**Studies on the nutritional profile of Shea caterpillars [Cirina butyrospermii, vuillet (1960)]**

**ABSTRACT**

In order to contribute to achieve food security in the North of Côte d’Ivoire, nutritional value ​​of shea caterpillars was studied.

Shea caterpillars were bought, dried on the sun, made into powder and their composition was determined. The nutritional value of shea caterpillar powder was compared to that of casein and fish powder. Then, three isoenergetic and isoproteic diets were formulated and each one was used to feed one of the three homogeneous batches of rats (n=6) constituted during 21 days. Animals were weight every four days and at the end of the experiment, we proceeded to the analysis of hematological parameters and to the plasma dosage of creatinine and urea

Protein content of caterpillar powder (42.64 ± 0.26 g/100gDM) and that of fish powder (46.32±0.03 g/100gDM) were almost equal (p>0.05). Total dry matter ingested and Total proteins ingested by rats fed with diet formulated using shea caterpillar as protein source were lower (p≤0.05) than that obtain when it is casein or fish powder which is used as protein source in diet. However, whatever the diet consumed growth of rats was regular and there was not a significant difference (p>0.05) on hematological parameters, on plasmatic protein concentration, on uremia and on serum creatinine.

In view of all the above, shea caterpillars constituted an interesting protein source for human nutrition which should be developed.

**Keywords:** shea caterpillars, nutritious value, nutritional value, rats

**1.INTRODUCTION**

Beyond being a source of energy for the body [1,2]in the same way as carbohydrates and lipids, proteins have also several roles. In fact, proteins help to fight infection [3,4, 5], to repair and build body’s tissues [6,7,8,9,10,11], to drive metabolic reactions [12], to maintain pH and fluid balance [13, 14,15]and also to transport and store nutrients [16, 17, 18, 19, 20]. Proteins are then vital because insufficient food intake induces Protein-Energy Malnutrition (PEM). The PEM symptoms include wasting, oedema, fatigue and weakness, skin and hair damages, impaired immune function and cognitive impairment [21]. Sources of protein for body are from plant origin or for animal origin. To meet the recommended nutritional intake which is 1 g/kg/day, we need a mixed diet requires both plant-based protein sources (oilseeds, legumes and cereals) and protein sources of animal origin (fish, meat, eggs, dairy products, insects). In sub-Saharan African countries and particularly in rural regions, plant protein sources are generally available at lower cost compared to conventional animal sources (fish, meat, eggs, dairy products). If we were to consume only plant-based sources of protein, large quantities would be required to meet the recommended nutritional intake because of their low protein content compare to animals’ sources [22]. This seems almost unrealistic. Moreover, plant-based sources of protein are often less well balanced in essential amino acids than animal-based sources of protein and then to meet the recommended nutritional intake the two based protein sources must be used [23]. Thus, if we want to help resolve the serious health problem caused by protein-energy malnutrition in developing countries [24,25]due to difficulties to access on animal protein (meat and fish), it is to seek to promote the unconventional sources of animal proteins that are culturally accepted and accessible in different cultural areas of Africa. Non-timber (NTFP), particularly caterpillars, could constitute a local alternative protein source [24]. The general objective of this study is to contribute to fight against protein-energy malnutrition by promoting an unconventional source of animal proteins which is accessible in north of Côte d’Ivoire: shea caterpillars (*Cirina butyrospermi*, Vuillet, 1960, *Lepidoptera*, *Saturnidae*).The specific objectives that emerge are to determine the chemical composition of the shea caterpillar and to evaluate the effect of consuming shea caterpillars in rats in comparison with a reference protein (casein) and fish meal.

**2. MATERIAL AND METHODS**

 **2.1 Ingredient used for food formulation**

Ingredients such as corn starch, sugar and agar-agar were the main sources of carbohydrates. Sunflower oil was used as lipid sources. Fish, casein and shea carterpillars were used as protein sources. Vitamin and mineral supplements have been used to balance diets.

 **2.2 Animals breeding**

Eighteen young albino Wistar rats weighing between 45 and 53 g were used. These animals were bred in the animal house of Ufr Biological sciences of the University Peleforo GON COULIBALY of Korhogo (Côte d’Ivoire). During the breeding period, rats were fed with food made by a society IVOGRAIN which is specialized in mass production of livestock food. This food is made up of crude protein matter (15%), crude fat matter (3.5%), cellulose matter (12%), mineral matter (9%), calcium (1%), phosphorus (0.9%), sodium (0.3%), vitamin A (15000 UI/kg), vitamin D3 (3000 UI/kg) and vitamin E (10 mg/kg).

**2.3 Shea carterpillars powder obtention**

Shea carterpillars (*Cirina butyrospermi*) were bought fresh in some markets located of Korhogo town (Côte d’Ivoire). Then, they were dried on the sun and made into powder using a grinder (magimix, automatic 41000 multicuve) before being stored in plastics bags until their used. A part of this powder was used to determine nutritious value of shea caterpillars when the other part was stored in order to be incorporated later in diet of laboratory animals.

**2.4 Determination of the composition of *Cirina butyrospermi* powder and fish powder**

The recommended methods of Association Analytical Chemists [26] were utilized to determine moisture content, ash content, crude protein content and crude fat content of the different powder. Moisture content was determined by heating 2 g of samples to a constant weight in crucible placed in an oven (MMM Medcenter Gmbh (D-82152, Munich, Germany) maintained at 105°C for 4 hours.

Ash was determined by incineration of 1 g samples placed in a muffle furnace (P Selecta, Espagna) maintained at 550°C for 6 hours.
Crude protein content (% total nitrogen × 6.25) was determined by Khedjahl method [27], using 1 g samples.

Crude fat was obtained by exhaustively extracted 5 g of each sample in a Soxhlet apparatus for 8 hours using hexane as the extractant [28].
Total carbohydrate (%) was estimated by difference as show in the equation:

Total carbohydrate (%) = 100 – [Protein (%) + Lipids (%) + Asch (%) +Fibre (%)]

**2.5 Experimental diets formulation**

Three diets isoenergetic and isoproteic were constituted (diet DC, diet DFP and diet DSP). These are:

- A reference diet (DC) whose protein source used was casein ;

-An experimental diet (DFP) containing fish powder as protein source ;

-and another experimental diet (DSP) with shea caterpillar powder as protein source.

The proportions of carbohydrates and lipids in the different diets were obtained by calculation in order to satisfy the required caloric level of the diets, taking into account the energy contributions of carbohydrates (4 kcal per 1 g), lipids (9 kcal per 1 g) and proteins (4 kcal per 1 g). All diets were balanced in vitamins and minerals with the vitamin mix and mineral mix respectively. The adjustment of their energy contents was done using corn oil and “Maizena” corn starch whose were available in the commerce. Sugar was used to make the different diets attractive and Agar-agar was used as source of fiber (Table 1).

**Table 1**: Diets formulation (g/100 MS)

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Diets |  |
| Ingredients | DC | DFP | DSC |
| Casein | 10.41 | - | - |
| Fish powder | - | 14.02 | - |
| Shea carterpilar powder | - | - | 23.45 |
| Ash | 1 | 1 | 1 |
| Vitamin | 1 | 1 | 1 |
| Sugar | 10 | 10 | 10 |
| Agar-agar | 2 | 2 | 2 |
| Corn starch | 69.662 | 71.98 | 62.13 |
| Sunflower oil | 5.928 | 1.42 | 0.42 |
| Totals (g) | 100 | 100 | 100 |
| PLD (%) | 10 | 10 | 10 |
| GE kcal/100DM | 420 | 420 | 420 |

NB : The gross energy of the diets was calculated by referring to the combustion values ​​of the different nutrients which are protein (4 kcal per 1 g), carbohydrate (4 kcal per 1 g) and lipids (9 kcal per 1 g).

DC : Diet with casein as protein source, DFP : Diet with fish powder as protein source, DSC : Diet with Shea caterpillar powder as ptotein source, PLD : Protein level in Diet, GE : Gross Energy.

**2.6 Animal testing condition**

Three homogeneous young groups of rats (six per group) were constituted. They were put individually in metabolic cages and maintained under standard laboratory conditions (temperature 25±2°C) with dark and light cycle (12/12 h). Five days before the beginning of the experiment, rats were acclimatized to this condition and were fed with the diet used during their breeding.

**2.7 Feeding method**

After the acclimatization period, each group of animals were fed *ad libitum* with one of the different diets constituted (diet DC, diet DFP and diet DSC) during 21 days. These diets were distributed *ad libitum o*nce a day, at 8 a.m, in form of puree in order to avoid waste. Water was served *ad libitum* and renewed every morning at 8 o'clock.

**2.8 Consumption measurement**

During the experimentation, every day, each kind of food used (diet DC, diet DFP and diet DSC), was made in paste by add in it a quantity of water clearly determined in order to minimize the waste. After that, a quantity of each mashed food made, was weighted and was given to each animal according to the group. Few mashed of these differents food was every day weighted after being dry during 4 hours in an oven (MMM Medcenter Gmbh (D-82152, Munich, Germany) at 105°C and the weight obtained was written in a notebook. Then, with this sample the dry matter in each food give to animals can be calculated. The following day, before distributing the diets, the rests of food give the day before were separately collected and were weighted after being dried during 4 hours in an oven at 105°C. The different weights obtained were also written in a notebook. This methodology permitted us to determine the total dry matter consumed every day by each animal which is the difference between the dry matter food give the day before and the rest collected and dry the following day. Then, the total dry matter of food consumed by each group during the time of the experiment (21 days) is obtained by the summation of the dry matter consumed per day by each rat of the group during the 21 days. The mean Dry Matter Ingested every day (DMI/d) by each animal is obtained by the difference between Total Dry Matter of food consumed divided by 21 [29].

When the quantity of dry matter ingested was determined, it became easy to determine the amount of total protein ingested. Total Protein Ingested (TPI) represents the quantity of dietary protein ingested during the duration of the experiment (21 days). These TPI was determined according to the following formula: PTI (g/d) = DMI x percentage of protein in each diet/ 21.

**2.9 Growth measurement**

 Growth was measured in terms of weight gains. The mean weight gain of each rat of each group during the time of the experimentation was calculated. The weight gain of each rat is obtained by the difference between the final body weight of a rat and the initial body weight of the same rat. Because there are six rats in a group and because the time of the experimentation is 21 days, the Mean Body Weight per group (MBW) is the summation of the difference between Final body weight and Initial body weight of the six rats of the group divided by 6 and by 21. Then, the Mean Body Weight (MBW) of each animal per group was obtained using the next formula:

FBW-IBW

 MBW=

6X 21

MBW: Mean Body Weight;
FBW: Final Body Weight;
IBW: Initial Body Weight.

**2.10 Calculation of the Mean Alimentary Efficacy Coefficient**

The Alimentary Efficacy Coefficient (AEC) expresses the efficiency with which the diet has being ingested. This value was obtained by dividing the body weight gain per day of each rat of the group during the time of the experimentation by the Dry Matter Ingested (DMI) every day by each rat. Seeing that there are six rats per group, the Mean Alimentary Efficacy Coefficient (MEAC) per group was obtained by summation the AEC of each rat in the group which value obtained was divided by the number of rats in the group (6).

**2.11 Blood sample collected**

Animals were observed for signs of abnormalities throughout the study. At the end of the experimentation, each animal was anesthetized by ether inhalation and blood sample of each animal was collected with sterilized individual syringe and put in two kinds of tubes which are tube with anticoagulant (EDTA) and tubes without anticoagulant.

**2.12 Measurement of blood parameters**

Blood samples contained in the EDTA tubes were used to make the blood cells count using Sysmex KX 21N as apparatus while blood samples contained in tubes without anticoagulant were utilized to measure the biochemical parameters that are total protein, urea and creatinine using HITACHI 902 Roche as apparatus.

**2.14 Statistical analysis**

The experimental results were expressed as the mean±S.E.M. Data were assessed by the method of analysis of ANOVA followed by Dunnett test [30, 31]. p. value of < 0.05 was considered as statistically significant.

**3. RESULTS AND DISCUSSION**

**3.1 Composition of dried Shea caterpillar powder compared to that of fish powder**

The proximate composition of dried shea caterpillars and Fish powder are shown on table 2.

Moisture content in shea caterpillars is inferior to the value 10 g/100gFM and it is under the value 12%: this suggested that shea caterpillars dry on the sun can be stored for a long time without spoilage [32, 33]. Moisture content in *Cirina butyrospermi* powder is slightly higher than that found by [34] in *Imbrasia truncata* powder (9.9 g/100gFM) and by [35] found in *Imbrasia oyemensis* powder (7.19 g/100gFM).

Shea caterpillars’ protein content is almost identical (p ­$\geq 0.05$) to that of fish. So, because fish is recognized as an excellent source of protein, we can conclude that shea caterpillars are also an excellent source of protein. The protein content of *Cirina butyrospermi* powder reported in this work is lower than that of the same species (63 g/100gDM) collected in Burkina Faso [36]. It is also lower than that of *Bunaeopsis aurantiaca* (49g/100gDM), *Antheua insignata* (61g/100gDM), *Imbrasia truncata* (70.63g/100gDM) reported by [34] and than that of *Imbrasia oyemensis* (55.49g/100gDM) reported by [35]. Thus, the incorporation of *Cirina butyrospermi* powder could be considered in human diet, especially in the diet of children of northern Côte d’Ivoire, an area where protein-energy malnutrition is one of the highest in the country. To reach humans, through an experiment on rats, we compared the effects of shea caterpillars used as protein source to that of casein and to that of fish powder. This experimentation conducted to the following results and discussion.

**3.2 Total dry matter ingested, total protein ingested, growth of rats, Feed Efficiency Ratio (FER) and Protein Efficiency Ratio (PER)**

Statistical analysis revealed that total dry matter ingested by rats fed with diet containing shea caterpillar powder was lower compared to the total dry matter ingested by rats fed with diet containing casein and than total dry matter ingested by rats fed with diet containing fish powder (p≤0.05). These results are shown on table 3. Also, statistical analysis indicated that the total proteins ingested was lower in the case of consumption of diet containing shea caterpillar than when it was diet containing casein or fish powder (p≤0.05). These results are shown on table 3.

According to the curve illustrating the evolution of body weights (Figure 1), whatever the diet consumed, rats had regular growth until the end of the experiment. However, the growth curves of rats fed with diet DFP or with diet DSC were higher than that of rats fed with diet DC (Figure 1). When we calculated the mean body weight, we noticed that mean body weight gain of rats fed with diet DFP (1.51 ± 0.20 g/d) and those fed with diet DSC (1.78 ± 0.76 g/d) were significantly higher (p≤0.05) than that of the rats fed with diet DC (0.80 ± 0.09 g/d). These results are shown on Figure 2.

Despite the low level of total dry matter ingested and the low level of protein ingested in the case of *Cirina butyrospermi* used as protein source, the evolution of weight gain was regular and even was greatest: this was justified by the feed Efficiency Ratio and the Protein Efficiency Ratio which were equal to that of rats of the other batches. This is a proof that shea caterpillar proteins have a diversify composition and then the recommendations need of each essential amino acid was fulfilled. In fact, according to [38], *Cirina butyrospermi* part of protein is constituted by 43.96 % of Albumin, 12.07 % of Globulin, 10.63 % of Prolamin and 25.98 % of Glutelin. Again, according to [39], the mass of total essential amino acid (TEAA), found in *Cirina butyrospermi* flour dry on the sun during a week, was 27.25 g/100 g of protein. In this part of total essential amino acid there were Methionine (0.69±0.06 g/100 g of protein), Isoleucine (2.64±0.05 g/100 g of protein), Threonine (3.70±0.04 g/100 g of protein), Valine (4.34±0.06 g/100 g of protein), Lysine (5.25±0.03 g/100 g of protein), Histidine (2.56±0.04 g/100 g of protein), Tyrosine (3.01±0.06 g/100 g of protein), Phenylalanine (2.32±0.04 g/100 g of protein) and Leucine (2.74±0.07 g/100 g of protein ). What a marvel for meeting the protein needs of human!!! What would be the impact of consuming these caterpillars on the functionality of living things? To answer this question, we measured total protein, urea, and creatinine.

**3.3 Dosage of total proteins, urea and creatinine**

No significant difference (p>0.05) was observed between plasmatic protein concentration in the blood sample of each group of rats fed with the different experimentation diets (diet DC or diet DFP or diet DSC). Uremia obtained with rats fed with diet DC or diet RFP or diet RDC were respectively 0.38±0.15 g/l; 0.43±0.11 g/l; 0.45±0.17 g/l. These values were not significantly different (p ≥ 0.05) to each other. Also, the serum creatinine levels of rats fed with diet DFP or diet DSC do not show any significant difference (p ≥ 0.05) between those fed with diet DC.

All these results are shown on Table 5.

The fact that there was no difference in total protein, uremia and creatinemia suggested similar glomerular filtration of rats kidneys and a similar functioning of rat livers extracted from the rats of the different batches whatever the diet consumed [40, 41, 42]. This suggested also that there wasn't a problem of malnutrition and a problem of malabsorption of amino acids contain in the different diet consumed by the rats. What is the impact on hematological parameters? To answer this question, we carried out the blood count.

**3.4 Hematological parameters**

There was no significant difference (p>0.05) in the number of blood cells whatever the kind of proteins in the diet. The Mean Cellular Volume (MCV) of rats fed with diet DC and that of rats fed with diet DFP were not significantly different (p ≥ 0.05), but that of rats fed with diet DSC was significantly higher (p≤0.05) than that of rats which consumed diet DC or diet DFP. Mean Cellular Hemoglobin (MCH) and Mean Cellular Hemoglobin Concentration (MCHC) values ​​were significantly higher (p≤0.05) in rats subjected to diet DFP or diet DSC than the value observed on rats subjected to diet DC. The value of hematocrit was high (p≤0.05) when rats are fed with diet DFP or diet DSC than when rats are fed with diet DC. Leukocytes content and platelet content of rats fed with diet DFP were higher (p≤0.05) than that determined on rats fed with diet DC or diet DSC. However, it appears that, whatever the diet consumed, values ​​of hemoglobin and red blood cell counts are within the range given by [43]suggesting that no diet caused anemia. All these results are shown on table 6**.** Rats which consumed diet in which *Cirina butyrospermi* powder is used as protein source (diet DSC) had a higher leukocyte count than rats which consumed diet in which casein is used as protein source, but these rats which consumed diet DSC had low leukocyte count than rats which consumed diet in which fish powder is used as protein source. According to [44] and [45], an increase in white blood cells can indicate infection, inflammation, or even blood disease. In our case, the comparison being made with two reference protein sources, and our test protein being in the middle, it is difficult to blame the quality of this caterpillar.
**4. CONCLUSION**

The aim of this work was to study the nutritional value of shea caterpillars an avaible and accessible source of protein in the north of Côte d’Ivoire. Chemical analysis of these shea caterpillar revealed that their protein content is almost equal to that of fish powder. Consumption of these caterpillars as a source of protein by rats gives results comparable to those of fish and casein without showing deleterious effects. In view of all the above, we can say that shea caterpillars (*Cirina butyrospermi*) can constitute an important source of protein which could contribute significantly to fight against food insecurity and protein-energy malnutrition in the North of Côte d’Ivoire.

**DISCLAMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**REFERENCES**

1. [Carbone](https://pubmed.ncbi.nlm.nih.gov/?term=Carbone+JW&cauthor_id=24945715)JW, [Pasiakos](https://pubmed.ncbi.nlm.nih.gov/?term=Pasiakos+SM&cauthor_id=24945715) SM, [Vislocky](https://pubmed.ncbi.nlm.nih.gov/?term=Vislocky+LM&cauthor_id=24945715) LM, [Anderson](https://pubmed.ncbi.nlm.nih.gov/?term=Anderson+JM&cauthor_id=24945715) JM, [Rodriguez](https://pubmed.ncbi.nlm.nih.gov/?term=Rodriguez+NR&cauthor_id=24945715) NR. Effects of short-term energy deficit on muscle protein breakdown and intramuscular proteolysis in normal-weight young adults. Applied Physiology, Nutrition, and Metabolism. 2014; 39(8):960-8.
2. Rui L. Energy Metabolism in the Liver. Comprehensive Physiology. 2014; 4(1): 177–197.
3. Li P, Yin Y-L, Li D, Kim SW, Guoyao Wu G. Amino acids and immune function, British Journal of Nutrition. 2007; 98, 237–252.
4. Fernández-Cruz E. Alecsandru D, Ramón SS. Mechanisms of action of immune globulin. Clinical and Experimental Immunology. 2009; 157 (Suppl. 1): 1–2.
5. Schroeder HW, Cavacini L. Structure and Function of Immunoglobulins. J Allergy Clinical Immunology. 2010; 125(202):S41–S52.
6. Genton L. Pichard C. Protein Catabolism and Requirements in Severe Illness. International Journal for Vitamin and Nutrition Research. 2011; 81 (2 -3):143-152.
7. Phillips SM, Van Loon LJ-C. Dietary protein for athletes: From requirements to optimum adaptation, Journal of Sports Sciences. 2011; 29(S1): S29–S38
8. Nowson C. O’Connell S. Protein Requirements and Recommendations for Older People: A Review. Nutrients. 2015; 7: 6874-6899.
9. Elango R. Ball RO. Protein and Amino Acid Requirements during Pregnancy. Advance in Nutrition. 2016;7(Suppl):839S–44S.
10. Kominiarek MA, Rajan P. Nutrition Recommendations in Pregnancy and Lactation. Medical Clinics of North America. 2016; 100(6): 1199-1215.
11. Yeung SE, Hilkewich L, Gillis C, Heine JA, Fenton TR. Protein intakes are associated with reduced length of stay: a comparison between Enhanced Recovery After Surgery (ERAS) and conventional care after elective colorectal surgery, American Journal of Clinical Nutrition. 2017; 106:44-51.
12. Hatzimanikatis V, Li C, Ionita JA, Broadbelt LJ, Metabolic networks: enzyme function and metabolite structure. Current Opinion in Structural Biology. 2004; 4(3):300-306.
13. Lamanda A, Cheaib Z, Turgut MD, Lussi A (2007) Protein Buffering in Model Systems and in Whole Human Saliva. PLoS ONE. 2007 ; 28; 2(2):e263.
14. Aoi W. Marunaka Y. Importance of pH Homeostasis in Metabolic Health and Diseases: Crucial Role of Membrane Proton Transport, BioMed Research International. 2014, Article ID 598986, 8 pages.
15. Lee HL, Nazih N, Kathleen H-S. Clinical Journal of the American Society of Nephrology. 2015. [10(12):2232-2242.](https://journals.lww.com/cjasn/toc/2015/12000)
16. [Levy](https://pubmed.ncbi.nlm.nih.gov/?term=Levy+E&cauthor_id=17495606)E, [Spahis](https://pubmed.ncbi.nlm.nih.gov/?term=Spahis+S&cauthor_id=17495606) S, [Sinnett](https://pubmed.ncbi.nlm.nih.gov/?term=Sinnett+D&cauthor_id=17495606) D, [Peretti](https://pubmed.ncbi.nlm.nih.gov/?term=Peretti+N&cauthor_id=17495606) N, [Maupas-Schwalm](https://pubmed.ncbi.nlm.nih.gov/?term=Maupas-Schwalm+F&cauthor_id=17495606) F, [Delvin](https://pubmed.ncbi.nlm.nih.gov/?term=Delvin+E&cauthor_id=17495606) E, [Lambert](https://pubmed.ncbi.nlm.nih.gov/?term=Lambert+M&cauthor_id=17495606) M, [Lavoie](https://pubmed.ncbi.nlm.nih.gov/?term=Lavoie+MA&cauthor_id=17495606) M-A, (2007). Intestinal cholesterol transport proteins: an update and beyond, Current Opinion Lipidology. 2007;18(3):310-318.
17. Elizabeth L. Mackenzie, Iwasaki K, Tsuji Y. Intracellular Iron Transport and Storage: From Molecular Mechanisms to Health Implications. Antioxid Redox Signal. 2008 ; 10(6):997–1030.
18. Diallinas G. Understanding transporter specificity and the discrete appearance of channel-like gating domains in transporters. Front Pharmacol.  2014 ; 12(5):207.
19. Mishra NK, Chang J, Zhao PX. Prediction of Membrane Transport Proteins and Their Substrate Specificities Using Primary Sequence Information. PLoS ONE. 2014; 9(6): e100278.
20. [Hashimoto](https://pubmed.ncbi.nlm.nih.gov/?term=Hashimoto+A&cauthor_id=26598820)A, [Kambe](https://pubmed.ncbi.nlm.nih.gov/?term=Kambe+T&cauthor_id=26598820) T**.** Mg, Zn and Cu Transport Proteins: A Brief Overview from Physiological and Molecular Perspectives. Journal of Nutritional Science and Vitaminology. 2015;61 Suppl:S116-8.
21. Grover Z. Ee LC. Protein energy malnutrition. Pediatric Clinics of North America, 2009; 56(5):1055-1068.
22. Guéguen J. Walrand S. Bourgeois O. 2016. Les protéines végétales : contexte et potentiels en alimentation humaine. [Cahiers de Nutrition et de Diététique](https://www.sciencedirect.com/journal/cahiers-de-nutrition-et-de-dietetique). 2016 ; 51(4) : 177-185.
23. Chardigny J-M., Walrand S. Plant protein for food: opportunities and bottlenecks. OCL Oilseeds and fats crops and lipids. 2016; 23 (4), 6 p.
24. FAO. Contribution des insectes de la forêt à la sécurité alimentaire : l’exemple des chenilles d’Afrique centrale. 2004. Produits forestiers non ligneux. Document de Travail N° 1, 107 pages.
25. FAO. La situation mondiale de l’alimentation et de l’agriculture. Organisation des nations unies pour l’alimentation et l'agriculture Rome, 2008 ; 113-143.
26. AOAC: 1995. Official methods of Analysis of AOAC International, 16th ed. AOAC International Arlington, VA, 250 p
27. Pearson D. Chemical analysis of foods. 7th edition, London, Church Hill Livingstone. 1976; 488- 497.
28. Bourely J. Observation sur le dosage de l’huile des graines du cotonnier. 1982. cot; Fib. Trop 27(2): 183-196.
29. Ouattara H. Touré A. Méité A. Kati-Coulibaly S. Côte d’Ivoire Blighia Sapida Aril Oil Composition and Efficacy on Rat’s compared with Palm Oil and Olive Oil. Journal of Food Research. 2017; Vol. 6, No. 5; 2017.
30. Ostle B. Statistics in Research. Iowa state university press, Iowa., USA. 1966; 310-361.
31. Woolson RF. Statistical methods for the Analysis of Biomedical Data. John Wiley and Sons Inc., New York. 1987.
32. Yu J. Anchordoquy TJ. Effects of Moisture Content on the Storage Stability of Dried Lipoplex Formulations. Journal of Pharmacological Science. 2009 ; 98(9): 3278–3289.
33. Muvundja AF. Pasche N. Bugenyi WBF. Isumbisho M. Müller B. Namugize J.P. Rinta, P. Schmid M. Stierli R. Wüest A. Balancing Nutrient Inputs to Lake Kivu. Journal of Great Lakes Research. 2009; 35: 406-418.
34. Mabossy-Mobouna G. Kinkela T. Lenga A. Malaisse F. Imbrasia truncata Aurivillius (Saturniidae): Importance en Afrique centrale, commercialisation et valorisation à Brazzaville. Geo-Eco-Trop. 2013 ; 37(2) : 313-330.
35. Foua Bi FG. Meite A. Dally T. Ouattara H. Kouame KG. Kati-Coulibaly S. Étude de la qualité biochimique et nutritionnelle de la poudre séchée d’Imbrasia oyemensis, chenilles consommées au Centre-Ouest de la Côte d’Ivoire. Journal of Applied Biosciences. 2015; 96:9039-9048.
36. Anvo MPA. Toguyéni A. Otchoumou AK. Zoungrana-Kaboré CY. Kouamelan EP. 2016. Nutritional qualities of edible caterpillars Cirina butryrospermi in southwestern of Burkina Faso. International Journal of Innovation and Applied Studies. 2016 ; 18(2): 639-645.
37. Koffi DM. Cissé M. Koua GA. Protein Fractions, Physicochemical and Functional Properties of Flour and Oil from the Shea Caterpillar Cirina butyrospermi Vuillet Consumed in Northern Côte d’Ivoire. International Journal of Biochemistry Research & Review. 2019; 26(3): 1-11.
38. Yapo ML. Amara MF. Tuo Y. Nutritional value of shea caterpillar (*Cirina butyspermii* Vuillet) sold at the market of Korhogo (Côte d’Ivoire). International Journal of Agronomy and Agricultural Research (IJAAR). 2017; 10(5):35-44.
39. Seronie S. Vivien M. Galteau M. Carlier M. Hadj A. “Dosage de la créatinémie en 2003: état des lieux analytique et essai de standardisation de l’étalonnage. Annales de Biologie Clinique. 2004 ; 62 : 165-175.
40. Lagrange M. Microangiopathies thrombotiques, une urgence diagnostique. Option/Bio. 2010. 21(446) : 16-17.
41. Pierre D. Etienne C. Nicolas M. Krzesinski JM. Christophe M. Cristol J-P. Laurence P. “Créatinine: d’hier à aujourd’hui,” Annale de Biologie Clinique. 2010 ; 68(5):531-543.
42. Johnson-Delaney CA. Exotic companion medicine handbook for veterinarians. 1996; 200 pages.
43. Pignel R. Bedouet A. Bilan biologique et biochimique (examens de laboratoire). Manuel de Formation Continue des Ostéopathes Professionnels (F.C.O.P.). France. 2008 ; 37p.
44. Balta S. Demirkol S. Aydogan M. Unlu M. Red cell distribution width is a predictor of mortality in patients undergoing coronary artery bypass surgery. European Journal of Cardio-Thoracic Surgery*.* 2013. 44(2):396–397.

**Table 2: Composition of dried Shea caterpillar and Fish powder**

|  |  |  |
| --- | --- | --- |
|  **Protein sources****Parameters** | **Shea caterpillar** | **Fish powder** |
| **Moisture (g/100gFM)** | 10 ± 0.10a | 07.87±0.11a  |
| **Dry Matter (g/100gDM)** | 90 ± 0.10a | 92.13± 0.11a |
| **Proteins (g/100gDM)** | 42.64 ± 0.26a | 46.32±0.03a  |
| **Fat (g/100gDM)** | 26.03 ± 0.50a | 10.33± 0.11b |
| **Ash (g/100gDM)** | 4.86 ± 0.28a | 25.95± 2.85b |
| **Carbohydrate (g/100gDM)** | 26.47 ± 0.15a | 09.53b |

FM : Fresh Material ; DM : Dry Material

Values are means±SE for three determinations.

a, b : On the same line, the means marked by the same letters are not significantly different (p ≤ 0.05) while those marked with different letters are significantly different from each other (p ≤ 0,05).

n : Number of rats per treatment.

**Table 3 : Consumption parameters**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Régimes |  |
| Parameters | DC | DFP | DSC |
|  | (n= 6) | (n=6) | (n=6) |
| DMI (g/j) | 8,49 ± 0,02a | 9,32 ± 0,02a | 7,81 ± 0,12b |
| TPI (g/j) | 0,84 ± 0,02a | 0,93 ± 0,02a | 0,79 ± 0,01b |

Values are means±SE for six determinations.

n : Number of rats per treatment.

a, b : On the same line, the means marked by the same letters are not significantly different (p ≤ 0.05) while those marked with different letters are significantly different from each other (p ≤ 0,05).

DC : Diet with casein as protein source ; DFP : Diet with fish powder as protein source ; DSC : Diet with Shea caterpillar as protein source ; DMI : Dry matter ingested ; TPI : Total Protein ingested.

##

**Figure 1: Growth of rats according to the kind of diet consumed**

DC : Diet with casein as protein source ; DFP : Diet with fish powder as protein source ; DSC : Diet with Shea caterpillar as protein source



**Figure 2 : Mean body weight gains of rats fed with the different diet**

a, b : On the same line, the means marked by the same letters are not significantly different (p ≤ 0.05) while those marked with different letters are significantly different from each other (p ≤ 0,05).

DC : Diet with casein as protein source ; DFP : Diet with fish powder as protein source ; DSC : Diet with Shea caterpillar as protein source

DSC

DFP

DC

**Table 4 : Feed Efficiency Ratio ; Protein Efficiency Ratio**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Diets  |  |
| Paramètres | DC | DFP | DSC |
|  | (n= 6) | (n=6) | (n=6) |
| FER (g/d) | 0.09 ± 0.02a | 0.16 ± 0.02a | 0.22 ± 0.12a |
| PER (g/d) | 0.94 ± 0.01a | 1.60 ± 0.02a | 1.62 ± 0.01a |

Values are means±SE for six determinations.

n : Number of rats per treatment

a, b : On the same line, the means marked by the same letters are not significantly different (p ≤ 0.05) while those marked with different letters are significantly different from each other (p ≤ 0,05).

DC : Diet with casein as protein source ; DFP : Diet with fish powder as protein source ; DSC : Diet with Shea caterpillar as protein source ; FER : Feed Efficiency Ratio ; PER : Protein Efficiency Ratio

**Table 5 : Blood parameters**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Régimes |  |
| Parameters | DC | DFP | DSC |
|  | (n= 6) | (n=6) | (n=6) |
| Total protein (g/l) | 42.07±3.64a | 43.02±2.84a | 43.13±3.60a |
| Uremia (g/l)Creatininemia (mg/l)  | 0.38±0.15a 0.82±0.18a   | 0.43±0.11a0.85±0.21a | 0.45±0.17a0.78±0.35a |

Values are means±SE for six determinations.

n : Number of rats per treatment.

a, b : On the same line, the means marked by the same letters are not significantly different (p ≤ 0.05) while those marked with different letters are significantly different from each other (p ≤ 0,05).

DC : Diet with casein as protein source ; DFP : Diet with fish powder as protein source ; DSC : Diet with Shea caterpillar as protein source ; DMI : Dry matter ingested ; TPI : Total Protein ingested.

**Table 6 : Mean value of blood cells of rats fed with the different diets formulated**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Diets |  |
|  | DC | DFP | DSC |
|  Blood Cells | (n=6) | (n=6) | (n=6) |
| RBC (106µL) | 5.93 ± 0.23a | 6.79 ± 0.30a | 5.67 ± 0.20a |
| Hemoglobin (g/dl) | 10,50 ± 0,37a | 13,03 ± 0,63b | 12,53 ± 0,63b |
| Hematocrit (%) | 28.97 ± 1.38a | 34.47 ± 2.32b | 34.37 ± 2.29b |
| MCV (fl) | 48.73 ± 0.95a | 50.80 ± 0.62a | 60.90 ± 1.75b |
| MCH (pg) | 36.37 ± 0.61a | 37.83 ± 0.59a | 36.50 ± 0.62a |
| MCHC (%) | 17.70 ± 0.27a | 19.23 ± 0.30a | 22.27 ± 0.99b |
| Leukocytes (103µL) | 4.10 ± 0.76a | 10.47 ± 2.29b | 7.80 ± 0.80a |
| Platelet (103µL) | 367.3 ± 42.35a | 648.3 ± 103b | 457.3 ± 43.68a |

Values are means±SE for six determinations.

n : Number of rats per treatment.

a, b : On the same line, the means marked by the same letters are not significantly different (p ≤ 0.05) while those marked with different letters are significantly different from each other (p ≤ 0,05).

DC : Diet with casein as protein source ; DFP : Diet with fish powder as protein source ; DSC : Diet with Shea caterpillar as protein source

RBC: Red Blood Cell ; MCV : Mean Cellular Volume ; MCH : Mean Cellular Hemoglobin ; MCHC : Mean Cellular Hemoglobin Concentration