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Effect of a Baobab Powder Diet on Growth and Digestive Balance in Growing Rats

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Abstract **Original Research Article**

Introduction: The fight against malnutrition (over- and undernutrition) requires knowledge of the fruits we eat. Baobab is a fruit from the north of Côte d'Ivoire whose consumption can help improve nutrition. ***Aim:*** The aim of this study was to investigate the chemical composition of baobab pulp and evaluate its nutritional impact after consumption in growing rats. ***Methodology:*** To achieve this objective, the physicochemical parameters and macronutrient contents of baobab flour were determined. Then, 3 batches of 5 rats were fed separately with three diets: RFB (baobab pulp), RM (baobab pulp + cornstarch) and RFM (cornstarch). Regular weighing was carried out to determine growth and digestibility parameters. ***Results:*** At the end of the work, it was found that baobab pulp is an acidic food (pH = 3.2), composed mainly of carbohydrates (92.47), mainly energy. It has a high starch content (56.34), a high sugar content (21.37), hence its sweet taste; with a considerable fiber content (7.82), in terms of dry matter (DM). Baobab flour contains very low levels of protein (2.08) and lipids (0.37). From a nutritional point of view, the baobab pulp diet (RFB) does not promote rat growth, and therefore the utilization of dietary protein. In addition, the RFB diet results in negative digestibility of dietary proteins and very low digestibility of the dry matter in the food consumed. On the other hand, rat growth and the digestibility of dietary protein and dry matter increased with the reduction (RM) or elimination (RFM) of baobab flour from the diet. ***Conclusion:*** Ultimately, these results enable us to assess the nutritional quality of baobab flour. Its consumption, which does not promote weight gain despite its high carbohydrate content, can therefore be used in the fight against obesity.

Keywords: Baobab powder, chemical composition, nutritional impact.

INTRODUCTION

A healthy diet helps protect against obesity and all forms of malnutrition, as well as non-communicable diseases including diabetes, heart disease, stroke and cancer [1]. It requires consumption of a variety of foods likely to meet consumers' nutritional needs. Côte d'Ivoire abounds in a diversity of plants whose fruits can be highly beneficial to the body [2]. Unfortunately, not all of them are well known to consumers. This is the case of baobab, a highly nutritious fruit that abounds in many vetures. The main objective of this dissertation is to contribute to the fight against malnutrition, through the valorization of baobab pulp in order to enable its insertion into the dietary habits of populations. Specifically, the aim is to carry out a chemical analysis of baobab pulp using various assay methods, and to determine the nutritional impact of baobab flour based on a growth and digestive balance experiment in Wistar rats.

MATERIAL AND METHODS

Material

Plant material

The plant material used in our study is the fruit of baobab tree (*Adansonia digitata*), from the north of Côte d'Ivoire, in the Poro region. Once harvested, the fruit was cleaned of sand and debris, the pulp powder was carefully removed and then dried. The flour obtained was packed in a bag and transported to the laboratory.

Animal material

The animals used were 15 growing rats (*Rattus norvegicus*), weighing an average of 54.6 ± 0.5 g and aged between 8 and 10 weeks. The animals were obtained from the vivarium of teacher's training college in Abidjan (Côte d'Ivoire). The temperature of the rearing room was approximately 25°C, and lighting was regulated by a cycle of 12 hours of light and 12 hours of darkness. Rats were treated according to Good Laboratory Practice [3]. Experimental protocols were followed in accordance with the protocols for the protection of experimental animals of the European Council on Legislation 2012/707 [4].

METHODS

Preparation of baobab powder

Harvested baobab fruits are crushed to extract the pulp. The pulp is dried and then ground. The mixture is coarsely sieved to remove fibers, seeds and debris, then finely sieved to obtain a refined powder.

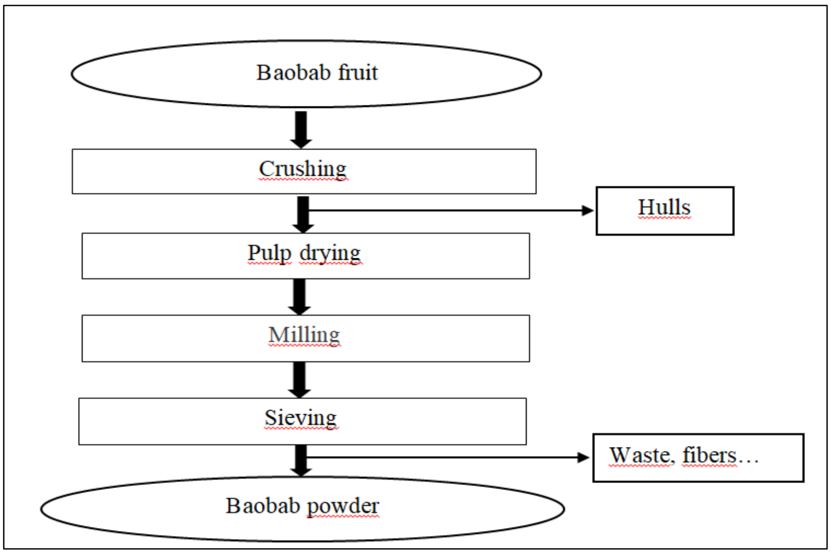

Figure 1: Steps in the production of baobab powder

Physicochemical analysis of baobab powder samples

Determination of physicochemical characteristics (ph, titratable acidity, water content, dry matter)

pH and titratable acidity were determined using AOAC method [5]. 5 g of baobab powder was diluted in 50 ml of distilled water and centrifuged at 4 200 rpm for 10 min with a centrifuge (Sigma). The pH reading was taken directly from the filtrate after calibration of the pH meter. Titratable acidity was measured in 10 ml of filtrate and titrated with NaOH solution (0.1N) until the color turned persistent pink, after adding 2 to 3 drops of phenolphthalein. Dry matter (DM) content was determined using AOAC method [5]. 5 g of baobab powder was weighed and oven-dried (Memmert UN 260) for 24 hours at 105°C. After drying, the sample was cooled in a desiccator for 1 hour, weighed and the moisture content determined. The ash content was determined according to AOAC method [5]. 5 g of baobab powder was weighed, then placed in a porcelain crucible. The whole was placed in an electrically heated furnace (Nabertherm Gmbh 20,28865) for 6 h at 550° C. After heating, the sample was cooled in a desiccator for 2 h and then weighed. The percentage of mineral matter (MM) was determined.

Macronutrient determination

The total carbohydrate content of baobab powder was determined by AOAC method [6]. Total and reducing sugars were determined by spectrometric assay [7-8], at 490 nm and 540 nm respectively. Fibers were determined according to the method described by AOAC [5], and fat was extracted by soxhlet apparatus using hexane as solvent. Proteins were determined using the Kjeldahl method [9], which comprises three essential stages: mineralization or digestion, distillation and the actual determination of the nitrogen compound. This method uses the factor 6.25 to convert the total nitrogen contained in the sample into protein. The energy value was calculated using the method of Cummings *et al.* [10].

Analysis of the effect of a baobab powder-based diet on growth and digestive balance in growing rats

Diet formulation

The various experimental and control diets were formulated according to Garcin *et al.* [11] with modifications (Table 1). These diets were each prepared to contain 18% crude protein, 40% starch, 5% lipids and an energy content of around 4 264 kcal/kg. Only the starch source differs from one food to another. Baobab flour provided the starch for the experimental feed (RFB). Cornstarch provided the starch for the control feed (RFM). A mixture of baobab flour starch (50%) and cornstarch starch (50%) was used to prepare the experimental feed (RM). Sugar was added to make the food palatable and cover energy requirements. Sunflower oil was the lipid source. In all, three (3) foods were formulated for the nutritional experiment.

Table 1: Composition of feeds formulated with baobab flour and fish powder

Ingredients	Diets		
	RFM	**RFB**	**RM**
Corn starch (g/kg)	400		200
Baobab flour (g/kg)		709,97	354,98
Fish powder (g/kg)	252,45	231,73	242,22
Sugar (g/kg)	296,55	7,3	151,8
Sunflower oil (ml/kg)	50	50	50
Premix (AMIN'TOTAL) (g/kg)	1	1	1
Water (ml/kg)	1000	1000	1000
Total feed solids (g/kg)	1000	1000	1000
Protein (%)	18	18	18
Total energy (Kcal/Kg feed)	4246	4246	4246

Calculated value: Crude protein 18%; Starch 40% and lipids 5%. Fish powder 71.3% protein. RFM: food formulated with cornstarch (MAÏZENA) enriched with fish powder; RFB: food formulated with baobab flour enriched with fish powder; RM: food formulated with cornstarch and baobab flour enriched with fish powder; Prémix: mix of vitamins and minerals (VITAFLASH).

Animal treatment

All growing rats were kept in the same cages and under the same environmental conditions. Fifteen 8-to-10-week-old rat pups were divided into three batches of five rats. Growing rats were then isolated in an individual cage until the end of the experiment. For the first two days prior to the start of the experiment, all rats were fed a basal diet (control). The rats were then fed experimental diets until the end of the experiment.

Growth experiment

Animals were housed in individual metabolic cages. These were 15 growing rats, with 5 rats per formulated feed. Each morning, between 07:00 and 08:00, the rats were fed and the water in the bottles was renewed. The food allocated to each treatment is weighed and fed to the rats in groups. The following day, leftovers are weighed to determine the amount of food ingested [12]. To assess the variation in body weight of growing rats, the animals were weighed regularly over the 21-day experiment period.

Digestive balance experiment

Digestive balance was measured during the last five days of animal experimentation, according to the protocols reported by Pellett & Young [13]. During this period, the animals were always housed in individual metabolic cages, and all food scraps and excreted faeces were weighed for each rat. Faeces from the same animal are mixed and oven-dried at 40°C. They are then pooled and stored in a freezer at 4°C for determination of total nitrogen and total starch. After five days, the faeces are dehydrated in an oven at 40°C. Total nitrogen content was determined using the Kjeldahl method at the UNA Chemistry Laboratory (Côte d'Ivoire). The values of the measurements taken were used to calculate the following digestive balance parameters:

Coefficient of Digestive Protein Utilization (CDPU): The CDPU reflects the digestibility of the proteins contained in each formulated feed. It is calculated as the ratio of the difference between total protein intake (TPI) and faeces protein (FP), to the total protein intake of the feed, multiplied by 100. Total protein intake (TPI) represents the amount of protein contained in the feed ingested over the duration of the experiment.

CDPU (%) = [(TPI(g)-FP(g)) × 100] / TPI (g)

Coefficient of Digestive Utilization of Dry Matter (CDUDM): The CDUDM reflects the digestibility of the dry matter contained in each formulated feed. It is calculated by multiplying the difference between the total dry matter ingested (DMI) and the total dry matter in feces (DMF) by 100. The total dry matter ingested (DMI) per day is the product of the total quantity of feed ingested by the animal and the dry matter rate divided by the number of days of the experiment. Faecal dry matter excreted (FDM) per day is the product of the total quantity of faeces excreted by the animal and the faecal dry matter rate divided by the number of days of the digestive balance experiment.

CDUDM (%) = (DMI (g)- DMF (g)) × 100/ DMI (g)

Statistical analysis

The results obtained during the various experiments were analyzed using Excel 2013, which was used to determine the means and standard deviations of the results obtained. Graph pad prism version 8.0.1 was used for statistical data analysis. All values are presented as means followed by standard deviations. Means were compared by analysis of variance (ANOVA) followed by Tukey's test at the 5% threshold. If $P > 0.05$, there is no significant difference; if $p<0.05$, the difference is considered insignificant; if $p<0.01$ this difference is significant; for $p<0.001$ the difference is very significant and for $p<0.0001$, this difference is highly significant.

RESULTS

Chemical composition of baobab flour

The chemical composition of baobab flour is shown in Table II. It consists largely of carbohydrates. The contents of total carbohydrates, digestible carbohydrates and starch are 92.47%, 84.64% and 56.34% respectively. Protein content was low (2.08 ± 0.1% DM).

Table 2: Chemical composition of baobab flour

Parameters	Baobab flour
pH	3,2±0
Moisture content (%)	6,33±0,8
DM (%)	93,67
Ash (%MS)	5,06±0,8
Protein (%MS)	2,08±0,1
Fat (%MS)	0,37±0,01
Reducing sugars (mg/100g DM)	5,13±0,02
Total sugars (mg/100g DM)	21,37±0,87
Digestible carbohydrates (%MS)	84,64±0,07
Total carbohydrates (%MS)	92,47±0,08
Starch content (%MS)	56,34±0,04
Dietary fiber (%MS)	7,82±0,01
TA (mEq/ 100 g DM)	15±0

Experiment duration: 21 days; TA: titratable acid; DM: dry matter.

Effect of baobab powder diet on rat growth

During the 21-day experiment, rats on the control diet (cornstarch) showed the greatest growth. They were followed by rats on the mixed diet of cornstarch and baobab flour (RM). The lowest growth was observed in rats on the baobab flour (RFB) diet (Figure 2).

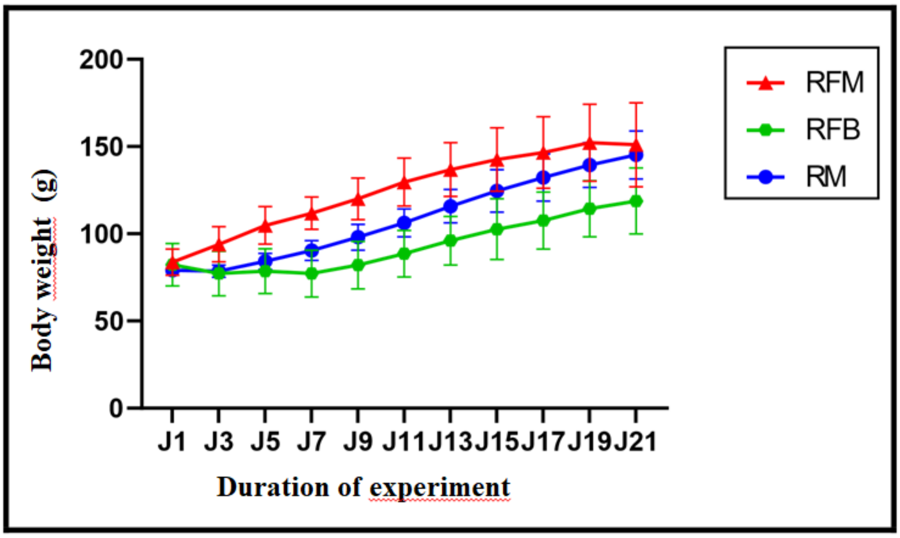

Figure 2: Changes in rat body weight as a function of diet

Experiment duration: 21 days; RFM: batch receiving the cornstarch-based diet; RFB: batch receiving the baobab flour-based diet; RM: batch receiving the mixed cornstarch and baobab flour-based diet. All diets had a protein content of 18% and an energy intake of 4246 kcal.

Digestive status of the baobab powder diet in rats

The dry matter digestibility and protein digestibility of the different diets are illustrated in Figures 2 & 3. Statistical analysis of dry matter digestibility shows that there is a significant difference ($P \leq 0.05$) between the different diets. The baobab powder diet (RFB) had a very low digestibility (negative value) compared with the other two diets. As for protein digestibility, statistical analysis shows that there is a significant difference ($P \leq 0.05$) between the different diets. The average protein digestibility value of the RFB diet (46.10 ± 0.00) is lower than that of the other diets (66.59 ± 0.00; 98.84 ± 0.00) RM and RFM respectively.

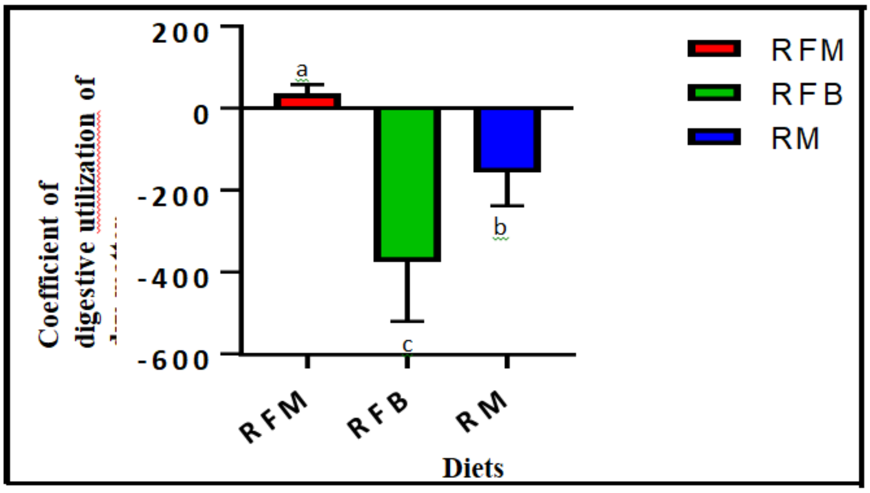

Figure 3: Coefficient of digestive utilization of dry matter

RFM: Cornstarch-based control diet; RFB: Baobab flour-based diet; RM: Mixed diet based on cornstarch and baobab flour; %BM: Body Mass Percentage. Letters (a, b, c) follow means derived from Newman-Keuls mean rankings. On the same line, means followed by different letters are significantly different (p≤0.05).

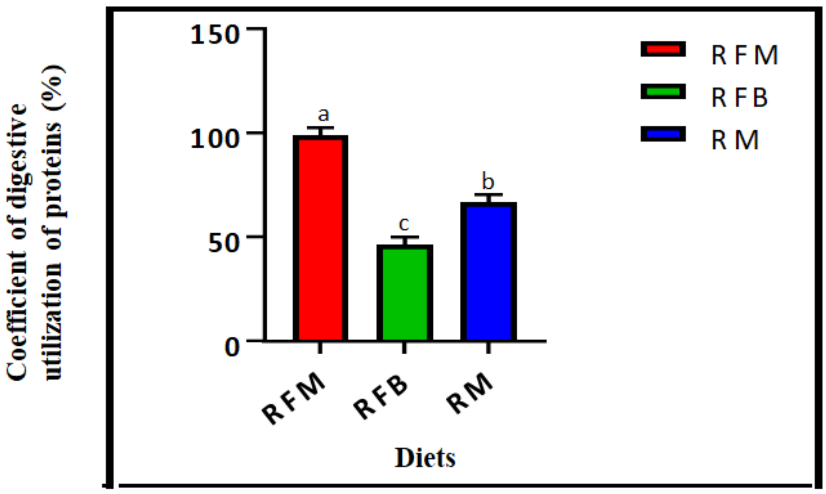

Figure 4 : Coefficient of digestive utilization of proteins

SRFM: Cornstarch-based control diet; RFB: Baobab flour-based diet; RM: Mixed diet based on cornstarch and baobab flour; % MC: Percentage of Body Mass. Letters (a, b, c) follow means derived from Newman-Keuls mean rankings. On the same line, means followed by different letters are significantly different (p ≤ 0.05).

DISCUSSION

Chemical composition of baobab flour

Baobab flour is essentially composed of carbohydrates. These values attest to those found by Kouamé *et al.* [14] on baobab. Indeed, baobab flour has a very high carbohydrate content. This is the case for tapioca [15] and attiéké [16]. The carbohydrates in these foods are mostly starch and contain small proportions of reducing sugars. Baobab flour, which is essentially energy-rich, has very low protein, lipid and ash contents. These values corroborate those of Kouassi [17] and Kouamé *et al.*, [14] on baobab. Consumed without any other source of nutritional intake, baobab flour could cause a nutritional imbalance. Moreover, the considerable presence of fiber, makes baobab a food that contributes to improving intestinal transit, prevents against cardiovascular disease and certain cancers. Baobab flour has an acid pH. The acidic pH of baobab is confirmed by the work of Kouassi [17] and Kouamé *et al.*, [14] on baobab. High acidity at pH is a favorable factor for inhibiting microorganisms that can cause fruit deterioration [18-19]. Baobab has a low moisture content. This value corroborates that of Kouamé *et al.* [14]. Indeed its low water content gives it an advantage in terms of foodstuff shelf life. In addition, Aryee *et al.*, [20] have shown that foods with high dry matter content and low moisture content can be stored for a long time, as low moisture content can limit the production of microorganisms, and the reproduction of microorganisms will lead to a decline in food hygiene quality.

Effect of baobab powder diet on rat growth and digestive balance

In animal experiments, the diets fed to rats had positive effects on their growth. This was evidenced by the daily weight gains observed in animals on the three carbohydrate diets. These results corroborate those observed by Coulibaly *et al*. [21], whose studies focused on rats fed plantain-based carbohydrate diets for 12 days. This variation could be explained by the fact that herring fish is an important source of protein available and assimilable by the body. Mass gain in experimental animals is a good indicator of animal protein utilization [12]. Rats fed a control diet (RFM) devoid of baobab flour showed significant growth. Rats grew moderately on the mixed diet (RM) and poorly on the baobab flour diet (RFB). In fact, the baobab diet does not promote rat growth. This low weight gain could be explained by the fact that the proteins contained in the baobab flour diet were not well assimilated by the rats. In fact, baobab powder is an important source of fiber. According to Mezajoug [22], fiber affects the amount of food ingested throughout the gastrointestinal tract. This high-fiber diet required a large amount of food, as evidenced by the high value of food ingested by rats on baobab-based diets. This food made the rats want to eat, but did not satisfy their appetite. This result is in line with the study by Jacquot and Guillemet [23] on shea cakes. They explained that the loss of animal mass due to the high fiber composition and its inclusion in the diet would lead to imbalance even in the most balanced diets. In addition, the amount of food assimilated by the rats, as measured by dry matter digestibility (CDUDM), was higher in rats fed the control diet than in those fed the baobab-based food. The dry matter digestibility values of the different diets are much lower compared to the dry matter digestibility values obtained by Yeboué [16] on cassava-based food diets. These results concur with those of Gnakri [24] obtaining a lower dry matter digestibility rate on Wistar rats fed a diet based on green plantain foutou. According to Gnakri [24], diet preparation affects dry matter digestibility.

CONCLUSION

The aim of this study was to investigate the chemical composition of baobab pulp and evaluate its nutritional impact after consumption in growing rats. Baobab pulp is an acidic food, composed of carbohydrates, mainly for energy. It has a high starch content and a high sugar content, giving it a sweet taste, with a considerable fiber content in terms of dry matter. Baobab flour contains very low levels of protein and lipids. From a nutritional point of view, the baobab flour diet is not conducive to rat growth, and therefore protein utilization. In addition, the diet's protein digestibility is negative, and the dry matter digestibility of the food consumed is very low. On the other hand, rat growth and protein and dry matter digestibility increased with the reduction or elimination of baobab flour from the diet. In a balanced diet, baobab flour does not promote weight gain, despite its high carbohydrate content. It can therefore be used to combat obesity.

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