administered to the intervention group and the control group

Experimental of the experiment	Treatment Administered	Sample size (n=30)	Mean	95% Confidence Interval for Mean		p-value
				Lower Bound	Upper Bound	
T ₃₀	E250	6	224.67	194.08	255.25	0.000
	E500	6	194.00	168.35	219.65	
	E1000	6	191.50	180.14	202.86	
	Glibenclamide controls	6	163.83	155.64	172.03	
	Solvent controls	6	275.17	241.24	309.10	

T ₆₀	E250	6	227.67	208.70	246.63	0.000
	E500	6	185.67	166.35	204.98	
	E1000	6	143.67	124.79	162.54	
	Glibenclamide controls	6	88.67	75.07	102.26	
	Solvent controls	6	260.67	253.26	268.08	
T ₁₂₀	E250	6	185.50	176.95	194.05	0.000
	E500	6	126.17	105.50	146.83	
	E1000	6	104.00	97.53	110.47	
	Glibenclamide controls	6	61.67	56.58	66.75	
	Solvent controls	6	216.17	198.79	233.54	
T ₁₈₀	E250	6	104.33	96.66	112.01	0.000
	E500	6	82.33	67.78	96.88	
	E1000	6	75.00	61.93	88.07	
	Glibenclamide controls	6	42.33	39.79	44.88	
	Solvent controls	6	217.83	178.08	257.59	

Table IV shows a statistically significant difference ($p < 0.05$) in blood glucose levels depending on the substances administered to the mice in the study. This means that E250, E500, E1000 and glibenclamide clearly cause a reduction in blood glucose levels in the study cohort at T₁₈₀.

Figure 1 below shows a low blood glucose level at T_0 , which rises at T_{30} following treatment, before finally beginning to fall steadily from T_{60} to T_{180} .

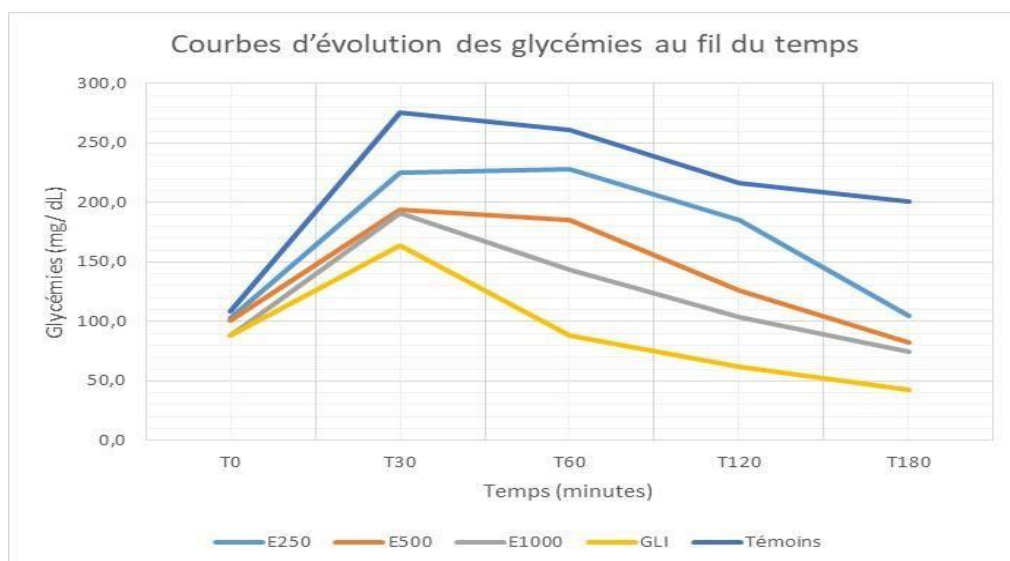


Figure 1: Physiological effect of the fruit pulp powder under study on blood glucose regulation

DISCUSSION OF THE RESULTS

Macronutrient composition

The results in Table II show the low water content of the fruit pulp of *R. sesede* Wild sourced from Gungu and purchased at the BITABE market (Kinshasa). This pulp is reported to contain 9.70 ± 0.23 per cent water; however, these values do not correspond to those reported by Malumba (2009). According to research conducted by this author, the pulp is reported to contain 8.15 ± 0.20 % water. As the pulp is dried to facilitate storage and transport, its moisture content remains at this level (an average of 10 to 15 g of water per 100 g under normal conditions).

The total ash content of a food provides important information about its potential mineral composition. According to our analyses, the content found here (3.13 ± 0.1) is slightly higher than that found by Malumba (2009) (2.30 ± 0.10).

The high fibre content found (26.75 ± 0.19) classifies these pulp residues among foods that are rich in fibre and which are thought to help prevent the onset of type 2 diabetes and combat constipation. According to Aude Rambaud (2018), fibre has numerous benefits and consuming sufficient amounts of fibre is essential for good health. Although fibre has no nutritional value, it helps to regulate blood glucose levels. This is because it forms a viscous gel in the gut, which slows down the absorption of glucose. By consuming sufficient fibre, blood sugar levels rise less sharply after a meal.

The same author states that dietary fibre helps prevent significant fluctuations in blood sugar levels, which can lead to fatigue, weight gain and reduced insulin sensitivity. It

is therefore an ally in preventing the risks associated with diabetes. In addition to its positive effect on the onset of diabetes, it can also increase faecal bulk by speeding up intestinal transit and, consequently, reduce the time of contact with toxic substances. Its high fibre content could be beneficial in the prevention of certain forms of cancer, particularly colon cancer (Georges, 1996). The value found is significantly higher than that reported by Georges (1996), which was 6.9 per cent. This large difference may be explained by the different harvesting environments.

Lipids are the slowest-release source of energy and are the most energy-dense nutrients. This means that each gram of lipid provides the body with 9 calories, which is more than double the amount supplied by proteins or carbohydrates. The nutritional analysis of our sample reveals a high total fat content of 21.51 ± 0.19 . This content amply demonstrates that the pulp studied is energy-dense. According to Georges (1996), its fat content could reach up to 58 per cent; this is higher than that of groundnuts (44.8 per cent) and equal to that of raw palm nut pulp (58.4 per cent). The fat content of this pulp is significant.

The human body requires lipids to synthesise hormones and numerous other substances necessary for its functioning. It should be noted that these lipids, which provide calories to the body, also help to maintain cholesterol at a reasonable level. Furthermore, the oily fraction of this pulp is of particular interest due to its unsaponifiable matter, which contains large quantities of carotenes (113 mg/100 g), tocopherols (33.0–54.0 mg/100 g) – predominantly α -tocopherol (32.0–47.0 mg/100 g) and phytosterols (104.0–147 mg/100 g), of which 88.0–120 mg/100 g is β -sitosterol. These results demonstrate excellent nutritional quality (Goténi et al., 2011). Finally, lipids, like proteins and carbohydrates, are essential macronutrients that must be consumed on a daily basis.

Proteins are complex molecules that take a long time to metabolise and are composed of around twenty amino acids. Proteins are an important source of energy that is slower-release and more sustained than that provided by carbohydrates. They serve as a backup energy source in the event that the body is not receiving sufficient calories from other nutrients or stored fats. Our bodies need protein to maintain and regenerate tissues, and to function and grow. According to our results, the pulp contained 8.36 ± 0.25 per cent protein. According to Malumba (2009), the fruit pulp studied is lower in protein (5.65 per cent) than groundnut seeds, but higher than palm nut pulp (1.9 per cent). This low protein content can help the body to maintain and regenerate its tissues, as well as to function and grow.

2. Minerals

Mineral analysis reveals the presence of macro- and trace elements, including calcium, magnesium, sodium, iron, copper, selenium and zinc, as well as low levels of selenium and cobalt. The particularly high magnesium content (574.33 mg) suggests that consuming this pulp appears to be a good source of this element, which is essential for nervous system stability, and may help with depression and generalised weakness; it is also thought to play a role in numerous metabolic functions and in the transmission of nerve impulses. The particularly high calcium content (931.50 mg) makes this product a food that helps combat rickets, osteomalacia and gastric acidity, and supports skeletal development. However, its high sodium content may be a limiting factor for conditions such as high blood pressure. Its high copper, zinc and selenium content makes the pulp a food rich in antioxidants capable of protecting the body against attacks by free radicals.

and helping to combat cancer. The particularly high iron content (17.46 mg) suggests that this pulp could be a good source of iron, albeit non-haem iron, and may be recommended for the prevention of iron-deficiency anaemia in young children, breastfeeding women and pregnant women (Tieguhong & Donn, 2015).

Its high chromium content could help consumers manage hyperglycaemia by improving glucose tolerance in people with diabetes (Masunda T.A. et al, 2014).

The presence of minerals in this pulp supports the normal functioning of cells in the brain, heart, bones, muscles, etc.

3. Secondary metabolites

Chemical screening reveals the presence of tannins, polyphenols and saponins, and provides sufficient evidence that the pulp under study could be useful in the prevention of certain conditions treated with polyphenols, particularly due to its anti-allergic, anti-inflammatory and antioxidant properties. The presence of tannins gives this pulp a bitter taste and endows it with antioxidant properties, as well as helping to combat certain conditions, notably diarrhoea, ulcers, etc.

4. Hypoglycaemic activity

To date, numerous hypoglycaemic plants have been identified. Results from *in vitro* and *in vivo* animal models have shown that plant extracts (aqueous, polyphenolic, alkaloid and saponin-rich) can act via various mechanisms to lower blood glucose levels. In this study, we administered an extract of the pulp of *R. sese* De Wild to SWISS mice with induced hyperglycaemia to test its hypoglycaemic effect. The results shown in Table V indicate that the anti-hyperglycaemic activity of glibenclamide, the reference antidiabetic agent used, remains superior to that of the plant's total extract.

Administration of this extract at different doses also demonstrates a reduction in blood glucose levels. Indeed, the water-soluble compounds other than tannins (flavonoids, saponins, alkaloids, etc.) contained in *R. sese* De Wild appear to provide additional hypoglycaemic activity. These results are similar to those found by Laetitia R. et al. (2015) in their article published on the hypoglycaemic and anti-hyperglycaemic effects of a 70% ethanolic extract of *Rauvolfia vomitoria* Afzel. roots.

The results in Figure 1 concerning the physiological effect of the pulp studied on blood glucose regulation show a low blood glucose level at T0, which rises at T30 following treatment and then begins to fall steadily from T60 to T180. We observe a steady decline in blood glucose levels at various time points during the experiment for all doses administered. Novo Nordisk (2021), in its article on postprandial blood glucose, states that blood glucose levels two hours after a meal should be between 130 and 160 mg/dl. In principle, blood glucose levels rise a few minutes after the start of a meal and do not exceed 140 mg/dl of blood after thirty minutes. They then fall back to 100 mg/dl of blood. This reduction generally occurs after two hours. It is brought about by the action of insulin, a hormone produced by the pancreas that regulates blood glucose levels.

The results obtained in our study are consistent with the theory put forward by this author.

On completion of this study, we are convinced of the importance of the pulp of the *R. sese* De Wild fruit in the treatment of diabetes. We therefore recommend its inclusion in the diet of people with diabetes.

CONCLUSION

The overall objective of this research was to evaluate the nutritional composition and physiological effect of the pulp of the *R. sese* De Wild fruit on blood glucose regulation.

To achieve this, we conducted two types of study: a nutritional analysis to identify the nutritional components of the pulp, and an experimental study in which mice with induced hyperglycaemia were administered the fruit pulp powder to assess changes in blood glucose levels.

Following analysis, the following significant results were observed:

✓ The fruit pulp studied contains appreciable levels of water, protein, ash and carbohydrates; however, the fibre and total fat content are higher. This pulp contains appreciable levels of copper, selenium, iron, zinc, chromium, sodium, calcium and magnesium.

✓ Identification of the phytochemicals reveals very high levels of catechin tannins, moderate levels of alkaloids and saponins, and low levels of polyphenols, including flavonoids, whilst anthocyanins and quinones are present in trace amounts. This suggests that this pulp is nutritious and therapeutic.

✓ We observed a significant reduction in blood glucose levels in response to the various treatments administered (E250, E500 and E1000) at Time 180 of the experiment.

These results partly confirm our hypotheses, which suggested that the pulp of the *R. sese* De Wild fruit, consumed by a section of the Congolese population, might contain nutrients – specifically macronutrients and micronutrients essential for regulating blood glucose levels by preventing sudden and significant fluctuations.

Our results support the use of this plant in traditional medicine for the treatment of diabetes. The higher the dose of this pulp consumed, the greater the reduction in blood glucose levels.

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