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Nutritional value of shea caterpillar (*Cirina butyspermii* Vuillet) sold at the market of Korhogo (Côte d'Ivoire)

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Abstract

Cirina butirospermii caterpillar is much appreciated by the population of Korhogo. But this population is unaware of its nutritional value. Thus, a study was carried out in order to know the nutritional characteristics of this caterpillar. Analyzes were carried out using appropriate methods. So, the moisture and ash levels were determined using the AOAC method. Calcium was assayed using the colorimetric method of Gindler and King using blue of thymol. Sodium and potassium were determined by the flame photometry using Pinta technique. Total sugars were extracted according to Martinez *et al.* (2000) and assayed according to Dubois *et al.* (1956) using phenol and concentrated sulfuric acid. The crude proteins were assayed according to BIPEA (1976) using Kjeldhal. The energy value corresponding to the available energy is calculated using the specific coefficients of Atwater and Benedict (1902) for proteins, lipids and carbohydrates. *Cirina butyrospermii* flour included 55.41% of crude protein, 28.71% of fat and 4.89% of ash. Ash contained minerals such as calcium, sodium, potassium, iron, magnesium and zinc. The moisture content is 7.02%. Total sugar content of this flour was 3.07%. There were 17 amino acids, of which, lysine, glutamic acid, glycine, aspartic acid, valine and arginine were predominant. Fatty acid profile was also determined. Stearic acid (39.53%) and linolenic acid (23.89%) were the most abundant fatty acids. All these properties show that the caterpillar *Cirina butyrospermii* is a food of great nutritional value. These properties also make it possible to predict its use in the food and pharmaceutical fields.

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Introduction

Insect consumption is very widespread in tropical and subtropical regions of the world (Bodenheimer, 1951). It concerns nearly 2000 species of insects grouped in 14 orders and 105 different families (Malaisse, 2003). The main families consumed in Africa are Saturniidae, Notodontidae and Sphingidae (Malaisse *et al.*, 2003). Among these insects, caterpillars or grub of butterfly, are much consumed by populations in search of source of protein in replacement of the meat and fish. In Mexico, butterfly caterpillar that ravages the agave (*Hypopaganis*) is eaten fried, as a delicacy (Ruddle, 1973). In Laos, *Oryctes rhinoceros* grub is cooked in coconut milk for one hour before being roasted (Dama and Dufour, 1987). Since caterpillars consumption is a source of protein, it contributes to malnutrition because malnutrition is a serious public health problem that is common in developing countries (FAO, 2004). Indeed, according to FAO (2008) of 842 million people suffering from malnutrition, 798 million live in poor countries. Protein-energy malnutrition is at the forefront of nutrition disorders and is a serious challenge for food security (Desjardin-Requir, 1989).

In Côte d'Ivoire, about 5% of the population is affected by difficulties in accessing traditional animal proteins such as meat and fish (INS, 2008). Apart from these conventional food resources, other local, available and highly valued alternatives can be present such as: snail, winged termite and especially the caterpillar (N'gasse, 2003). These caterpillars have a very high and varied nutritional value (Latham, 2001). Because of their high nutritional value, caterpillars are mixed in some areas with cereal flour to combat child malnutrition (FAO, 2004). Many other species play an important role in traditional medicines as well as in Chinese cultures (Chen and Feng, 2002). For example *Cirina butyrospermii* is used for healing of the wound. The caterpillars also represent a good source of essential vitamin and fatty acids. Indeed, the daily consumption of 50g of dried caterpillars covers the human requirements for flavin and pantothenic acid as well as 30% of niacin needs. The nutritional value of the caterpillars also indicates that the latter contain essential fatty acids for man, in particular linoleic and linolenic acid (Malaisse, 1997).

In Côte d'Ivoire the caterpillars are also widely consumed. At the market of Korhogo, *Cirina butyrospermii* caterpillar is sold in large quantities. This caterpillar, like many edible insects, plays an important role in the food balance and the sale of which constitutes an income for the marginal populations (Ouedraogo, 1993; Unesco, 2004; N'Tema , 2000). However, its nutritional value remains unknown. The general objective of this study is to establish the nutritional potential of this dried caterpillar sold at the Korhogo market.

Material and methods

Biological material

The biological material is *Cirina butyrospermii* caterpillar. It was bought at the Korhogo market.

Grinding of caterpillars

Two (2) kg of caterpillars (*Cirina butyrospermii*) sold at the Korhogo market were sorted and cleared of all kinds of plant debris and stones. They were dried in the sun for a week. They were then placed in an oven at 65 ° C for 72 hours and then ground with a porcelain mortar to obtain the caterpillars flour.

Nutritional value of caterpillars's flour

The moisture and ash levels of caterpillars's flour were determined using the AOAC method (1995). Calcium was assayed using the colorimetric method of Gindler and King (1972) using blue of thymol. Sodium and potassium were determined by the flame photometry using Pinta technique (1954). Total sugars were extracted according to Martinez *et al.* (2001) and assayed according to Dubois *et al.* (1956) using phenol and concentrated sulfuric acid. The crude proteins were assayed according to BIPEA (1976) using Kjeldhal. The energy value corresponding to the available energy is calculated using the specific coefficients of Atwater and Benedict (1902) for proteins, lipids and carbohydrates.

Amino acid composition

Total amino acid composition of samples was determined after hydrolysis in 6 M HCl with phenol (1 %) at 150 °C for 60 min, in Pico-Tag system (Waters, Milford, Mass., U.S.A.). The phenylisothiocyanate (PITC®) amino acid derivatives were eluted on HPLC Applied Biosystems Model 172 A (Applera Corp, Foster City, Calif., U.S.A.) equipped with a PTC RP-18 column (2.1 mm × 22 cm). Sodium acetate (45 mM, pH 5.9) and sodium acetate (105 mM, pH4.6; 30 %), and acetonitrile (70 %) were used as buffers.

Extraction and estimation of the fat content and fatty acids analysing

The fat of the caterpillars's flour was extracted according to AFNOR (1991) method using the soxhlet. The extraction yield corresponds to the fat content per 100 g of caterpillars's flour. Fatty acids were analyzed according to Legrand *et al.* (2010) by using a gas chromatograph (WATERS Agilent, model HP 6890N) coupled by mass spectrometer (Quattro micro GC, MICROMASS), with a split injector (1:10) at 250°C, a bonded silica capillary column (30 m x 0.25 mm x 0.25 µm, model DB5-MS) and nonpolar stationary phase of 5% phenyl 95% methylpolysiloxane. Helium was used as the carrier gas (a constant velocity of 1.0 ml/min). The column temperature program started at 150°C, was firstly ramped at 1.3°C/min to 220°C, then from 220°C to 260°C at 40°C/min and held at 260°C for 5 min. Triplicate determinations were carried out in each case.

Results and discussion

Proximate and minerals composition of Cirina butyrospermii flour

The chemical analysis of the caterpillar gave a moisture content of 7.92% ± 0.02 and a fat content of 28.71% ± 0.32. This caterpillar consists of 55.41% ± 0.03 of crude protein, 4.89% ± 0.03 of ash, 3.07% ± 0.04 of sugars and 2.68% ± 0.01 of fiber. The levels of calcium, sodium, potassium, magnesium, zinc, and iron are 70.02 ± 0.12 mg/kg; 22.40 ± 0.09 mg/kg; 17.7 ± 0.41 mg /kg; 11.99 ± 0.07 mg/kg; 183.01 ± 0.01 mg/kg; 28.15 ± 0.23 mg/kg respectively. The results of the biochemical analysis are shown in Table 1 and 2. *Cirina butyrospermii* caterpillar's flour is an important source of protein (55.41% ± 0.03), fat (28.71% ± 0.32) and minerals. This animal is an important source of protein because its protein content is very high.

Table 1. Proximate composition of *Cirina butyrospermi* caterpillar flour (%).

Parameters	*Composition*
Dry matter (%)	28.71±0.32
Crude Protein (%)	55.41±0.03
Moisture (%)	7.92±0.02
Ash (%)	4.89±0.03
Sugar (%)	3.07±0.04
Fibre (%)	2.68±0.01
Energy (Kcal/100g)	492.31±0.76

Mean ± standard deviation of three determinations.

This result is in line with that of FAO (2004), which noted a high protein content in caterpillars, thus promoting their incorporation into protein-poor meals to combat children malnutrition. The essential function of a dietary protein is to satisfy the body's requirements for nitrogen and essential amino acids (OMS, 1985).

However, this amount of dried *Cirina butyrospermii* caterpillar protein (55.41% ± 0.03) is similar to that obtained by Amon *et al.* (2009) on *Imbrasia oyemensis* (55.77%) and Xiaoming *et al.* (2010) with edibles Lepidoptera. It is equivalent to that of salted dried beef (55.4%) and is higher than that of dried fish (47%) (Anonymous, 2004).

The value of the proteins obtained in our study is lower than those of 63% and 62.74% respectively observed by Ouedrago (1993) and by Anvo *et al.* (2016) on *Cirina Butyrospermii* in Burkina Faso. The protein content in *Cirina butyrospermii* is higher than the 20.2%, 48.70% and 52.39% values obtained respectively by Banjo *et al.* (2006), Ogunleye & Omotoso (2005) and Badanaro *et al.* (2014) on *Cirina forda*. Variation in the biochemical composition of insects may be due to the host tree because the amount of protein varies between insect species and within the same species depending on the nutritional quality of the leaves of the host tree (Banjo *et al.*, 2006).

Table 2. Minerals composition of *Cirina butyrospermi* caterpillar flour (mg/kg).

Minerals	Composition
Fe (mg/kg)	28.15±0.23
K (mg/kg)	17.70±0.41
Mg (mg/kg)	11.99±0.07
Na (Mg/kg)	22.40±0.09
Ca (mg/kg)	70.02±0.12
Zn (mg/kg)	183.01± 0.01

Mean ± standard deviation of three determinations.

The ashes resulting from the incineration of caterpillar's flour have made it possible to quantify certain mineral substances (calcium, sodium magnesium, iron, zinc and potassium) essential to the organism. These levels confirm that the caterpillars provide the populations that consume them with a sufficient quantity of mineral salts. Calcium, sodium and potassium interact in the body by fortifying the bones of adults, acting as a bioactivator and osmotic balance in cellular metabolism. They also promote the growth of children (Schapira, 1981).

Table 3. Amino acid composition of *Cirina Butyrospermi* caterpillar flour (g/100g Protein).

Amino acid	Composition
Methionine*	0.69±0.06
Isoleucine*	2.64±0.05
Threonine*	3.70±0.04
Valine*	4.34±0.06
Lysine*	5.25±0.03
Histidine*	2.56±0.04
Tyrosine*	3.01±0.06
Phenylalanine*	2.32±0.04
Leucine*	2.74±0.07
Glutamic acid	7.20±0.10
Glycine	5.10±0.01
Cysteine	0.30±0.03
Proline	2.94±0.02
Alanine	3.24±0.08
Aspartic acid	4.54±0.03
Serine	2.21±0.04
Arginine	6.74±0.05
Total essential amino acid (TEAA)	27.25
Total non-essential amino acid (TNEAA)	32.27
Total amino acid (TAA)	59.52
Ratio of TEAA/TNEAA	0.84
Ratio of TEAA/TAA	0.46

*Essential amino acid

Mean ± standard deviation of three determinations.

The minerals are represented by, among others, calcium at 70.02 ± 0.12 mg/kg and 11.99 ± 0.07 mg/kg for magnesium. Compared to the EFSA (2015a, 2015b) reference nutritional values recommended for adults at 10 mg/kg/day for calcium and 5-7 mg/kg/day for magnesium, *Cirina butyrospermii* could provide on nutritional plan a sufficient amount of minerals to the body. Indeed, magnesium is a cofactor participating in more than 300 enzyme reactions, making it an essential element for the synthesis of carbohydrates, lipids, nucleic acids and proteins as well as for other actions in different organs of the cardiovascular and neuromuscular systems (Chen and Feng, 2002, EFSA 2015a). Calcium enters bone formation, helps maintain acid-base balance in the body and promotes control of energy metabolism (FAO/OMS, 1993; Osasona and Olaofe, 2010). Calcium is an integral component of the skeleton, about 99% of total body calcium is found in bones and teeth, where it plays a structural role.

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*Essential amino acid

Mean ± standard deviation of three determinations.

The remaining 1% exerts vascular, neuromuscular and endocrine functions in cells and tissues (EFSA, 2015b). Moreover, this flour contains iron, this trace element, of 28.15 ± 0.23 mg/kg, less quantitatively important than that obtained on *Imbrasia truncata* by Mabossy-Mobouna *et al.* (2013) with 81mg/100gMS but 2.6 times higher than the level obtained by Banjo *et al.* (2006) on *Macrotermes bellicosus* and 2.17 times higher than that obtained by Anvo *et al.* (2016) on *Cirina butyrospermii*. This quantity would respect the iron content recommended by EFSA (2015b) and FAO (2004) which is 9 to 20 mg/kg/day. Iron is an indispensable element in the functioning of cells and is a fundamental constituent of red blood cells. Its deficiency is frequent worldwide, especially among pregnant women and anemic persons (OMS, 1985). Its lack can be easily compensated by certain species of insects such as *Cirina butyrospermii* which are richly provided (FAO, 2004). The flour of this caterpillar can therefore supply the populations which consume a sufficient quantity of minerals. We note that *Cirina butyrospermii* has low moisture content (7.92%).

Table 4. Fatty acid composition of oil extracted from *Cirina butyrospermi* caterpillar.

Fatty acids	Composition
Lauric acid (C12: 0)	1.23±0,02
Myristic acid (C14: 0)	1.45±0.01
Palmitic acid (C16 : 0)	12.05±0.06
Stearic acid (C18: 0)	39.53±0.52
Oleic acid (C18: 1n9)	0.72±0.22
Linoleic acid (C18: 2n6)	6.03±0.02
Linolenic acid (C18: 3n3)	23.89±0.03
Gadoleic acid (C20: 1n9)	0.19±0.35
Total Saturated fatty acids	54.26%
Total unsaturated fatty acids	30.83%
Total Monounsaturated fatty acids	0.91%
Total Polyunsaturated fatty acids	29.92%

Mean ± standard deviation of three determinations.

This value is close to those found by Niaba *et al.* (2011) with 8%, Mabossy-Mobouna *et al.* (2013) with 7.3% and by Foua Bi *et al.* (2015) with 7.19%. This low moisture content allows, on the one hand, good physical preservation of the caterpillars, thus avoiding their rotting and disintegration (Mabossy-Mobouna *et al.*, 2013). On the other hand, this moisture preserves qualitatively most of the nutrients present in these caterpillars because they are easily consumed and exported to other regions and to Europe throughout the year (Hoare, 2007, Muvundja *et al.*, 2012). The moisture content of 7.92% obtained in *Cirina butyrospermii* is low but it is higher than that obtained by Anvo *et al.* (2016) in the same specie (4.34%) and superior to the value of 5.40% observed by Paiko *et al.* (2014) for the grub of *C. forda*. This difference could be attributed to the drying method (sun-drying or oven-drying). Indeed, the caterpillars are harvested in the rainy season when the sun is not always available.

Like this, sun-drying could slow the drying and also change the nutritional quality of the caterpillars (Anvo *et al.*, 2016). Note also that the sugar content of this caterpillar is low. The low sugar content (3.07% ± 0.04) is also an asset for its consumption in order to avoid metabolic diseases related to the variation in blood sugar (diabetes mellitus, tooth decay). The fat of the caterpillar *Cirina butyrospermii* could be used in the manufacture of soap such as certain animal fatty substances such as herring fat (FAO, 1975; Riziki, 2011). The amount of energy of food depends on its lipid, protein and carbohydrate contents. The energy calculated for this caterpillar is 492.31±0.76 Kcal/100g. By comparing the energy value of *Cirina butyrospermii* flour (492.31±0.76 Kcal /100g) with those of Anvo *et al.* (2016) on this same specie (432Kcal), Mabossy-Mobouna *et al.* (2013) on *Imbrasia truncata* (433Kcal), Amon *et al.* (2009) and Foua Bi *et al.* (2015) on *Imbrasia oyemensis* (470Kcal) and (476.96Kcal) respectively, it turns out that *Cirina butyrospermii* is more energetic against the caterpillars quoted.

Our result is more important than that obtained by the authors quoted. Moreover, this value of 492.31±0.76 kcal is high than that of beef (273 Kcal) and fish (269 Kcal) obtained by Anonymous (2004). This energy can be used by the body for its daily needs. It is also noted that this value is higher than that of *Burina aurantiaca* (433 Kcal) and *Cirina forda* (375 Kcal) found by Agbidye *et al.* (2009) and that of *Cirina forda* (387 Kcal) observed by Paiko *et al.* (2014). However, this rate is in line with that of FAO (2004) (413 Kcal), which noted a high energy content in feeding caterpillar flours, thus encouraging their incorporation into infant flours.

Amino acid composition of Cirina butyrospermi caterpillar flour

The amino acid profile of this caterpillar is shown in table 3. Among the amino acids, 17 were determined, and the most predominant ones were lysine, glutamic acid, glycine, aspartic acid, valine and arginine. This was in agreement with those reported by Li *et al.* (1995), Gbogouri *et al.* (2013) and Apkossan *et al.* (2014). The results presented suggest that the caterpillar (*Cirina butyrospermii)* is rich in essential amino acids. The ratio of essential amino acids to total amino acids was 0.84.

The quality of a food protein depends largely on its amino acid content. The cells, in making their own protein, need a full array of amino acids from food. Cells can synthesize non-essential amino acids when they are unavailable from food, but essential amino acids can only be obtained from foods (Sizer and Whitney, 2000). The high scores of essential amino acids present in this insect implied that it has a high biological protein value.

Fatty acid composition of Cirina butyrospermii flour

Fatty acid composition of *Cirina butyrospermii* fat is shown in Table 4. The fatty acid profile has 8 fatty acids. Stearic acid and linolenic acid have the highest content (39.53% and 23.89%). The polyunsaturated fatty acids are represented by linoleic acid and linolenic acid with respective contents of 6.03% and 23.89%. The overall content of saturated fatty acids is higher (54.26%).

This fat contains 30.83% unsaturated fatty acids including 0.91% monounsaturated fatty acid and 29.92% polyunsaturated fatty acid. In this work, linolenic acid (23.89%) which is essential fatty acid, stearic acid (39.53%) and palmitic acid (12.05%) were the most abundant fatty acids. This result is in agreement with that of Anvo *et al.* (2016).While, the predominant fatty acids for *Cirina forda* were linolenic acid (45.5%), stearic acid (16.0%) and oleic acid (13.6%) (Akinnawo and Ketiku, 2000) Concerning *Imbrasia oyemensis* which also belongs to the Lepidoptera order, oleic acid (40.28%), stearic acid (38.53%) and palmitic acid (10.05%) were the most abundant fatty acids (Foua Bi *et al.*, 2015).

Conclusion

Cirina butyrospermii is a food of great nutritional value because it contains an important protein source and other properties. All these properties make it possible to predict its use in the food and pharmaceutical fields. This animal is an important source of essential nutrients entering into the proper functioning of the human organism.

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