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Effect of Protein Substitution with *Irvingia gabonensis* Flour on Anthropometric Parameters in a Rat Growth Diet

N'Guessan Yao Firmin[1*], Kouamé Djè Kouamé Wenceslas[1,2], Oulai Tokpa Louya[1], Touré Megnan Seigeo[1], Doumbia Idrissa[1]

[1]Polytechnic University of Man, BO box 20 Man, Côte d'Ivoire, Training and Research Unit-Engineering, Agronomic, Forestry and Environmental (UFR-IAFE)
[2]Nangui Abrogoua University, Department of Natural Sciences, Laboratory of Physiology, Pharmacology and Pharmacopoeia, 02 BO box 801 Abidjan 02, Côte d'Ivoire

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***Corresponding author:** N'Guessan Yao Firmin
Polytechnic University of Man, BO box 20 Man, Côte d'Ivoire, Training and Research Unit-Engineering, Agronomic, Forestry and Environmental (UFR-IAFE)

Abstract **Original Research Article**

Irvingia gabonensis, known as the African wild mango or "ogbono," is a widespread species. Its seeds are traditionally used as food and have a significant content of lipids, proteins, dietary fiber, and minerals. The overall objective of this study was to evaluate the effect of protein substitution with *Irvingia gabonensis* flour on anthropometric parameters in rats on a growth diet. Ten rats were used and divided into two groups: five (5) control rats and five (5) rats in the protein-substituted group, which was fed our specially formulated diets for three weeks. Protein substitution with *Irvingia gabonensis* flour resulted in a slight, gradual increase in body weight compared to initial weights. A decrease in feed intake was observed, along with very low fecal production. An increase in digestibility index from 6.77% to 578.37%, an increase in feed conversion ratio from 6.48% to 8.64%, and an increase in energy efficiency from 206.89% to 360.90% were observed. Finally, substituting *Irvingia gabonensis* meal for protein in a rat growth diet highlighted the nutritional and biological potential of this meal.

Keywords: Protein, anthropometric, diet, meal, rat, droppings.

INTRODUCTION

Improving the nutritional quality of diets is a major public health challenge in the prevention of malnutrition, nutritional deficiencies, and metabolic diseases [1]. Proteins, in particular, are essential macronutrients for growth, development, and tissue repair, as well as for maintaining body mass and regulating numerous physiological functions, including enzyme synthesis, hormone production, the immune response, and the transport of various molecules [2, 3]. However, the high cost of conventional protein sources and the need to utilize local food resources have encouraged the exploration of plant-based alternatives with nutritional and functional benefits [4]. Among these resources, *Irvingia gabonensis* (African wild mango or "ogbono") is a forest species widely distributed in Central and West Africa. Its seeds are traditionally used as a thickener in cooking and have an interesting nutritional composition, characterized by significant levels of lipids, proteins, dietary fiber, and minerals. Furthermore, the flour derived from its seeds possesses functional properties that make it a potential ingredient in the formulation of new foods [5, 6]. Beyond its technological qualities, *Irvingia gabonensis* is attracting increasing interest for its biological effects. Several experimental and clinical studies have reported its involvement in modulating carbohydrate and lipid metabolism, reducing body weight, and improving certain anthropometric and metabolic parameters. In laboratory animals, administration of *Irvingia gabonensis* derivatives has improved body weight and certain metabolic indicators, while in humans, seed extracts have shown a significant decrease in body weight, waist circumference, and several markers of metabolic syndrome [7, 6, 8]. Despite these promising results, few studies have investigated the use of *Irvingia gabonensis* flour as a partial or total substitute for dietary protein in a growth diet. However, the quality of dietary protein directly influences growth performance and anthropometric parameters [2]. In this context, the present study aims to evaluate the effect of protein substitution with *Irvingia gabonensis* flour on anthropometric parameters in rats fed a growth diet. The expected results will allow us to assess the nutritional potential of this local resource as an alternative ingredient in feed formulations designed to improve growth and nutritional status.

1. MATERIALS AND METHODS

1.1. Plant Material

The plant material consisted of the seeds of *Irvingia gabonensis*, commonly called Pklé in the Yacouba language. These seeds were harvested, cleaned, dried, and then ground into a fine flour. This flour was used as a partial protein substitute in the diet of our experimental subjects.

1.1. Animal Material

The animal material consisted of albino laboratory rats (Rattus norvegicus). These rats were young, growing, with an initial weight between 50 and 100 g. They were raised under standard laboratory conditions. These animals had free access to water and food with a 12 hour light/dark cycle. They were treated according to good laboratory practices [9]. The various experimental protocols were followed in accordance with the European Council's Legislation 2012/707 on the protection of experimental animals [10].

1.3 Technical Equipment

The technical equipment consists of laboratory equipment and instruments used for sample preparation and analysis. It includes a precision electronic balance, a grinder for converting seeds into flour, an oven for drying, and glassware such as beakers, test tubes, and pipettes, etc.

1.4 Method of Protein Substitution with *Irvingia gabonensis* in a Growth Diet

This test is described as those in [11]. Ten (10) rats were used and divided into two groups: five (5) control rats and five (5) rats in the protein-substituted group. The control rats are designated as the control group. Their diets consisted of maize (55g), fish (22g), lipids (4g), mineral salts (6g), and water (13g). The diet of rats whose protein was replaced with *Irvingia gabonensis* meal was the same as that of the control rats. The protein (fish) was replaced with *Irvingia gabonensis* meal. Anthropometric parameters were assessed to evaluate the effect of protein substitution with *Irvingia gabonensis* meal on rat growth. The rats' body weight was measured using a precision electronic scale at the beginning of the experiment and then weekly for three weeks. Weight gain was determined by the difference between the weight at the end of the week and the initial weight for the corresponding week. Food consumption was estimated daily from the amount of feed ingested by the animals. Anthropometric parameters such as feed conversion ratio, energy efficiency, and digestibility index were calculated to assess feed utilization efficiency in relation to body weight gain, as in the work of [12].

Mean weight gain (MG):

GP = mass of the animal at a given period - initial mass

Feed feed conversion ratio (FFR):

$$\text{FFR} = \frac{\text{Quantity of feed consumed during a given period}}{\text{Weight gain during the same period}}$$

Energy efficiency (EE):

$$\text{EE} = \frac{\text{amount of energy consumed during a given period}}{\text{weight gain during the same period}}$$

Digestability index (DI):

$$\text{ID} = \frac{\text{(Amount of feed consumed - mass of droppings produced during a given period)}}{\text{weight gain during the same period}}$$

1.5 Statistical Analysis

The results obtained are presented as the mean followed by the standard error of the mean (M±SEM). Statistical analysis was performed using GraphPad Prism 5.01 software (San Diego, California, USA). One-way analysis of variance (ANOVA) followed by Dunnett's test was used to identify differences between the treatment and control groups. Differences were considered significant for $p < 0.05$.

2. RESULTS

2.1. Change in Rat Body Weight Following Protein Substitution with *Irvingia gabonensis* Flour

The changes in rat body weight are presented in Table 1. Before protein substitution, the initial weights of the different groups were homogeneous and did not vary significantly ($p>0.05$). During the first week, a weight increase of 8.21% (83.0 ± 2.08 g) was observed in the control group, and a 2.77% increase (85.66 ± 21.33 g) was observed in the protein-substituted group. By the second week, growth had resumed in all groups, with an increase of 9.63% (101 ± 3.46 g) for the control group and a larger increase of 5.41% (90.3 ± 5.78 g) for the protein-substituted group. At the third week, growth continued in the control group, with a 10.21% increase in body weight (115 ± 1.76 g), while the protein-substituted group showed a smaller increase of 4.09% (94.0 ± 5.77 g).

2.2. Average Daily Feed Consumption for Each Group Following Protein Substitution with *Irvingia gabonensis* Flour

The average amount of feed consumed by the rats is shown in Table 2. The results show that the control group maintained relatively stable consumption throughout the experiment, with values ranging from 42.6 ± 3.36 g to 47.7 ± 1.64 g. During the first week, the protein-substituted group recorded a significantly lower intake (23.0 ± 3.96 g), reflecting a significant decrease ($p<0.01$) in food intake compared to the control rat groups. In the second week, the control group's intake was 47.7 ± 1.64 g. The amount of food consumed by the protein-substituted group (30.1 ± 2.69 g) was significantly lower ($p<0.05$ and $p<0.001$) compared to the control group. In the third week, the control group remained stable (45.7 ± 1.51 g). The amount of feed in the protein-substituted group (27.4 ± 3.03 g) decreased significantly ($p < 0.05$ and $p < 0.001$) compared to that of the control group (45.7 ± 1.51 g).

2.3. Amount of feces produced per day by each group of rats following protein substitution with *Irvingia gabonensis* meal

The amounts of feces produced by the rats during the different weeks are presented in Table 3. During the first week, the rats in the control group produced 40 ± 5.23 g of feces. The amount of feces produced by rats whose protein diet was substituted with Irvingia gabonensis meal (5 ± 3.11 g) decreased significantly.

Table 1: Change in rat weight following protein substitution with *Irvingia gabonensis* meal

	Change in animal weight (g)/Percentage (%) increase or decrease in parentheses			
Groups	**Initial weight**	**Week 1**	**Week 2**	**Week 3**
Group : Control	76.7 ± 1.76	83.0 ± 2.08 (+8.21)	91±3.46 (+9.63)	100±1.76 (+10.21)
Group: protein substituted by FIg	83.0 ± 4.73	85.66± 2.33 (+2.77)	90.3±5.78 (+5.41)	94.0±5.77 (+4.09)

$p>0.05$; no significant difference between the weights of rats whose feed was substituted with protein and those of control rats. n=5; FIg: *Irvingia gabonensis* flour.

Table 2: Variation in the average daily feed intake for each group following protein substitution with *Irvingia gabonensis* flour

	Quantity of food consumed (g)		
Groups	**Semaine 1**	**Semaine 2**	**Semaine 3**
Group : Control	42.6 ± 3.36	47.7 ± 1.64	45.7 ± 1.51
Group: protein substituted by FIg	23.0 ± 3.96**	30.1 ± 2.69***	27.4 ± 3.03***

**p<0,01 ; ***p<0,001 ; Significant difference between the amount of feed consumed by rats whose feed was substituted with protein and those of control rats. n=5; Fig: Irvingia gabonensis flour.

Table 3: Quantity of droppings produced per day by each batch of rats following protein substitution with *Irvingia gabonensis* meal.

	Quantity of droppings (g) / Percentage (%) increase or decrease (in parentheses)		
Groups	**Week 1**	**Week 2**	**Week 3**
Group : Control	40± 5.23	41 ± 4.31	33 ± 2.38
Group: protein substituted by FIg	5 ± 3.11*** (-87.5%)	4± 5.33*** (-90.24%)	6± 6.19*** (-81.81%)

***p<0.001; Significant difference between the quantity of droppings produced by rats whose protein was replaced with FIg compared to that of control rats. n=5; FIg: *Irvingia gabonensis* meal.

($p<0.001$) of 87% compared to the control group. In the second week, droppings production in the control group remained stable (41 ± 4.31 g). The amount of droppings in rats whose protein was replaced with *Irvingia gabonensis* meal decreased significantly ($p<0.001$) by 90.24% (4 ± 5.33 g) compared to the control group. During the third week, the control group produced 33 ± 2.38 g of droppings. The amount of droppings in rats whose protein was replaced with *Irvingia gabonensis* meal decreased significantly ($p<0.001$) by 81.81% (6 ± 6.19 g) compared to the control rats.

2.4. Digestibility Index (%) after protein substitution with Irvingia gabonensis meal

The digestibility index values for the different diets are presented in Table 4. During the first week, the control group had a digestibility index of 41.26%, indicating normal nutrient utilization. The digestibility index in rats fed a diet where *Irvingia gabonensis* meal replaced proteins decreased by 6.77% compared to the control rats. In the second week, the control group had a digestibility index of 83.75%, while the group of rats fed a diet where *Irvingia gabonensis* meal replaced proteins showed a sharp increase of 562.5%, indicating a gradual adaptation of the animals to the diet. During the third week, the control group showed a marked increase in digestibility index (136.55%), indicating improved nutrient utilization. The digestibility index of rats fed a diet where *Irvingia gabonensis* replaced proteins was extremely high (578.37%), indicating a strong and progressive adaptation of the animals to the diet.

Table 4: Digestibility Index (%) after protein substitution with Irvingia gabonensis meal

	Digestibility Index (%)		
Groups	**Week 1**	**Week 2**	**Week 3**
Group : Control	41.26	83.75	136.55
Group: protein substituted by FIg	6.77	562.5	578.37

Digestibility index calculated as a percentage of feed quantity, fecal mass, and weight gain. n=5; Fig: *Irvingia gabonensis* meal.

2.5. Feed Consumption Index (%) after protein substitution with *Irvingia gabonensis* flour

The feed conversion ratio values for the different batches are presented in Table 5. During the first week, the control batch had a feed conversion ratio of 6.76%, indicating normal feed utilization. The batch substituted with protein showed an increase in feed conversion ratio of 8.64%. In the second week, the feed conversion ratio decreased by 5.96% in the control batch. In the third week, the control batch had a value of 4.91%. The batch substituted with protein saw a significant increase of 7.40%.

2.6. Energy Efficiency (%) after protein substitution with *Irvingia gabonensis* flour

The energy efficiency values for the different batches are presented in the table. During the first week, the control group exhibited a high energy efficiency of 211.74%, indicating good energy conversion. The protein-substituted group showed a 360.90% increase in energy efficiency compared to the control group. In the second week, the energy efficiency of the control group decreased by 166.75%, while the protein-substituted group showed a 206.89% increase, exceeding that of the control group. During the third week, the control group decreased by 143.44%. Conversely, the protein-substituted group showed a 259.45% increase compared to the control group.

Table 5: Feed conversion ratio (%) after carbohydrate and protein substitution with *Irvingia gabonensis* meal

	Consumption index (%)		
Groups	**Week 1**	**Week 2**	**Week 3**
Group : Control	6.76	5.96	4.91
Group: protein substituted by FIg	8.64	6.48	7.40

Feed conversion ratio calculated based on feed quantity and weight gain. n=5; Fig: *Irvingia gabonensis* flour.

Table 6: Energy efficiency (%) after substitution of carbohydrates and proteins with *Irvingia gabonensis* flour

	Energy efficiency (%)		
Groups	**Week 1**	**Week 2**	**Week 3**
Group : Control	211,74	166,75	143,44
Group: protein substituted by FIg	360,90	206,89	259.45

Energy efficiency calculated based on energy consumption and weight gain. n=5; Fig:*Irvingia gabonensis* flour.

DISCUSSION

The variations in body weight of the rats show that the substitution of carbohydrates and proteins with *Irvingia gabonensis* flour influences growth depending on the group receiving the protein substitute. The results obtained reveal a progressive improvement in weight in the control group, while the protein-substituted group shows a slight, progressive increase in body weight compared to their initial weights. Indeed, the weight gain observed in the control group reflects good nutrient utilization and favorable adaptation to the diet. In contrast, the initial weight loss followed by a moderate recovery in the protein-substituted group could be explained by poor physiological adaptation or low utilization of ingested nutrients. Indeed, according to [13], body weight is an essential indicator of nutritional efficiency and proper metabolic function in growing rats.

The average amount of feed consumed shows that the substitution of proteins with *Irvingia gabonensis* flour influences feed intake depending on the group. The results reveal relatively stable feed intake in the control group, while the substituted groups, particularly the protein-substituted group, exhibit lower intake. Indeed, the decreased intake observed in the protein-substituted group could be explained by poor adaptation to the diet or difficult physiological adaptation. Several authors report that food intake directly influences growth and nutrient utilization [11].

The amount of feces produced by the rats shows that protein substitution with *Irvingia gabonensis* flour influences digestive activity. The results reveal high and relatively stable production in the control group, while the substituted groups, especially the protein-substituted group, exhibit very low fecal production. Indeed, the low fecal production observed in the control group could reflect either decreased feed intake or impaired digestion and nutrient absorption. Several authors report that variations in fecal matter reflect changes in intestinal absorption and diet digestibility [14].

The control group and the protein-substituted group showed an increase in digestibility indices. Some authors have shown that significant variations in digestibility can be linked to diet composition and nutrient bioavailability [11 ; 14].

Feed feed conversion ratio (FFR) values show that protein substitution with *Irvingia gabonensis* flour influences feed efficiency. The control group exhibited generally moderate FFR values, while the protein-substituted group showed an increase in FFR. Indeed, the low values observed in the protein-substituted group reflect good feed conversion. These results show that FFR depends on the body's ability to convert feed into weight gain. Several studies indicate that diet composition, particularly fiber and fat content, can influence feed efficiency [11 ;15]. These observations confirm that *Irvingia gabonensis* flour can modify feed conversion ratios depending on the level of incorporation.

Energy efficiency values show that protein supplementation with *Irvingia gabonensis* flour influences energy conservation. The control group showed a high energy efficiency value, as did the protein-substituted group. This high energy efficiency observed in both the control and protein-substituted groups is explained by the significant energy utilization. The energy efficiency value is explained by an energy adaptation for better energy conservation. These results show that energy efficiency depends on the organism's ability to utilize energy for growth. Supported by several experimental studies, energy depends on diet balance and nutrient digestibility [16]. Furthermore, nutrient bioavailability and physiological adaptation strongly influence this efficiency [11 ; 15]. These observations confirm that *Irvingia gabonensis* meal can modulate protein efficiency depending on the level of incorporation and the animals' adaptation to the diet.

CONCLUSION

In conclusion, we can say that this study on the effect of protein substitution with *Irvingia gabonensis* meal in a rat growth diet has highlighted the potential

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