



Effect of substituting carbohydrates with *Irvingia gabonensis* flour on anthropometric parameters in a growth diet for rats

¹N'Guessan Yao Firmin, ¹Oulai Tokpa Louya,
¹Silué Kalamourou, ^{1,2}Kouamé Djè Kouamé Wenceslas,
¹Doumbia Idrissa

¹N'Guessan Yao Firmin, firmen.nguessan@univ-man.edu.ci; +2250709004498

¹Oulai Tokpa Louya, louya.oulai@univ-man.edu.ci, +2250707288431

¹Silué Kalamourou, kalamourou.silue@univ.edu.ci, +225 0747209442

^{1,2}Kouamé Djè Kouamé Wenceslas, kouamedjekw@outlook.fr, +2250779101981

¹Doumbia Idrissa, idrissa.doumbia@univ-man.edu.ci, +2250707872284

¹Polytechnic University of Man, BO box 20 Man, Côte d'Ivoire, Training and Research Unit-Engineering, Agronomic, Forestry and Environmental (UFR-IAFE)

²Nangui Abrogoua University, Department of Natural Sciences, Laboratory of Physiology, Pharmacology and Pharmacopoeia, 02 BO box 801 Abidjan 02, Côte d'Ivoire.

Corresponding author: ^{1,2}Kouamé Djè Kouamé Wenceslas, kouamedjekw@outlook.fr, +2250779101981

Abstract

Irvingia gabonensis, commonly known as the African wild mango or African bush mango, is a plant species whose seeds are used as a thickener for sauces and as an energy-providing ingredient in various local dishes. The general objective of this study was to evaluate the impact of incorporating *Irvingia gabonensis* flour to replace a portion of the carbohydrates in the standard diet of young, growing rats. Ten rats were used and divided into two groups: five (5) control rats and five (5) rats in the carbohydrate-substitution group. Their diets consisted of maize (55 g), fish (22 g), lipids (4 g), minerals (6 g), and water (13 g). The diet of the test group was identical to that of the control group, except that the 55 g of maize (carbohydrates) was replaced by *Irvingia gabonensis* flour. Substituting carbohydrates with *Irvingia gabonensis* flour resulted in increases of 17.09% (1st week), 18.39% (2nd week), and 15.53% (3rd week) compared to the control group. The average amount of food consumed decreased by 41.9 ± 3.60 g (1st week), 47.7 ± 1.64 g (2nd week), and 38.4 ± 2.26 g (3rd week) compared to the control. Fecal output in the carbohydrate-

substitution group decreased significantly ($p < 0.01$) by 42.5% (1st week), 7.31% (2nd week), and 37 ± 4.05 g (3rd week) compared to the control group. The digestibility index increased by 148.81% (1st week), 16.87% (2nd week), and 8.75% compared to the control. The feed conversion ratio was low, at 1.81 (1st week), 2.27 (2nd week), and 2.4 (3rd week). Protein efficiency in the groups where carbohydrates were substituted showed a decrease of 35.43% (1st week) and 28.12% (2nd and 3rd weeks). Energy efficiency decreased by 35.43% (1st week) and 28.12% (2nd and 3rd weeks) in the rats from the carbohydrate-substituted group. In conclusion, *Irvingia gabonensis* flour represents a promising food resource that could serve as a partial carbohydrate substitute in human diets.

Keywords: Carbohydrates, *Irvingia gabonensis*, substitution, rats, anthropometric, diet.

Introduction

Diet is a key determinant of growth, development, and the maintenance of physiological balance in living organisms. Macronutrients particularly carbohydrates and proteins play a central role in energy supply, tissue building, and the regulation of metabolic functions. Carbohydrates constitute the body's primary energy source (Guyton et Hall 2014). Substituting a carbohydrate source can alter intestinal nutrient absorption due to the specific composition of the foodstuff involved (Nangue et al., 2011). *Irvingia gabonensis* commonly known as the African wild mango or African bush mango is a plant species whose seeds are used as a thickening agent for sauces and as an energy-rich ingredient in various local dishes (Etebuet Nwauzoma. 2014). Furthermore, these seeds are used in traditional medicine to treat certain metabolic and digestive disorders (Emeje et al., 2011 et Nangue et al., 2011). Processing the seeds into flour allows for their incorporation into various diets, opening up possibilities for their use as a partial substitute for conventional carbohydrate sources (FAO/WHO. 1991). Moreover, using whole-seed flour entails the simultaneous consumption of all the seed's nutritional constituents, which may produce physiological effects distinct from those observed with purified extracts. Any qualitative or quantitative alteration in these nutrients can lead to metabolic disturbances, manifesting as changes in growth, body composition, and the functioning of vital organs such as the liver, kidneys, and hematopoietic tissues (Guyton et Hall 2014). However, despite the vast availability of food resources, access to food remains limited for many populations; malnutrition and under

nutrition persist as significant challenges for certain groups (FAO/WHO. 1991). Against this backdrop, there is growing interest in identifying alternative food sources capable of partially replacing conventional carbohydrates particularly in low-income and developing countries, where food insecurity remains a major issue and access to traditional animal protein sources is both limited and costly. This research project is titled: "Effect of substituting carbohydrates with *Irvingia gabonensis* flour on anthropometric parameters in a growth diet for rats." The general objective of this study is to evaluate the impact of incorporating *Irvingia gabonensis* flour as a replacement for a portion of the carbohydrates in the standard diet of young, growing rats.

To achieve this objective, we aim to:

- Determine changes in body mass and weight gain in the rats throughout the experiment.
- Measure variations in anthropometric parameters.

1. Materials and Methods

1.1. Plant material

The plant material consists of *Irvingia gabonensis* seeds, commonly known as "Pklé" in the Yacouba language. These seeds were harvested, cleaned, dried, and then ground to produce a fine flour. This flour was used as a partial substitute for carbohydrates in the experimental diet.

1.2. Animal material

The animal material consists of albino laboratory rats (*Rattus norvegicus*). These rats were young

and in a growth phase, with an initial weight ranging from 50 to 100 g. They were housed under standard laboratory conditions. The animals had free access to food and water and were kept on a 12-hour light/dark cycle. They were handled in accordance with Good Laboratory Practice (OCDE, 1998). The experimental protocols followed the guidelines for the protection of laboratory animals set out in European Council Directive 2012/707 (EU, 2012).

1.3. Technical equipment

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

Average weight gain (WG):

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):

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

1.5 Statistical analysis

Results 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-

1.4 Method for substituting protein with *Irvingia gabonensis* in a growth diet

This test follows the procedure described in (Adrian *et al.*, 1991); ten rats were used and divided into two groups: five (5) control rats and five (5) rats in the substitution group. The control rats constitute the control group. Their diet consists of maize (55 g), fish (22 g), lipids (4 g), minerals (6 g), and water (13 g). The diet of the rats in the test group is the same as that of the control rats, except that the 55 g of maize. Anthropometric parameters such as the feed conversion ratio, feed efficiency, and digestibility index were calculated to evaluate feed utilization efficiency in relation to body weight gain, as in the work of Bohué *et al.*, (2011).

way analysis of variance (ANOVA) followed by Dunnett's comparison test was used to identify differences between treated and control groups. Differences were considered significant at $p < 0.05$.

2. Results

2.1. Variation in rat body weight following the substitution of carbohydrates with *Irvingia gabonensis* flour

Changes in rat body weight are presented in Table I. Prior to supplementation, the initial weights of the various groups were generally similar, indicating good group homogeneity. During the first week, a weight increase was observed in the control group (8.21%; 83.0 ± 2.08 g) and the carbohydrate-substituted group (17.09%; 87.0 ± 2.08 g). In the second week, growth resumed in all groups, with an increase of 9.63% (101 ± 3.46 g) for the control group and 18.39% (103 ± 2.03 g) for the carbohydrate-substituted group. By the third week, growth continued in the control group with a body weight increase of 10.21% (115 ± 1.76 g), while the carbohydrate-substituted group showed an increase of 15.53% (119 ± 2.89 g), reflecting less efficient growth.

2.2. Average daily feed intake per group following the substitution of carbohydrates with *Irvingia gabonensis* flour

The average amount of feed consumed by the rats is presented in Table II. 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 group receiving the carbohydrate substitution showed consumption levels close to those of the control group (41.9 ± 3.60 g), reflecting a significant decrease ($p < 0.01$) in food intake compared to the control group. In the second week, consumption in the control group was 47.7 ± 1.64 g; the food intake of the carbohydrate-substituted group (40.7 ± 2.48 g) was significantly lower ($p < 0.05$ and $p < 0.001$) than that of the control group. In the third week, the control group remained stable (45.7 ± 1.51 g), while food intake in the carbohydrate-substituted group (38.4 ± 2.26 g) was significantly lower ($p < 0.05$ and $p < 0.001$) than in the control group (45.7 ± 1.51 g).

Table I: Variation in rat weight following the substitution of carbohydrates with *Irvingia gabonensis* flour.

Groups	Change in animal weight (g)/Percentage (%) increase or decrease in parentheses			
	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: carbohydrates substituted by FIg	$74. \pm 0.33$	87.0 ± 2.08 (+17.09)	103 ± 2.03 (+18.39)	$119 \pm 2.89a^*$ (+15.53)

Table II: Average daily feed intake for each group following the substitution of carbohydrates with *Irvingia gabonensis* flour.

Groups	Quantity of food consumed (g)		
	Week 1	Week 2	Week 3
Group : Control	42.6 ± 3.36	47.7 ± 1.64	45.7 ± 1.51
Group: carbohydrates substituted by FIg	41.9 ± 3.60	$40.7 \pm 2.48a^*$	$38,4 \pm 2.26$

2.3. Daily fecal output of each rat group following the substitution of carbohydrates and proteins with *Irvingia gabonensis* flour

The quantities of feces produced by the rats over the various weeks are presented in Table III. During the first week, rats in the control group produced 40 ± 5.23 g of feces. The fecal output of the carbohydrate-substituted group decreased significantly ($p < 0.01$) by 42.5% compared to the control group. In the second week, fecal production in the control group remained stable (41 ± 4.31 g). The carbohydrate-substituted group showed a non-significant decrease ($p > 0.05$) to 38 ± 3.73 g a 7.31% reduction compared to the controls bringing the value closer to that of the control group.

During the third week, the control group produced 33 ± 2.38 g of feces, maintaining high levels. The carbohydrate-substituted group maintained relatively stable production (37 ± 4.05 g), comparable to that of the control. The protein-substituted group, meanwhile, recorded a slight

increase (6 ± 6.19 g) but remained significantly lower than the other groups.

2.4. Digestibility index (%) following carbohydrate substitution with *Irvingia gabonensis* flour

Digestibility index values for the different diets are presented in Table IV. During the first week, the control group showed a digestibility index of 41.26%, reflecting normal nutrient utilization. The carbohydrate-substituted group recorded a very high value (148.81%), indicating high apparent dietary efficiency. By the second week, the control group showed a slight decrease in the index (37.22%). The group with carbohydrate substitution showed a decrease of 16.87%, suggesting reduced digestive efficiency. During the third week, the control group exhibited a marked increase in the digestibility index (136.55%), indicating improved nutrient utilization. In contrast, the carbohydrate-substituted group continued to show a decline (8.75%), reflecting poor digestive efficiency.

Table III: Daily quantity of feces produced by each group of rats following the substitution of carbohydrates with *Irvingia gabonensis* flour.

	Quantity of feces (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: carbohydrates substituted by Flg	23 ± 4.51 a** (-42.5%)	38 ± 3.73 (-7.31%)	37 ± 4.05 (+12.12%)

Table IV: Digestibility index (%) after substitution of carbohydrates with *Irvingia gabonensis* flour.

	Digestibility index (%) / Percentage (%) increase or decrease in parentheses		
Groups	Week 1	Week 2	Week 3
Group : Control	41.26	83.75	136.55
Group: carbohydrates substituted by Flg	148.81	16.87	8.75

2.5. Feed conversion index (%) following carbohydrate substitution with *Irvingia gabonensis* flour

Feed conversion index values for the different groups are presented in Table V. During the first week, the control group shows a feed conversion index of 6.76%, indicating normal feed utilization. The group with carbohydrate substitution records a lower value (1.81%). In the second week, the index decreases for the control group (2.27%), reflecting improved feed efficiency. The group with carbohydrate substitution remains close to the control (2.54%). In the third week, the control group shows a value of 3.26%. The group with carbohydrate substitution remains relatively stable (2.4%), indicating low feed efficiency.

2.6. Protein efficiency (%) following carbohydrate substitution with *Irvingia gabonensis* flour

Protein efficiency values for the different groups are presented in Table VI. During the first week, the control group shows high protein efficiency (211%), indicating good protein conversion. The group with carbohydrate substitution showed

lower protein efficiency (35.43%). In the second week, the protein efficiency of the group with carbohydrate substitution is 28.12%. During the third week, the value for the control group decreased (143.44%) but remained higher than that of the group with carbohydrate substitution, which maintained a constant value (28.12%), confirming moderate protein utilization.

2.7. Energy efficiency (%) following carbohydrate substitution with *Irvingia gabonensis* flour

Energy efficiency values for the different groups are presented in Table VII. During the first week, the control group shows high energy efficiency (211.74%), indicating good energy conversion. The group with carbohydrate substitution showed a decrease in energy efficiency (35.43%). By the second week, the energy efficiency of the control group had decreased (166.75%) but remained higher than that of the carbohydrate-substituted group (28.12%). During the third week, the value for the control group decreased (143.44%) yet remained higher than that of the carbohydrate-substituted group, which maintained a constant value (28.12%), confirming moderate energy utilization. In contrast.

Table V: Feed conversion ratio (%) following the substitution of carbohydrates with *Irvingia gabonensis* flour.

Groups	Consumption index (%) / Percentage (%) increase or decrease in parentheses		
	Week 1	Week 2	Week3
Group : Control	6.76	5.96	4.91
Group: carbohydrates substituted by FIg	3.29	2.54	2.4

Table VI: Protein efficiency (%) after substitution of carbohydrates with *Irvingia gabonensis* flour.

Groups	Protein efficiency (%) / Percentage (%) increase or decrease in parentheses		
	Week 1	Week 2	Week 3
Group : Control	211.74	166.75	143.44
Group: carbohydrates substituted by FIg	35.43	28.12	28.12

Table VII: Energy efficiency (%) after substituting carbohydrates with *Irvingia gabonensis* flour.

	Energy efficiency (%) / Percentage (%) increase or decrease in parentheses		
Groups	Week 1	Week 2	Week 3
Group : Control	211.74	166.75	143.44
Group: carbohydrates substituted by Flg	35.43	28.12	28.12

Discussion

Variations in rat body weight indicate that substituting carbohydrates with *Irvingia gabonensis* flour influences growth, depending on the specific carbohydrate-substitution group. The results reveal a progressive weight gain in both the control group and the carbohydrate-substitution group relative to their initial weights. Indeed, the weight increase observed in the control and carbohydrate-substitution groups reflects efficient nutrient utilization and favorable adaptation to the diet. This weight progression highlights the importance of dietary nutritional quality for rat growth. According to **Bouafou *et al.*, (2011)**, body weight is a key indicator of nutritional efficiency and proper metabolic function in growing rats. Furthermore, several authors report that weight gain depends heavily on nutrient intake and bioavailability within the body (**Adrian *et al.*, 1991; Pawlak *et Pion.* 1968**). These analyses confirm that *Irvingia gabonensis* flour can enhance growth, although its effectiveness varies based on the level of inclusion in the diet.

Data on average feed consumption indicate that substituting carbohydrates with *Irvingia gabonensis* flour influences feed intake. Results show relatively stable consumption in the control group. In contrast, consumption in the carbohydrate-substitution group was comparable to that of the control group, reflecting good dietary acceptability. This variation in intake underscores the importance of diet composition and palatability in regulating feed intake.

According to **Bouafou *et al.*, (2011)**, feed consumption serves as an indicator of nutritional efficiency and the rats' adaptation to the diet. Moreover, several authors report that feed intake directly influences growth and nutrient utilization (**Adrian *et al.*, 1991; Bouafou *et al.*, 2011**). Thus, *Irvingia gabonensis* flour can alter feed intake depending on the level of inclusion in the diet. The quantity of fecal matter produced by the rats indicates that substituting carbohydrates with *Irvingia gabonensis* flour influences digestive activity. Results reveal high and relatively stable production in the control group, whereas the substitution groups particularly the protein-substitution group exhibit very low fecal output. Indeed, the progressive increase observed in the carbohydrate-substitution group reflects a digestive adaptation to the modified diet. This trend highlights the importance of the balance between intake, digestion, and absorption in nutrient utilization. According to **Bouafou *et al.*, (2011)**, fecal production serves as an indirect indicator of digestive efficiency and feed utilization in growing rats. Furthermore, several authors report that variations in fecal output reflect changes in intestinal absorption and dietary digestibility (**Adrian *et al.*, 1991; Pawlak *et Pion.* 1968**). These observations confirm that *Irvingia gabonensis* flour can influence digestion depending on its level of inclusion in the diet.

Digestibility index values indicate that substituting carbohydrates with *Irvingia gabonensis* flour could influence nutrient utilization. The control group showed an increase in the digestibility index, whereas the carbohydrate-substitution group showed a decrease. The drop in values observed in the carbohydrate-substitution group could be attributed to low feed intake and insufficient weight gain, which influence the index calculation. However, the progressive improvement observed reflects adaptation to the diet. These results indicate that digestibility depends on both intake and growth; indeed, according to **Bouafou *et al.*, (2011)**, it serves as an indicator of nutrient utilization efficiency in rats. Furthermore, several studies show that significant variations in digestibility can be linked to diet composition and nutrient bioavailability (**Adrian *et al.*, 1991**; **Pawlak *et al.*, 1968**). Additionally, other studies have reported that the dietary fiber and lipid content of *Irvingia gabonensis* seeds can influence digestion and intestinal absorption (**Ngondi *et al.*, 2005**; **Ejiofor *et al.*, 1987**). These observations confirm that *Irvingia gabonensis* flour can modulate diet digestibility depending on the level of inclusion and the animals' physiological adaptation. Feed conversion ratio values indicate that substituting carbohydrates with *Irvingia gabonensis* flour affects feed efficiency. The control group shows generally moderate values, whereas the carbohydrate-substituted group exhibits poorer performance compared to the control. Indeed, the drop in values recorded for the carbohydrate-substituted group indicates poor nutrient utilization. Over time, the improvement observed in certain groups reflects gradual adaptation to the diet, while the rise in the ratio for the carbohydrate-substituted group in the third week reflects low feed efficiency. These results demonstrate that the feed conversion ratio depends on the organism's ability to convert feed into weight gain; indeed, according to **Bouafou *et al.*, (2011)**, it serves as an indicator of nutritional efficiency in rats. Furthermore, several studies indicate that diet composition specifically fiber

and lipid content—can influence feed efficiency (**Adrian *et al.*, 1991**; **Ngondi *et al.*, 2005**). These observations confirm that *Irvingia gabonensis* flour can alter the feed conversion ratio depending on the level of inclusion.

Protein efficiency values show that substituting carbohydrates with *Irvingia gabonensis* flour influences the conversion of dietary protein into weight gain. Both the control group and the carbohydrate-substituted group exhibit a progressive decline in protein efficiency. Indeed, the low values observed in the carbohydrate-substituted group indicate limited protein utilization. Over the weeks, the improvement observed in the carbohydrate-substituted group reflects adaptation to the diet. These results show that protein efficiency depends on the organism's ability to utilize nutrients for growth; indeed, according to **Bouafou *et al.* (2011)**, it serves as an indicator of nutritional quality and metabolism in growing rats. Evidence from several experimental studies indicates that protein efficiency depends on dietary balance and nutrient digestibility (**Kouadio *et al.* (2020)**). Furthermore, nutrient bioavailability and physiological adaptation strongly influence this efficiency (**Adrian *et al.*, 1991**; **Ngondi *et al.*, 2005**). These observations confirm that *Irvingia gabonensis* flour can modulate protein efficiency depending on the level of inclusion and the animals' adaptation to the diet.

Energy efficiency values indicate that substituting carbohydrates with *Irvingia gabonensis* flour affects energy conservation. The control group exhibits a high energy efficiency value, whereas the carbohydrate-substituted group shows a stable energy efficiency value from the second week onwards. The high energy efficiency value observed in both the control group and the carbohydrate-substituted group is attributed to the significant energy utilization in the control rats, while the stability of the value in the substituted group is explained by an energy adaptation aimed at improved energy conservation. These results demonstrate that energy efficiency depends on the

organism's ability to utilize energy for growth. Indeed, according to **Bouafou *et al.*, (2011)**, it serves as an indicator of nutritional quality and metabolism in growing rats. Evidence from several experimental studies indicates that energy efficiency depends on dietary balance and nutrient digestibility (**Kouadio *et al.*, 2020**). Furthermore, nutrient bioavailability and physiological adaptation strongly influence this efficiency (**Adrian *et al.*, 1991**; **Ngondi *et al.*, 2005**). These observations confirm that *Irvingia gabonensis* flour can modulate protein efficiency depending on the level of inclusion and the animals' adaptation to the diet.

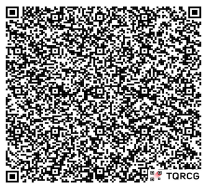
Conclusion

In conclusion, this study on the effect of substituting carbohydrates with *Irvingia gabonensis* flour in a growth diet for rats has highlighted the nutritional and biological potential of this flour. Regarding carbohydrate substitution, the observed digestibility indices and weight changes indicate that *Irvingia gabonensis* flour contributes to the energy and nutritional metabolism of the rats, despite some variations linked to the substitution level.

Références bibliographiques

- Adrian. J., Potus, J., and Frangne R. 1991.** La science alimentaire de A à Z. *Technique et Documentation Lavoisier*, Paris. 1991.
- Bohué, C.C., Koffi, D.M., Kouamé, K.G., and Yapi, H.F. 2016.**Évaluation des paramètres anthropométriques et nutritionnels chez des rats soumis à différents régimes alimentaires expérimentaux. *Journal of Applied Biosciences*, 104, 9987-9996. 2016.
- Bouafou, K. G. M., Kouamé, K. G., Offoumou, A. M., and Zannou-Tchoko, V. 2011.** Évaluation nutritionnelle et biochimique de farines végétales utilisées dans l'alimentation expérimentale du rat. *Journal of Applied Biosciences*, **49**, 3366-3378.
- Ejiofor, M. A. N., Okafor, J. C., and Ubbaonu, C. N. 1987.** Studies on the biochemical composition and utilization of *Irvingia gabonensis* seeds. *Nigerian Food Journal*, **5**, 42-47.
- Emeje, M., Ofoefule, S., Nnaji, A., Ofoefule, A., and Brown, S. A. 2011.** Assessment of the physicochemical properties of *Irvingia gabonensis* gum as a suspending agent in acetaminophen suspension. *Tropical Journal of Pharmaceutical Research*, **10**(4), 421-425.
- Etebu, E., and Nwauzoma, A. B. 2014.** A review on *Irvingia gabonensis* (African mango): A multipurpose tree species. *Journal of Medicinal Plants Research*, **8**(5), 223-228.
- EU (European Union). 2012.** Commission implementing decision of 14 november 2012 establishing a common format for the submission of the information pursuant to Directive 2010/63/EU of the European parliament and of the council on the protection of animals used for scientific purposes (notified under document C (2012) 8064) text with EEA relevance. *Special Education Croatian*, **15**(28), 163-180.
- FAO/WHO. 1991.***Protein Quality Evaluation: Report of the Joint FAO/WHO Expert Consultation.* Food and Agriculture Organization of the United Nations/World Health Organization, Rome.
- Guyton, A. C., and Hall, J. E. 2014.** *Traité de physiologie médicale* (13e éd.). Elsevier Masson.
- Kouadio, K.K., Yao, N.A., and Koffi, D.M. 2020.**Influence des régimes alimentaires expérimentaux sur les paramètres biochimiques et physiologiques chez le rat. *International Journal of Biological and Chemical Sciences*, **14**(3), 1021-1034.
- Nangue, T. J., Womeni, H. M., Mbiapo, F. T., and Fanni, J. 2011.** Effect of cooking and drying on the nutritional quality of *Irvingia gabonensis* kernels. *Journal of Food Research*, **1**(3), 157-165.
- Ngondi, J. L., Oben, J. E., and Minka, S. R. 2005.** The effect of *Irvingia gabonensis* seeds on body weight and blood lipids in obese subjects in Cameroon. *Lipids in Health and Disease*, **4**, 12.

- OCDE. 1998. *Principes de bonnes pratiques de laboratoire*. Organisation de Coopération et de Développement Économiques, Paris.
- Pawlak, M., and Pion, R. (1968). Influence de la digestibilité des aliments sur la croissance du rat. *Annales de Biologie Animale Biochimie Biophysique*, 8(4), 517-528.

Access this Article in Online	
	Website: www.ijarbs.com
	Subject: Clinical Nutrition
Quick Response Code	
DOI: 10.22192/ijarbs.2026.13.10.005	

How to cite this article:

N'Guessan Yao Firmin, Oulai Tokpa Louya, Silué Kalamourou, Kouamé Djè Kouamé Wenceslas, Doumbia Idrissa. (2026). Effect of substituting carbohydrates with *Irvingia gabonensis* flour on anthropometric parameters in a growth diet for rats. Int. J. Adv. Res. Biol. Sci. 13(10): 41-50.
DOI: <http://dx.doi.org/10.22192/ijarbs.2026.13.10.005>