

Effects of consumption of *Mauritia flexuosa* fruits on renal and hepatic functions in growing rats

Amanda Batista da Rocha Romero¹, Nayara Ravenna Trindade Ferreira¹, Ana Karolinne da Silva Brito¹, Francisco Valmor Macedo Cunha¹, Simone Kelly Rodrigues Lima^{1,2}, Alessandro de Lima³, Francisco Cardoso Figueiredo⁴, Sidney Gonçalo de Lima⁴, Márcia dos Santos Rizzo⁵, Paulo Humberto Moreira Nunes¹, Daniel Dias Rufino Arcanjo¹, Maria do Carmo de Carvalho e Martins¹

¹Departamento de Biofísica e Fisiologia, Universidade Federal do Piauí (UFPI) – Teresina (PI), Brazil

²Departamento de Educação, Instituto Federal de Educação, Ciência e Tecnologia do Maranhão (IFMA) – Bacabal (MA), Brazil

³Laboratório de Análise de Alimentos, Instituto Federal de Educação, Ciência e Tecnologia do Piauí (IFPI) – Teresina (PI), Brazil

⁴Programa de Pós-Graduação em Química, Laboratório de Geoquímica Orgânica, Universidade Federal do Piauí (UFPI) – Teresina (PI), Brazil

⁵Departamento de Morfologia, Universidade Federal do Piauí (UFPI) – Teresina (PI), Brazil

ABSTRACT

Introduction: Previous studies have reported that buriti (*Mauritia flexuosa* L. f.) is a typical fruit from the Brazilian cerrado ecosystem and an important food source for low-income populations. Its composition is rich in carotenoid polyphenols, monounsaturated fatty acids, and ascorbic acid. However, studies on the biological effects resulting from the consumption of this fruit are scarce. **Objective:** To evaluate the effects of a diet supplemented with buriti (*Mauritia flexuosa* L. f.) on kidney and liver functions in growing rats. **Methods:** Determination of centesimal composition, carotenoids, and fatty acids content for buriti pulp, standard chow, and buriti-supplemented chow were performed. Then, Wistar rats of both sexes were fed a standard diet or supplemented with buriti pulp. Blood samples were collected at the end of the experiment to determine biochemical parameters. The unpaired t-test was applied, and differences were considered significant when $p < 0.05$. **Results:** A diet enriched with buriti pulp did not interfere with kidney function and most markers of liver function in animals. Alkaline phosphatase showed significantly higher plasma concentration in female rats, and albumin and uric acid showed lower concentrations in male rats in both experimental groups. **Conclusion:** The changes observed in biochemical markers did not provide evidence of adverse effects of buriti pulp supplementation on liver function. Thus, the intake of buriti pulp can be encouraged as it is a low-cost food source for the general population.

Keywords: Arecaceae; metabolism; fruit.

INTRODUCTION

Plant-based foods represent an important nutritional source, and their regular consumption is related to reduced morbidity and mortality by Noncommunicable Diseases (NCDs)^{1,2}. These effects have been associated mainly with the presence of substances such as vitamins, minerals, and bioactive compounds, which can act by stimulating endogenous

How to cite this article: Romero et al. Effects of consumption of *Mauritia flexuosa* fruits on renal and hepatic functions in growing rats. ABCS Health Sci. 2023;48:e023229 <https://doi.org/10.7322/abcshs.2021077.1813>

Received: Jul 21, 2021

Revised: Dec 16, 2021

Approved: Jan 21, 2022

Corresponding author: Maria do Carmo de Carvalho e Martins – Departamento de Biofísica e Fisiologia, Universidade Federal do Piauí - Avenida Universitária s/n, Campus Ministro Petrônio Portella – Ininga - CEP 64049-550 – Teresina (PI), Brazil - E-mail: carminhamartins@ufpi.edu.br

Declaration of interest: nothing to declare



This is an open access article distributed under the terms of the Creative Commons Attribution License
© 2023 The authors

defense systems or directly on reactive species, promoting protective action through complex interactions with the body³.

Thus, the concept of functional foods is inserted beyond the context of basic nutrition, from the perspective of proposing a diet capable of benefiting the organic functions and establishing additional health benefits⁴. In this scenario, the buriti fruit (*Mauritia flexuosa* L. f.) has received special attention for its potential due to its diversity in phytochemical and nutritional constituents⁵⁻⁷.

A native fruit of the Amazon, the buriti can also be found throughout the Brazilian cerrado. It has a dark reddish color, scaly and hard shell, and soft, dark yellow flesh^{8,9}. It is considered an important food source in this region because it is the most abundant palm fruit in this territory¹⁰. The main derivatives of the buriti fruit are pulp and products such as oils, nectars, sweets, and fermented drinks. Besides its recognized nutritional value, it stands out for its content of carotenoids and ascorbic acid, presenting potential use in the prevention of diseases caused by oxidative stress^{7,11-13}.

Although there are consolidated studies about its composition that strongly point to the benefits of consuming its pulp^{6,7} and its by-products¹⁴⁻¹⁶, there is still a gap in the literature about the effects of its dietary intake in experimental studies.

Considering the possibility of dietary inclusion of foods with the ability to provide additional health benefits, this study hypothesized that the inclusion of buriti pulp in the diet of growing animals could enable greater intake of bioactive compounds without risk of adverse effects on kidney and liver function.

METHODS

Raw materials and feed preparation

The buriti pulp was purchased in a local market in Teresina, Brazil and added to the standard feed for rodents (Purina labina) previously ground in the proportion of 10 g of dehydrated pulp for every 100 g of commercial feed. The choice of fruit proportion was based on the studies of Mastrodi et al.¹⁷ who used feed prepared with avocado, a fruit with a profile of fatty acids similar to that found in buriti. The feed was prepared weekly and stored in a closed container until use.

Chemical analyses of the buriti pulp and standard and enriched with buriti pulp feed

Analyses of the composition of the standard feed and feed enriched with buriti pulp were performed in triplicate. The contents of ash and moisture, as well as protein and lipids, were determined as recommended by the Association of Official Analytical Chemists (AOAC)¹⁸. The quantification of carotenoids was performed according to the method described by Rodriguez-Amaya¹⁹ and the results were expressed in μg of β -carotene- g^{-1} of the sample.

Moisture content determination

The humidity was determined by gravimetry¹⁸. For this, five grams of sample were homogenized, ground and dried in an oven at 105 °C for three hours, followed by cooling. The heating and cooling operation was repeated until a constant weight was obtained. The moisture content (%) was obtained by the formula:

Moisture content = $100 \times N/P$, where:

N = number of grams of moisture

P = several grams of sample.

Determination of fixed mineral residue

The ash was determined by gravimetry in a muffle furnace at 550 °C to constant weight¹⁸. Three grams of sample were weighed and carbonized in a muffle furnace at 250 °C for four hours and then incinerated for 12 hours at 550 °C. The ash content (%) was obtained by the formula:

Ash content = $100 \times N/P$, where:

N = number of grams of ash

P = number of grams of sample

Lipid determination

The lipids (corresponding to the ether extract fraction) were obtained in Soxhlet intermittent extractor, using Hexane P.A. as solvent¹⁸. For extraction, three grams of the samples were added to 150 mL of hexane and kept for six hours at 60 °C and, after one hour in an oven at 105 °C, the weight of the residue was used to determine the lipid content (%) by the formula:

Lipid content = $100 \times N/P$, where:

N = number of grams of lipids

P = number of grams of sample

Protein determination

Protein determination was performed by the Kjeldahl (macro) method, which is based on the destruction of organic matter followed by distillation, and the nitrogen was determined by volumetry. Factor 6.25 was used to convert the total nitrogen content into protein¹⁸. Digestion of 0.5 mg of sample was performed at 350 °C for four hours and 30 minutes in a 5 mL volume of concentrated sulfuric acid and catalyst mixture. The samples were then distilled and titrated for nitrogen determination and subsequent calculation of protein content using the formula:

Protein content = $V \times 0.14 \times f/p$, where:

V = volume of sulfuric acid used - the volume of Sodium Hydroxide used in the titration

f = conversion factor = 6.25

p = sample weight

Determination of carbohydrates and Total Energy Value (TEV)

The carbohydrate content was determined by difference, after quantification of protein, lipid, ash, and moisture content¹⁸. The VET was calculated by summing the calories provided by carbohydrates, lipids, and proteins by multiplying the values found in grams by the Atwater factors 4 Kcal, 9 Kcal, and 4 Kcal, respectively.

Determination of total carotenoids

The determination of the carotenoid content was performed according to the method described by Rodriguez-Amaya¹⁹, with adaptations. For this, 5 g of sample and 2 g of celite were weighed. 20 mL of cold acetone (5 °C) was added, and after homogenization for 10 minutes, the material was vacuum filtered in a Buchner funnel with filter paper. The sample was then washed with acetone until the extract was colorless, and the filtrate was transferred to a separatory funnel, to which 30 mL of petroleum ether and 100 mL of distilled water were added. The lower phase was discarded and the procedure was repeated four times to remove all the acetone. The upper extract was transferred to a 300 mL flask made up of petroleum ether. It was read in a spectrophotometer at 450 nm (λ_{max} β -carotene), using petroleum ether as a blank. The carotenoid content was determined by the equation shown below and the results were expressed as μg of β -carotene- g^{-1} of the sample.

μg of carotenoids- g^{-1} sample = $(A \times V \times 10^6) - (100 \times \epsilon^{1\%} \times P) \cdot 1$, where:

A = Absorbance

V = total volume obtained from the upper phase (200 mL)

$\epsilon^{1\%}$ (molar absorptivity of β -carotene) = 2.592

P = sample weight

Determination of the fatty acid composition of buriti pulp

The lipid fraction was obtained in a Soxhlet intermittent extractor using Hexane P.A. as solvent¹⁸. Then a transesterification reaction was conducted under constant heating and stirring, and the oil was first heated in a water bath at 55 °C. Sodium hydroxide was dispersed in methanol and then added to the flask containing the oil. After the addition of the sodium methoxide, the reaction took place for a time of 45 minutes, with constant stirring and at room temperature. At the end of the reaction, the mixture was put into a separating funnel for phase separation. After 30 minutes the glycerine residue was collected and the esters were

purified by successive washings with hydrochloric acid and water. Subsequently, the moisture was removed by adding anhydrous sodium sulfate and heating the esters²⁰ to 100°C.

Then, the analysis by Gas Chromatography Coupled to Mass Spectrometry (GC-MS) was performed in a SHIMADZU GC-17A equipment coupled to a GC-MS-QP5050A mass spectrometer. For chromatography of the components a DB-5HT column (J&W Scientific) was used, with 30 m x 0.25 mm, an internal film thickness of 0.10 μm , and helium as a carrier gas, with a flow rate of 1.0 mL/min. The column temperature was programmed to maintain 80 °C for two minutes, followed by an increase of 4 °C per minute until reaching 210 °C for four minutes. Afterward, a further increase of 10 °C was made until 270 °C was reached, keeping this temperature constant for six minutes. The injector temperature was 280 °C and the detector (or interface) temperature was 280 °C.

In vivo studies

Newly weaned rats of both sexes (36 ± 0.6 g), 21 days old, from the Central Animal Facility of the Federal University of Piauí (UFPI), were arranged into four groups with 13 to 15 animals each and kept in individual metabolic cages receiving water ad libitum and standard rat chow (Labina-Purina, Brazil; control males and control females) or feed enriched with dehydrated buriti pulp (buriti males and buriti females), for 60 days. The animals were kept at room temperature ($25 \text{ °C} \pm 2 \text{ °C}$), with a 12/12 h light/dark cycle.

Body mass gain and feed consumption per animal were checked daily. A known amount of standard feed or feed enriched with buriti was placed in the feeders of the metabolic cages and feed intake was determined by the difference between the amounts of feed initially provided and the remaining amounts after 24 hours.

At the end of the 60-day experimental period, the animals were anesthetized with thiopental sodium (50 mg/kg) + lidocaine (10 mg/kg) intraperitoneally, and 5 mL of blood were collected from the caudal vena cava for biochemical dosages. Then, the animals were euthanized with an overdose of thiopental sodium (150 mg/kg). The kidneys and liver were removed for weighing and later, the latter was stored for histopathological analysis.

For the evaluation of renal function, serum levels of urea, creatinine, and uric acid, were determined. Liver function was evaluated by quantifying the enzymes alanine transaminase (ALT), aspartate transaminase (AST), and alkaline phosphatase (ALP) besides the determination of total protein, albumin, and total bilirubin in a Labmax Plenno[®] biochemical analyzer using commercial kits and according to the manufacturer's instructions (Labtest, Lagoa Santa, MG, Brazil).

For histopathological analysis of liver tissue, liver fragments were fixed in 10% buffered formaldehyde and kept for a minimum period of 48 h to be subsequently submitted to the usual

histological routine, which consists of dehydration, clarification, paraffin embedding, embedding, and microtomy. Cross-sections of 4 μm thick liver tissue were made and adhered to glass slides. Then, the slides were subjected to diaphanization, and rehydration, and stained by Hematoxylin-Eosin (HE)²¹.

The experimental protocols performed were previously submitted and approved by the Ethics Committee for the Use of Animals of the Federal University of Piauí (CEUA/UFPI) with opinion No. 446/18 and an approval date on August 28, 2018.

Statistical Analysis

Results are presented as mean \pm standard error of the mean. Differences between the control groups and their respective experimental groups were evaluated by unpaired t-test. Differences were considered significant when $p < 0.05$.

RESULTS

The chemical composition and energy value of the buriti pulp and the standard and enriched feed with pulp are presented in Table 1. It can be seen that the pulp is a food of high nutritional value and has a high content of carotenoids and that the enriched

Table 1: Chemical composition in macronutrients, ash, and total energy value (TEV) of buriti (*M. flexuosa*) pulp and standard and enriched feeds.

Variable	Buriti pulp	Feed	
		Standard	Enriched
Humidity (%)	6.4 \pm 0.09	6.2 \pm 0.3	6.7 \pm 0.2
Ash (g.100 g ⁻¹)	2.7 \pm 0.007	10.5 \pm 0.2	9.7 \pm 0.3
Proteins (g.100 g ⁻¹)	9.0 \pm 0.2	21.7 \pm 0.3	20.0 \pm 0.4*
Carbohydrates (g.100 g ⁻¹)	36.3 \pm 0.4	57.1 \pm 0.4	57.7 \pm 0.5
Lipids (g.100 g ⁻¹)	45.7 \pm 0.2	4.5 \pm 0.3	5.9 \pm 0.02'
VET (Kcal.100 g ⁻¹)	592.4 \pm 1.1	351.9 \pm 1.2	363.4 \pm 0.3*
Carotenoids (mg.100 g ⁻¹)**	23.9 \pm 0.5	1.6 \pm 0.03	5.3 \pm 0.4*

**Expressed as mg β -carotene per 100 g sample. Unpaired t-test; * $p < 0.05$ relative to standard feed.

feed showed energy value (3%), lipid content (31%), and carotenoids higher than the same parameters compared to the standard feed, but lower protein content compared to the standard feed (7.8%).

Figure 1 shows the chromatographic profile of the methyl esters derived from fatty acids of buriti pulp. Four major constituents (Table 2) were identified by interpretation of the fragmentation pattern of the respective mass spectra, comparison with the National Institute of Standards and Technology (NIST 08S) library, and authentic standards. Oleic acid showed the highest relative abundance (71.6%), followed by palmitic acid (16.9%).

The average daily and total feed intake and estimated average consumption of energy, macronutrients, and carotenoids of the control and buriti-enriched feed groups are presented in Table 3. There were no statistically significant differences in water intake, feed intake, and feed efficiency index during the experimental period between the control and experimental groups fed with feed enriched with buriti pulp. In turn, the intake of carotenoids in the groups fed with buriti pulp was statistically higher ($p < 0.05$) than in the respective control groups. No statistically significant differences were observed in daily and total feed intake, energy, and macronutrients.

The evaluation of biochemical markers of liver function revealed no statistically significant differences in serum levels of AST, ALT, total bilirubin, and total proteins between the control

Table 2: Main fatty acid-derived methyl esters from buriti pulp identified by GC-MS.

Fatty Acids	Number of carbons: Number of unsaturations	Retention time (min)	Content (%)
Palmitic acid	16:0	25.353	16.9
Linoleic Acid	18:2	29.118	9.9
Oleic Acid	18:1	29.301	71.6
Stearic Acid	18:0	29.308	1.6

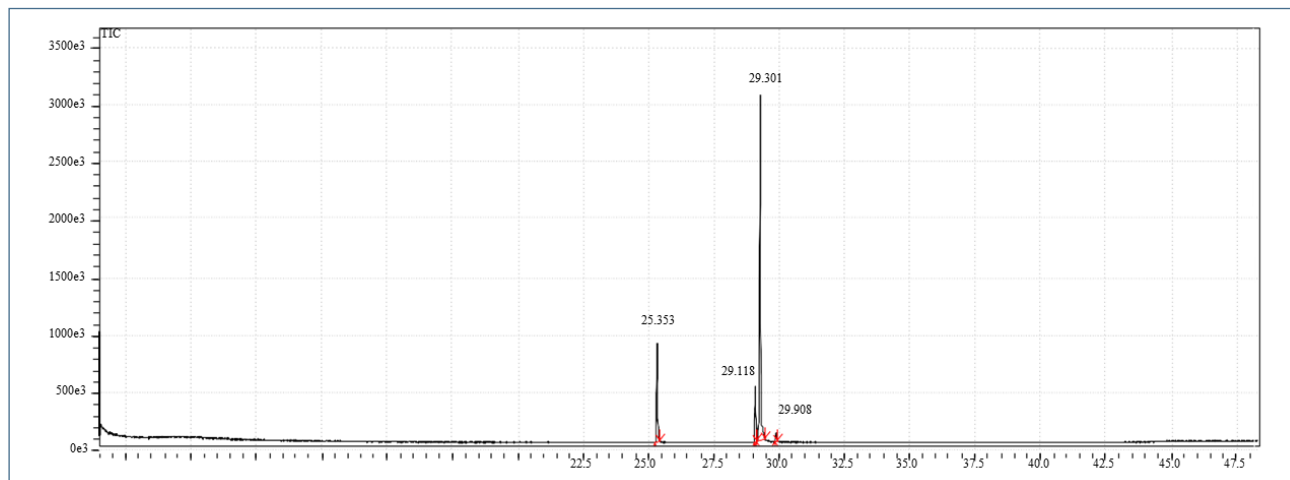


Figure 1: Chromatographic profile obtained by GC-MS of the methyl esters derived from fatty acids from buriti pulp.

groups and those fed with feed enriched with buriti pulp. On the other hand, it was observed a significant reduction of 6.7% of plasma albumin in the male animals fed with enriched food in the respective control group, and a significant increase of 36% of alkaline phosphatase in the females of the experimental group in their respective control group. The uric acid levels of the male animals in the control group were statistically higher ($p < 0.05$) when compared to the male animals fed with buriti-enriched feed. On the other hand, no differences were observed in serum levels of urea and creatinine between the control and experimental groups (Table 4). Despite the differences between liver and kidney parameters, no statistically significant differences were observed in the relative weights of livers and kidneys of the diverse groups studied.

Figure 2 shows micrographs of histological sections of the liver examined at 400x magnification by light microscopy. The qualitative analysis revealed no degenerative changes in the control groups and the group of male animals fed with enriched food. In the experimental group composed of females we observed, in some animals (25%), sparse foci of hepatocytes with mild

vacuolar degeneration, and without the occurrence of adjacent inflammatory infiltrate. Moreover, the increase in the volume of a few hepatocytes with vacuolated cytoplasm and a slightly reticulated aspect is suggestive of hydropic degeneration.

DISCUSSION

In studies to determine the composition it is common to find divergence in the contents of macro, micronutrients, and bioactive compounds. These differences are expected as a result of external or inherent factors of the fruit, which directly interfere with the components of the food matrix, such as climate, maturation stages, post-harvest conditions, or even the type of processing to which the fruits used to obtain the pulp were submitted^{6,9}.

In this study, the buriti pulp showed a high concentration of macronutrients and consequently, a high energy value. The results show higher values for the composition of the pulp when compared to the studies conducted by Nascimento et al.²² and Cardoso et al.¹² who found, respectively, values that ranged from 1.26 to 1.66% for proteins, 11.29 to 11.73% for lipids, 16.24 to 17.89% of

Table 3: Average daily and total feed intake and estimated energy intake Total feed intake and estimated total energy intake, macronutrients, and carotenoids of the groups fed standard feed (control) and fed feed enriched with buriti (*M. flexuosa*) pulp during the 60-day follow-up period.

Variable	Males		Females	
	Control	Buriti	Control	Buriti
<i>Average daily consumption</i>				
Feed (g/day)	19.8 ± 1.9	17.4 ± 1.0	15.1 ± 1.0	14.0 ± 1.3
Energy (Kcal/day)	68.9 ± 7.2	62.6 ± 4.1	52.3 ± 4.9	50.3 ± 5.2
Carbohydrates (g/day)	11.2 ± 1.2	9.9 ± 0.6	8.5 ± 0.8	8.0 ± 0.8
Proteins (g/day)	4.2 ± 0.4	3.4 ± 0.2	3.2 ± 0.3	2.8 ± 0.3
Lipids (g/day)	0.9 ± 0.09	1.0 ± 0.7	0.7 ± 0.06	0.8 ± 0.08
Carotenoids** (mg/day)	0.3 ± 0.03	0.9 ± 0.06*	0.2 ± 0.02	0.7 ± 0.07*
<i>Total consumption (60 days)</i>				
Feed (g/60 d)	1,174.3 ± 123.1	1,027.5 ± 73.1	897.9 ± 86.7	830.6 ± 86.7
Energy (Kcal/60 d)	4,132.5 ± 433.4	3,755.3 ± 246.3	3,159.7 ± 305.0	3,017.7 ± 314.5
Carbohydrates (g/60 d)	670.5 ± 70.3	596.3 ± 39.1	512.7 ± 49.5	479.3 ± 49.9
Proteins (g/ 60 d)	254.8 ± 26.7	206.7 ± 13.6	194.8 ± 18.8	166.1 ± 17.3
Lipids (g/60 d)	52.8 ± 5.5	61.0 ± 4.0	40.0 ± 3.9	49.0 ± 5.1
Carotenoids** (mg/60 d)	18.8 ± 2.0	54.8 ± 3.6*	14.4 ± 1.4	44.0 ± 4.6*

**Expressed as mg of β -carotene per 100 g sample. *Unpaired t-test; $p < 0.05$.

Table 4: Serum levels of liver and kidney function markers in *Rattus norvegicus* of the groups fed the standard diet (control) and fed the diet enriched with buriti (*M. flexuosa*) pulp at the end of 60 days of follow-up.

Bookmark	Males		Females	
	Control	Buriti	Control	Buriti
AST (U/L)	79.3 ± 2.8	73.1 ± 2.4	84.3 ± 5.5	87.9 ± 5.9
ALT (U/L)	53.2 ± 2.1	54.9 ± 2.7	46.2 ± 1.3	50.8 ± 3.4
Albumin (g/dL)	3.0 ± 0.9	2.8 ± 0.06*	3.2 ± 0.07	3.2 ± 0.08
Total Proteins (g/dL)	5.7 ± 0.05	5.5 ± 0.08	5.9 ± 0.1	5.8 ± 0.1
Total bilirubin (mg/dL)	0.4 ± 0.05	0.4 ± 0.03	0.5 ± 0.05	0.7 ± 0.1
Alkaline Phosphatase (U/L)	153.1 ± 11.1	181.6 ± 14.8	89.1 ± 3.6	121.1 ± 7.9*
Urea (mg/dL)	37.0 ± 1.3	34.2 ± 0.9	37.6 ± 1.4	40.4 ± 2.4
Creatinine (mg/dL)	0.4 ± 0.02	0.4 ± 0.02	0.4 ± 0.01	0.4 ± 0.01
Uric acid (mg/dL)	4.2 ± 0.8	2.2 ± 0.5*	3.1 ± 0.6	2.6 ± 0.4

*Unpaired t-test; $p < 0.05$. n=13-15 animals.

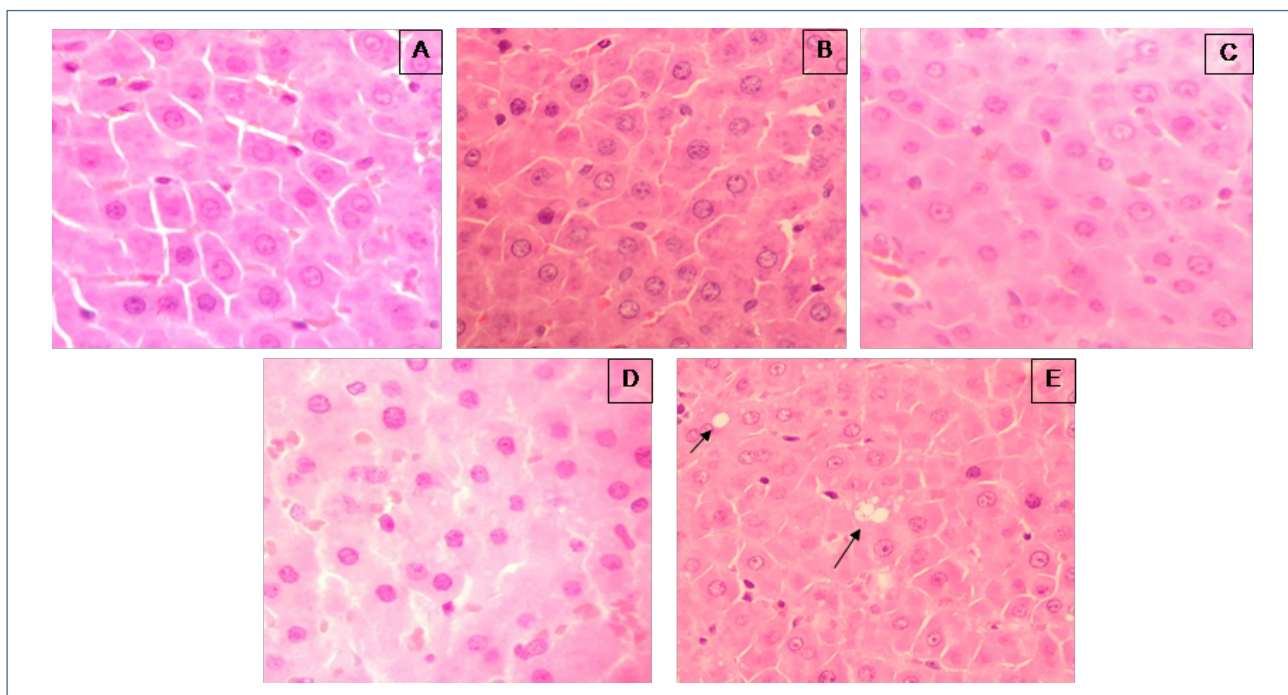


Figure 2: Photomicrographs of liver tissue from *Rattus norvegicus* of the groups fed the standard diet (A and C) and fed the diet enriched with buriti (*M. flexuosa*) pulp (B, D, and E) at the end of 60 days of follow-up. Staining: H.E. Magnification: 400x. Tissue sections showing hepatocytes arranged in branched plates separated by narrow sinusoid capillaries (A, B, C, and D). In this image (E) we observe foci of hepatocytes with vacuolar degeneration (arrows).

carbohydrates and total energetic value of 171.61 to 183.50 Kcal. In the present study, the feed enriched with buriti pulp showed higher energy, lipids, and carotenoid content and lower values of protein compared to the standard feed. The experimental and respective control groups presented similar feed consumption, although the enrichment of the formulated feed with the addition of buriti pulp has promoted a higher intake of carotenoids, lipids, and energy in the experimental groups.

Besides this aspect, the results concerning the content of carotenoids reaffirm the relevance of this fruit as a source of this compound, as already reported by Freire et al.²³ where the carotenoid content of the pulp, skin, and rind of the buriti fruit was reported. Moreover, Milanez et al.²⁴ compared the levels found in the buriti with other plant foods of popular consumption, such as tomato (27.11 mg-100 g⁻¹) and acerola (42.30 mg-100 g⁻¹). Thus, it is evident that the buriti is an important source of carotenoids.

The chromatographic study of the profile of fatty acids present in the buriti pulp showed that the majority constituent fatty acid was oleic acid, followed by palmitic, linoleic, and stearic acids. Comparable results were described by Freire et al.²⁵ who determined a high content of oleic acid as the major fatty acid, and also the presence of palmitic acid, linoleic acid, and stearic acid. Compared to other fruits, the buriti fruit presented a composition similar to that described for açai, an Amazonian fruit widely used and of great commercial importance, whose lipid content

is represented by monounsaturated fatty acids (up to 61%) and polyunsaturated fatty acids (approximately 10.6%)²⁶.

Experimental studies support the conclusion that dietary supplementation with natural products can interfere with renal and hepatic functions, and such influences can be evidenced, in part, by the increase or reduction of specific biochemical markers of the function of these organs²⁷. In the present study, the dietary inclusion of buriti did not interfere with markers of kidney function (urea and creatinine), the relative weight of kidneys and liver, total bilirubin concentration, and activity of AST and ALT enzymes, but induced an increase in ALP concentrations in females, and reduced serum albumin and uric acid concentrations in male animals.

Studies have focused on the potential hepatoprotective effect of vitamin A precursor substances, such as the carotenoids meso-zeaxanthin and β -carotene. There is evidence that there is an inverse association between serum retinol concentrations and serum AST and ALT²⁸. When administered orally, these carotenoids can promote a significant reduction of serum ALT, AST, alkaline phosphatase, and bilirubin enzymes in situations of methanol-, paracetamol- and carbon tetrachloride-induced liver injury in experimental models^{29,30}. In the present study, the animals fed with buriti-enriched feed consumed approximately three times more carotenoids than those in the control group, a fact that could have had repercussions on the increased serum levels of alkaline phosphatase and the presence of sparse foci of vacuolar degeneration in hepatocytes of a quarter of the females studied.

Some recent studies have reported beneficial effects regarding buriti supplementation and the presence of bioactive compounds, such as carotenoids, tocopherols, ascorbic acid, phenolic compounds, fibers, phytosterols, and mono- and polyunsaturated fatty acids. These compounds have been related to antioxidant, hypolipemic, photoprotective, antiaggregant, anti-thrombotic, anti-inflammatory, hypoglycemic, antimicrobial, and antitumor activities^{25,31}.

Still, about the hepatoprotective effect, Bicalho et al.³² evaluated the effects of a low-cost supplementation derived from buriti fruit on the liver recovery of malnourished mice and the results showed that biochemical and histological parameters, the groups treated with the supplement showed a significant decrease in ALT levels, inflammation, and oxidative stress in the liver, which demonstrates the potential of the fruit as an economically more accessible nutritional alternative.

ALP reflects biliary excretory function, and isolated elevations in serum ALP levels no more than three times normal values, without changes in other liver markers, are seen in cases of partial and intermittent bile duct obstruction. Also, it is not uncommon for several degenerative but potentially reversible changes to occur in hepatocytes, mainly associated with hydropic degeneration, glycogen storage, steatosis or lipidosis, or by cholestasis³³. Thus, the presence of enlarged hepatocytes with vacuolar degeneration in focal areas of the liver tissue suggests a possible idiopathic and reversible interference with the bile flow in some females of the treated group, responsible for the slight elevation in serum levels of ALP. In addition, the non-specific degenerative changes found were not enough to interfere with the relative liver weight of the affected females.

Moreover, considering the nonspecificity of the alkaline phosphatase enzyme, the absence of changes in other biochemical markers of liver function and histopathological lesions, the changes observed in this study do not seem to indicate functional impairment or liver damage. In agreement with the findings of

this study, Cunha et al.³⁴ in a research conducted to evaluate the acute and subacute toxicity of natural products also showed increased serum concentrations of alkaline phosphatase in rats, without changes in other parameters related to liver function, and considered that this increase had no clinical significance and could be attributed to the biological variability of the animals.

Uric acid is the end product of purine catabolism mediated by the bifunctional enzyme xanthine oxidase dehydrogenase, which in its dehydrogenated form produces uric acid and the nicotinamide-adenine dinucleotide, and in its oxidized form produces uric acid and superoxide. Research suggests that increased uric acid concentrations are associated with lactic acidosis, altered kidney function, and increased oxidative stress³⁵. In contrast, evidence points to both the deleterious and positive effects of uric acid. Alcaíno et al.³⁶ reinforce the antioxidant action of uric acid in the body. However, they state that there are controversies about the metabolic role of this compound, which can go from an excellent antioxidant molecule to a strong pro-oxidant molecule.

The uric acid levels of the buriti-fed males are not a risk factor, since possible liver or kidney diseases are associated with hypouricemia and could have been detected by other tests conducted in this study. Among the probable explanations for the results found here of reduced uric acid and a slight decrease in albumin levels can be cited the lower intake of food components of animal origin and increased consumption of plant products by the animals in the experimental groups.

The diet enriched with the pulp of the buriti fruit (*Mauritia flexuosa* L.f.), a regional food rich in bioactive compounds and monounsaturated fatty acids, in the proportion used in this study, did not interfere with the renal function of the animals. As for hepatic function markers, only isolated alterations in alkaline phosphatase activity in females and serum albumin levels in males of the groups fed with buriti were found. The analysis of the results obtained indicates that the fruit of the buriti tree can be a healthy and safe alternative food for the general population.

REFERENCES

- Jarisarapurin W, Sanrattana W, Chularojmontri L, Kunchana K, Wattanapitayakul SK. Antioxidant properties of unripe carica papaya fruit extract and its protective effects against endothelial oxidative stress. *Evid Based Complement Alternat Med*. 2019;2019:4912631. <https://doi.org/10.1155/2019/4912631>
- Liu W, Hu B, Dehghan M, Mente A, Wang C, Yan R, et al. Fruit, vegetable, and legume intake and the risk of all-cause, cardiovascular, and cancer mortality: a prospective study. *Clin Nutr*. 2021;40(6):4316-23. <https://doi.org/10.1016/j.clnu.2021.01.016>
- Mazzoni L, Fernández MTA, Capocasa F. Potential health benefits of fruits and vegetables. *Appl Sci*. 2021;11(19):8951. <https://doi.org/10.3390/app11198951>
- Cordeiro SA, Souza VKS, Souza GSF, Silva ECA, Oliveira JCS, Silva ECA, et al. Importância dos alimentos funcionais na prevenção e tratamento de doenças. *Int J Nutrology*. 2018;11(S01):S24-327. <https://doi.org/10.1055/s-0038-1674754>
- Rodrigues TT, Silva RPM, Abreu RMM. O buriti (*Mauritia flexuosa*) como planta medicinal para um melhor envelhecimento. *Rev Cient Saude*. 2021;3(1):23-46.
- Nascimento-Silva NRR, Silva FA, Silva MR. Physicochemical composition and antioxidants of buriti (*Mauritia flexuosa* Linn. F.) – pulp and sweet. *J Bioenergy Food Sci*. 2020;7:e2792019JBFS. <http://dx.doi.org/10.18067/jbfs.v7i1.279>
- Lage NN, Lopes JMM, Pereira RR, Guerra JFC, Pereira MFA, Silva M, et al. Antioxidant potential of Buriti (*Mauritia flexuosa*) pulp flour in diabetic rats. *Arch Latinoam Nutr*. 2018;68(1).

8. Reis AF, Schmiele M. Características e potencialidades dos frutos do Cerrado na indústria de alimentos. *Braz J Food Technol.* 2019;22:e2017150. <https://doi.org/10.1590/1981-6723.15017>
9. Cândido TLN, Silva MR, Agostini-Costa TS. Bioactive compounds and antioxidant capacity of buriti (*Mauritia flexuosa* L. f.) from the Cerrado and Amazon biomes. *Food Chem.* 2015;177:313-19. <https://doi.org/10.1016/j.foodchem.2015.01.041>
10. Rudke AR, Mazzutti S, Andrade KS, Vitali L, Ferreira SRS. Optimization of green PLE method applied for the recovery of antioxidant compounds from buriti (*Mauritia flexuosa* L.) shell. *Food Chem.* 2019;298:125061. <https://doi.org/10.1016/j.foodchem.2019.125061>
11. Cravalho RS, Assis MWV, Santos TT. Propriedades químicas, medicinais e nutricionais do buriti (*Mauritia flexuosa* L.). *Rev Desafios.* 2020;7(3):56-70. <http://dx.doi.org/10.20873/uftv7-6691>
12. Cardoso FC, Costa APS, Crispino ACS, Silva APR, Oliveira JAR. Physicochemical characterization, bioactive compounds and antioxidant activity of pulp, peel, endocarp and food paste developed with buriti pulp and waste (*Mauritia flexuosa* L.). *Sci Plena.* 2020;16(11):1-10. <http://dx.doi.org/10.14808/sci.plena.2020.111501>
13. Morais RA, Melo KKS, Oliveira TTB, Teles JS, Peluzio JM, Martins GAS. Chemical, physical and technological characterization of fish meal from Buriti shell (*Mauritia flexuosa* L. f.). *Braz J Dev.* 2019;5(11):23307-22. <https://doi.org/10.34117/bjdv5n11-050>
14. Moraes AVS, Uhlmann LAC. Propriedades medicinais da *Mauritia flexuosa*. *Pub Saude.* 2021;7:a200. <https://dx.doi.org/10.31533/pubsauade7.a200>
15. Soares JF, Borges LA, Brandi IV, Santos SHS, Lima JP. Characterization of buriti oil produced in northern region of Minas Gerais: quality parameters, fatty acid profile and carotenoids content. *Res Soc Dev.* 2021;10(3):e58010313734. <https://doi.org/10.33448/rsd-v10i3.13734>
16. Aquino JS, Tavares RL, Medeiros LB, Martins CCL, Pessoa DCNP, Stamford TLM. Effect of the consumption on buriti oil on the metabolism of rats induced by iron overload. *Arch Endocrinol Metab.* 2015;59(11):422-7. <https://doi.org/10.1590/2359-399700000105>
17. Salgado JM, Bin C, Mansi DN, Souza A. Efeito do abacate (*Persea americana* Mill) variedade hass na lipidemia de ratos hipercolesterolêmicos. *Cienc Tecnol Aliment.* 2008;28(4):922-8. <https://doi.org/10.1590/S0101-20612008000400025>
18. Latimer Jr GW. Association of Official Analytical Chemists (AOAC). Official methods of analysis. 20th Edition. USA: AOAC, 2016.
19. Rodriguez-Amaya DB. A guide to carotenoid analysis in foods. Washington: International Life Sciences Institute Press, 2001.
20. Lima JRO, Silva RB, Silva CCM, Santos LSS, Santos Jr JR, Moura EM, et al. Biodiesel de babaçu (*Orbignya sp.*) obtido por via etanólica. *Quim Nova.* 2007;30(3):600-3. <https://doi.org/10.1590/S0100-40422007000300019>
21. Behmer OA, Tolosa EMC, Freitas Neto AG. Manual de técnicas para histologia normal e patológica. São Paulo: Edart, 1976.
22. Nascimento ALAA, Brandi IV, Durães CAF, Lima JP, Soares SB, Mesquita BMAC. Chemical characterization and antioxidant potential of native fruits of the Cerrado of northern Minas Gerais. *Braz J Food Technol.* 2020;23:e2019296. <https://doi.org/10.1590/1981-6723.29619>
23. Pereira-Freire JA, Oliveira GLS, Lima LKF, Ramos CLS, Arcanjo-Medeiros SR, Lima ACS, et al. In vitro and ex vivo chemopreventive action of *Mauritia flexuosa* products. *Evid Based Complement Alternat Med.* 2018;2018:2051279. <https://doi.org/10.1155/2018/2051279>
24. Milanez JT, Neves LC, Colombo RC, Shahab M, Roberto SR. Bioactive compounds and antioxidant activity of buriti fruits, during the postharvest, harvested at different ripening stages. *Sci Hortic.* 2018;227:10-21. <https://doi.org/10.1016/j.scienta.2017.08.045>
25. Freire JAP, Barros KBNT, Lima LKF, Martins JM, Araújo YC, Oliveira GLS, et al. Phytochemistry Profile, Nutritional Properties and Pharmacological Activities of *Mauritia flexuosa*. *J Food Sci.* 2016;81(11):R2611-22. <https://doi.org/10.1111/1750-3841.13529>
26. Nascimento RJS, Couri S, Antoniassi R, Freitas SP. Composição em ácidos graxos do óleo da polpa de açaí extraído com enzimas e com hexano. *Rev Bras Frutic.* 2008;30(2):498-502. <https://doi.org/10.1590/S0100-29452008000200040>
27. Tavares IM, Botelho BHLL, Donadel G, Colla IM, Beletini ST, Lourenço ELB, et al. Effects of Curcuma longa on healthy animals undergoing chemotherapy. *Braz J Dev.* 2019;5(12):30697-719. <https://doi.org/10.34117/bjdv5n12-183>
28. Aquino JS, Soares JKB, Magnani M, Stamford TCM, Mascarenhas RJ, Tavares RL, et al. Effects of dietary brazilian palm oil (*Mauritia flexuosa* L.) on Cholesterol profile and Vitamin A and E status of rats. *Molecules.* 2015;20(5):9054-70. <https://doi.org/10.3390/molecules20059054>
29. Sindhu ER, Firdous AP, Preethi KC, Kuttan R. Carotenoid lutein protects rats from paracetamol-, carbon tetrachloride- and ethanol-induced hepatic damage. *J Pharm Pharmacol.* 2010;62(8):1054-60. <https://doi.org/10.1111/j.2042-7158.2010.01123.x>
30. Firdous AP, Sindhu ER, Kuttan R. Hepato-protective potential of carotenoid meso-zeaxanthin against paracetamol, CCl4 and ethanol induced toxicity. *Indian J Exp Biol.* 2011;49(1):44-9.
31. Amorim VR, Rodrigues DCN, Silva JN, Ramos CLS, Almeida LMN, Almeida AAC, et al. Anti-inflammatory mechanisms of fruits and by-products from *Mauritia flexuosa*, an exotic plant with functional benefits. *J Toxicol Environ Health A.* 2021;84(11):441-57. <https://doi.org/10.1080/15287394.2021.1881672>
32. Bicalho AH, Santos FR, Moreira DC, Oliveira LP, Machado AS, Farias L, et al. Liver damage produced by malnutrition is improved by dietary supplementation in mice: assessment of a supplement based on Buriti (A Cerrado Fruit) and dairy by-products. *Recent Pat Food Nutr Agric.* 2021;12(1):29-35. <https://doi.org/10.2174/2212798411999210101224626>
33. Cunningham RP, Porat-Shliom N. Liver zonation - revisiting old questions with new technologies. *Front Physiol.* 2021;12:732929. <https://doi.org/10.3389/fphys.2021.732929>
34. Cunha LC, Azeredo FS, Mendonça ACV, Vieira MS, Pucci LL, Valadares MC, et al. Avaliação da toxicidade aguda e subaguda, em ratos, do extrato etanólico das folhas e do látex de *Synadenium umbellatum* Pax. *Rev Bras Farmacog.* 2009;19(2a):403-11. <https://doi.org/10.1590/S0102-695X2009000300012>
35. Velloso JCR, Biavatti M, França PCO, Mello BJ, Almeida AC, Bueno GE. Oxidative stress: an introduction to the state of art. *Braz J Dev.* 2021;7(1):10152-68. <https://doi.org/10.34117/bjdv7n1-688>
36. Alcaíno H, Greig D, Castro P, Verdejo H, Mellado R, García L, et al. Ácido úrico una molécula con acciones paradójicas en la insuficiencia cardiaca. *Rev Med Chil.* 2011;139(4):505-15. <http://dx.doi.org/10.4067/S0034-98872011000400014>