



Effect of Cooking Methods on the Nutritive Value and Lipid Oxidation of Two Cricket Species Consumed In Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NT and RP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NT, BT, AM and LAM managed the analysis of the study. Authors NT and AM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present study was performed in order to evaluate the effect cooking on the proximate composition and lipid oxidation of two cricket species (*Hieroglyphus daganensis* and *Paracinema tricolor*) commonly consumed in Cameroon.

Study Design: *Paracinema tricolor* and *Hieroglyphus daganensis* harvesting, cleaning, killing, cooking and drying, evaluation the effect cooking treatment on the nutritive value and lipid oxidation of these crickets species.

Place and Duration Study: University of Maroua, Cameroon and University of Yaounde I in Cameroon from November 2018 to July 2019.

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Methodology: The two types of crickets after harvesting and transporting to the laboratory, were killed by freezing at -20°C for 24 hours. Common cooking methods (pan roasting and pan frying) were used to cook it. The raw, roasted and fried crickets were left at ambient temperature and then one part was transformed into powder using an electric grinder. Before analysis, the powders and the whole samples were stored at 4°C. The ash, lipid, protein, carbohydrates and crude fiber content were determined in powder samples. The oil was extracted from whole samples of raw, roasted and fried insects. Various chemical parameter (acid value, peroxide value, iodine value and thiobarbituric acid) were used to assess crickets' lipid qualities during the cooking methods.

Results: The proximate analysis of raw samples revealed that the ash content of *Paracinema tricolor* and *Hieroglyphus daganensis* was 3.17% and 3.49% (% of dry weight) respectively. The lipid content was generally high ranging from 15.80% to 18.10% and the protein content ranged from 41.69% to 48.59%. The raw *Paracinema tricolor* compared to *Hieroglyphus daganensis* was found to have the higher contents of lipid, protein and energy. All the cooking methods increased the lipid, protein and ash contents, as well as the calorie values of the two cricket's species, while the moisture content was reduced. The free fatty acids and thiobarbituric acid reactive substances (TBARS) values of the two crickets' oil were significantly increased after roasting and frying processing. Iodine value decreased.

Conclusion: From these results, it can be concluded that soaking combined with frying method appeared to be the best cooking method in the two species of crickets in terms of caloric content and lipid oxidative stability.

Keywords: *Crickets; Hieroglyphus daganensis; Paracinema tricolor; proximate composition; roasting; frying; lipid oxidation.*

1. INTRODUCTION

The world's population and that of developing countries in particular nowadays is facing a major problem which is that of food insecurity. These populations do not have access to adequate food in terms of quality and quantity which is the origin of a serious nutritional problem also called malnutrition [1]. Malnutrition is taking its toll worldwide with about 815 million people affected. Africa is severely affected by this scourge with 243 million people affected [2]. Cameroon, a country located in the centre of Africa is witnessing a critical situation with around 32% of severe malnutrition and 13% acutely [3]. The Far North region presents an emergency situation in terms of severe acute malnutrition with a prevalence of 2%. The major causes of this scourge are among others: unavailable resources, poverty, ignorance, rapid population growth, and inappropriate nutritional practices. Globally, the impact of malnutrition is not related to inadequate consumption of calories but the lack of various nutrient intakes. This affects largely the quality of life. Malnutrition has disastrous consequences such as: anaemia, vitamin deficiency, and child death [4].

In Cameroon and particularly in the northern site, the food intake of proteins, lipids, and minerals of best quality is limited due to rapid growth of population, low productivity to the level that

satisfies food demand, cultural and religious factors. They are also due to the high cost of meat and fish [5].

In order to solve this problem, the United Nation and the state of Cameroon have reinforced the feeding of children with micronutrients and food supplements. Food and Agriculture Organization on its part, promote the popularisation and the consumption of local resources [6]. The use of insects by the population may be an alternative to limit the problem of food insecurity. Mainly in developing countries, about 1.900 species of insects are consumed by about 2 billion of the population [7]. In Africa and Cameroon in particular, several species of edible insects have been reported. The most abundant ones include termites, crickets, larvae of *Rhynchophorus phoenicis* F., caterpillars, crabs, locusts, consumed by the rural, and urban population. They can serve as an important nutrients source [8].

With a very high growth rate, a short reproductive cycle and a high reproductive potential, insects have a high nutritional value, which is close to that of meat and fish. In fact, the protein content of chicken does not usually exceed 23%, beef 18%, shrimp 24% and pork 17%. Grasshoppers on the other hand, have a protein content which ranges between 50% to 75% and termites 35%. Certain amino acids such as threonine and lysine

are generally present in small quantities in cereals but abundant in insects. The edible insects' proteins are of good quality and easily digestible [9]. Proteins are sources of important nutrients that play an important role in human metabolism and biological functions. Yeng et al. [10] have shown that edible insects are a considerable source of fat. Their lipids are rich in n-3 polyunsaturated fatty acids such as linolenic acid (C18:3n-3), eicosapentaenoic acid (EPA, C20:5n-3), and docosahexaenoic acid (DHA, C22:6n-3). The fatty acid composition of edible insects varies between species and within the same species. The unsaturated fatty acids play an important role in the prevention of coronary diseases, hypertension, diabetes and cardiovascular diseases in humans [11]. Edible insects are found to be a rich source of important minerals especially potassium, calcium, iron, magnesium, and selenium. The iron and calcium content of insects is higher compared to those of beef, chicken and pork [12]. In addition, insects are also a source of vitamins mainly; vitamin A, E and C [13].

Edible insects, therefore constitute an important potential in the fight against malnutrition worldwide but are still neglected or even ignored. Rumpold et al. [13] reported that the proximate composition of insects varies between species and within the same species. This may be due to environmental conditions, geographical location, feeding habits, and the development stages of the insects.

In Cameroon particularly in the Far North Region, there is an important and multitude type of edible insects at one time of the year, these include *H. daganensis* and *P. tricolor*. These edible crickets are accessible even by the poorest. They are rarely eaten raw but are usually cooked in different ways before consumption. These treatments can affect the nutritional value of insects.

Several studies have reported the nutritive value and effect of processing on the proximate composition and lipid oxidation of some edible insects in some countries. These included: nutritional composition of six edible insects in Java [14], nutritional quality and anti-nutrient composition of two edible grasshoppers (*Orthoptera: acrididae*)- A search for new food alternative [15], fatty acids and proximate composition of eight Thai edible terricolous insects [16], preliminary proximate composition and mineral content of five edible insects from

Cameroon [8], nutritional value and effect of cooking, drying, and storage process on some functional properties of *Rhynchophorus phoenicis* consumed in Cameroon [17] and change that occurred in the lipid quality of *Rhynchophorus phoenicis* during cooking and storage [18].

Though considerable attention has been given to the study of insects. There is very limited information on the proximate composition and effect of cooking on lipid oxidation of cricket varieties consumed in Cameroon. Therefore, the aim of this study was to investigate the effect of cooking on the proximate composition and lipid oxidation of two cricket varieties (*Hieroglyphus daganensis* and *Paracinema tricolor*) present and consumed in Far-North Cameroon.

2. MATERIALS AND METHODS

2.1 Materials and Study Site

The two cricket species presented in Fig. 1 were chosen for this study. They are the most commonly consumed insects by the rural population in Far-North Cameroon. These two life species of crickets (*Paracinema tricolor* and *Hieroglyphus daganensis*: about 900 for each specie) were captured from nature in November 2018 at Doubaye (Far North Cameroon). This area is located between latitude 10 and 13° North and between longitude 13 and 16° East [19]. After collection, they were immediately transported firstly, to the Laboratory of Animal Biology and morphological features where species were identified. After that, they were transferred to the Laboratory of Food biochemistry. On arrival at the Laboratory, only life crickets were selected for the study. The two cricket species were killed by freezing at -20°C for 24 hours according to the method described by Adedire and Aiyesanmi [20]. After thawing at room temperature, common cooking methods were used. The crickets were divided into three batches. The first batch was used as a control sample; the second and the third batches were respectively used for pan roasting and pan-frying process.

2.2 Chemical Reagents

Potassium hydroxide, bicarbonate of sodium, starch, chlorhydric acid 35% and sulfuric acid 98% were purchased from SD-fine Chemicals limited (Ahmedabad, India). Acetic acid, thiobarbituric acid, carbone tetrachloride, sodium

thiosulfate, ethanol 95°, hexane, Wijs reactive, phenolphthalein, chloroform, and ethanol, were procured from HiMedia Laboratories Pvt. Ltd (Mumbai, India). All reagents used in the analysis were of laboratory grade.

2.3 Cooking Methods

2.3.1 Roasting procedure

For the roasting process, four hundred grams of crickets were pan-roasted on an electric cooker for 25 minutes. The roasting temperature was around 130 °C. The crickets during pan-roasting were turned over from time to time to ensure homogenous cooking.

2.3.2 Frying procedure

The crickets used for pan-frying were in three types: bleached, soaked in Na₂CO₃ (0.5%) for 5 minutes and raw crickets. The treatments represent and imitate the common local cooking practices. Approximately 400 g of cricket samples were fried at 25 min in 140 cm diameter stainless pan frying with 30 mL of cooking oil. Frying temperature was around 125-145°C. Each treatment was performed in triplicate.

Samples of raw crickets were homogenized and used as untreated control crickets. The raw, roasted and fried crickets were left at ambient temperature, and then one part was rendered powder using an electric grinder (Panasonic, Kyoto, Japan). Before analysis, the powders and the whole samples were stored at 4 °C.

2.4 Lipid Extraction

After processing, the oil was extracted from the raw, roasted and fried insects' samples according to the method described by Bligh and Dyer [21]. The extracted oil was stored at 4 °C for further analysis.

2.5 Analytical Methods

2.5.1 Digested according

Moisture, ash, lipid, protein, carbohydrate and crude fibre in the raw, roasted and fried cricket samples were determined using standard analytical methods described by AOAC [22]. Moisture content was determined by drying the raw cricket samples in the oven at 103 °C until a constant weight was achieved according to the

AOAC procedures 925.40 [22]. Ash content was determined by the incineration of raw cricket samples at 550 °C according to the AOAC procedures 942.05 [22]. Lipid content was determined using Soxhlet apparatus with hexane, following AOAC 963.15 methodology [22]. Nitrogen (N) content was determined using micro-Kjeldahl method, according to AOAC procedures 984.13 [22], the protein content was calculated as N x 6.25. The carbohydrate content was calculated by difference. Crude fibre was determined using a fibre digester according to the AOAC procedures 973.18 [22]. The energy content was calculated using Atwater method [23]. All samples were analysed in triplicate.

2.5.2 Effect of cooking on lipid quality of crickets'

2.5.2.1 Measurement of free fatty acids

Free fatty acids (FFA) content was determined according to the method of AFNOR [24]. The insect oil sample (1g) was dissolved in 100 mL of ethanol and some drops of phenolphthalein were added as an indicator and swirled vigorously. The mixture was then titrated with potassium hydroxide (0.1 N). The FFA was expressed as % oleic acid.

2.5.2.2 Measurement of Iodine value

The iodine value (IV) in the cricket oil samples was determined using the Wijs method as described by O'Keefe and Pike [25]. The IV was expressed as a gram of iodine absorbed per 100 g sample (g I₂/100 g).

2.5.2.3 Measurement of peroxide value

Peroxide value (PV) was determined according to the method described by AFNOR [24]. The lipid sample (1 g) was treated with a 25 mL mixture of organic solvent (chloroform: acetic acid, 2:3). It was then shaken vigorously followed by the addition of 1 mL of saturated potassium iodide solution. The mixture was kept in the dark for 5 min. 75 mL of distilled water was added and the mixture was shaken. In the mixture, 0.5 mL of starch solution (1%, w/v) was added as an indicator. The peroxide value was determined by titrating the iodine liberated from potassium iodide with standardized 0.01 N sodium thiosulfate solution. The PV was expressed in milliequivalents of O₂/kg of lipid. These determinations were performed in triplicate.



Fig. 1. *Paracinema tricolor* (a) and *Hieroglyphus daganensis* (b)

2.5.2.4 Measurement of Thiobarbituric Acid Reactive Substance (TBARS)

The secondary oxidation products were evaluated using the thiobarbituric acid reactive substance method as described by Dapper and Hadley [26]. The results were expressed as mg of malondialdehyde (MDA) per kg of sample.

2.6 Statistical Analysis

Data were analysed by a one-way analysis of variance (ANOVA) and comparison was made between species and treatments. The statistical treatment was performed at a 5% significance level using the Statistical Package of Social Science (SPSS 16.0 version).

3. RESULTS AND DISCUSSION

3.1 Effect of Cooking On Proximate Composition of Cricket Species

The proximate compositions of raw, roasted and fried crickets are presented in Table 1. The results indicated significant ($P < 0.05$) variations in nutrients quantity of the two cricket species. *H. daganensis* contain 52.20% of moisture, 3.49% of ash, 15.80% of lipid, 41.69% of protein, 17.54% of crude fibre and 18.00% of carbohydrate. Lipid and protein content of *Parcinema tricolor* were significantly ($P < 0.05$) higher than those of *H. daganensis*, but the carbohydrate content was less than that noted for *H. daganensis*. Moisture, ash and crude fibre contents of *Parcinema tricolor* were not significantly ($P > 0.05$) different from those of *H. daganensis*. The energy value of raw *H. daganensis* was 381.1 Kcal, lower than that for *Parcinema tricolor* (405.3 Kcal). The results of this study confirm the findings of Kuntadi et al. [14] suggesting that the nutritive value of insects

varies greatly among species. The moisture contents obtained in this study are similar to those noted by Yahia [27] in Algeria (53.21-58.7%) for other species of crickets (*Acrotylus patruelis*).

The ash content of the two species of crickets obtained in this study is higher than that noted by Loh et al. [8] in five edibles insects consumed in Cameroon. This gives an indication in the mineral content of insects. These crickets could be a high source of minerals.

The lipid contents observed in the current study in the two raw cricket species were higher compared to the value obtained by Womeni et al. [28] in *Zonocerus variegates*, but remain lower than the value obtained by Akullo et al. [29] in Northern Uganda in termite (*Macrotermes bellicosus*: 44.88%) and Womeni et al. [28] in *R. Phoénicis* (25.30%). These lipid contents obtained in this study are in accordance with the findings of Finke [30,31] who obtained in *Adult Acheta domesticus* the values of 18.55-22.80%. The lipid content of raw *H. daganensis* and *P. tricolor* were higher than those of Mackerel fish (11.14%; [14]), and chicken (1.5%; [32]). When compared to beef or fish, these insects had higher lipid contents and are therefore a good source of energy. The second large nutritional component found in insect after protein is lipid. Lipids are important for humans because they can act as an energy producer, and also provides essential fatty acids and fat-soluble vitamins [33]. Some studies mentioned that edible insects are mostly dominated by polyunsaturated fatty acids (PUFAs), but others showed that monounsaturated fatty acids (MUFAs) are the most important fatty acids present in insects. So, the edible insects can be considered as a healthy food in relation to their fatty acid composition [34].

The higher protein content in *Parcinema tricolor* compared to *H. daganensis* may be due to their diets [35]. The protein content of *H. daganensis* was similar to that of *Macrotermes bellicosus* (40.12%) mentioned by Akullo et al. [29]. The values obtained in this study are higher compared to protein content of chicken eggs (12.6%), beef (22.3%) (Stadlmayr et al. [32]), *R. Phoenicis* larvae (Coleoptera; 30.3%), and *R. Phoenicis* adult weevil (Coleoptera; 32.72%) [36].

The consumption of these species of crickets may help to prevent deficiency of protein in the diet of consumers in developing countries.

The value of crude fibre presented in this work is higher compared to those of five edible insects consumed in Cameroon (2.10-5.60%; [8]), but still lower than the value obtained by Bednářová et al. [37] from the other types of crickets (27%). The high crude fibre content present in *H. daganensis* and *P. tricolor* indicate that their consumption may help to prevent the appearance of non-communicable diseases and greatly enhance digestion [38].

The carbohydrate contents of the two crickets were higher than those obtained by Loh et al. [8] (5-8.54%) from five insects consumed in Cameroon. However, these values are in line with those noted by Yahia [27] on female *Acrotylus patruelis* and *Cetonia p.* (9.80-33.3%). The carbohydrate contents noted in this study are similar to those reported by Ajakaiye and Bawo [39] on termites (19.47%).

The variation of the chemical composition of raw crickets may be due to the environment, the type of diet, sex, the degree of maturation, and species [31].

The results presented in Table 1 also indicated a significant ($P < 0.005$) change in the proximate composition of the two cricket species during cooking. After roasting and frying, the moisture content of all cricket samples decreased significantly ($P < 0.05$). The roasted crickets of the two species gave the highest moisture content compared to others cooked samples. In the case of *H. daganensis* except for roasted samples, the values of all the fried samples were not significantly ($P > 0.05$) different. The decrease of moisture content that occurred during the cooking process is a result of water loss. However, dehydration during roasting was lower than during frying. This explains the results obtained in this study concerning moisture

content. The ash content in all the treatments except frying, in the case of *P. tricolor*, increased significantly ($P < 0.05$) and roasted samples in the two cases, soaked + fried samples in the case of *P. tricolor* presented a high ash content. Roasted *H. daganensis* compared to roasted *P. tricolor* had the higher ash content. The ash content of fried, soaked + fried and bleached + fried samples in the case of *H. daganensis* were similar statistically ($P > 0.05$). In the case of *P. tricolor* raw, fried and bleached + fried samples presented similar ash content. An increase in ash content during processing is in agreement with the study of Yahia [27] who observed it in some cricket species during roasting and frying. The high ash content of cooked crickets proved that these samples were rich in minerals and it is recognized to play important metabolic and physiological roles in the living system [40]. The data showed that the lipid content of the two cooked samples ranged between 15.80 and 26.28% with significant variation in content between individual treatments. In the case of *H. daganensis*, the raw sample was found to have the lower lipid content while the bleached + fried sample presented the highest lipid content. The fried and soaked + fried samples in the case of *P. Tricolor* provided the highest lipid content. The significant increase ($P < 0.05$) in lipid content during processing can be due to the water loss during processing. The variation in the lipid content during treatment may be due to the processing method applied. The increase in lipid content in fried samples compared to roasted samples may be linked to the oil absorption during processing. The lipids in the diet are very important because the increase the palatability of food by absorbing and retaining their flavour. They are also the main form in which energy is stored in insect [10].

There was a significant difference ($P < 0.05$) in protein content between raw and cooked cricket samples. The protein content ranged from 41.69 to 55.64%. The highest protein content in the two cases were found in soaked + fried and roasted samples. So, the consumption of these samples may help to prevent malnutrition due to protein deficiencies.

The soaked + fried and roasted *P. tricolor* presented the highest protein content compared to all samples. The increase in protein content during processing is attributed to dehydration which occurred during processing. After processing, it was observed that the carbohydrate contents of cricket samples

decreased when compared with raw samples. In the case of *H. daganensis*, the lowest carbohydrate content was found in soaked + fried and bleached + fried samples while in *P. tricolor* the lowest value of carbohydrate was found in soaked + fried samples. The roasted *H. daganensis* had the higher carbohydrate content compared to that of roasted *P. tricolor*. The decrease in carbohydrate content implies that the bioavailability of carbohydrate molecules in crickets decreases during processing due to the Maillard reaction [41]. From the results obtained, there was a significant difference ($P < 0.05$) in the crude fibre of the cricket species analysed. When compared to the control (untreated samples), the crude fibre decreased with processing and roasted crickets were found to have the lowest crude fibre content (10.45% and 10.79% respectively in *H. daganensis* and *P. tricolor*). The fried sample in the two species had the highest crude fibre (~14%). Balogun and Fetuga [42] mentioned that low crude fibre in food is nutritionally appreciable because it traps fewer proteins and carbohydrates. As shown in Table 1, the energy value of the two crickets species analysed varies. When compared to the control, the calorific value (energy value) increased with treatment. The lowest calorific values were recorded for the control in the two cases. The fried sample in the case of *H. daganensis* had the highest calories (496.63 Kcal/100g), while soaked + fried in the case of *P. tricolor* was found to present the highest calories (463.02Kcal/100g). In the case of *H. daganensis*, roasted samples had the lowest calorific value while fried samples in the case *P. tricolor* showed the lowest calorific value. The roasted *P. tricolor* compared to the roasted *H. daganensis* showed a high energy value. The increase in energy values during processing is linked to dehydration occurring during the treatments which concentrate the nutrients content and thereby increases their availability.

3.2 Effect of Cooking On Lipid Quality of Crickets Species

3.2.1 Effect on Free Fatty Acid (FFA)

To have information about the amount of free fatty acids released from triglycerides and phospholipids present in oil or fat, the acid test was used. This test is an indicator of lipid rancidity. They may contribute directly to rancidity or generated subsequent oxidation compounds. The free fatty acids of untreated and cooked cricket species are presented in Table 2.

As shown in this Table, the raw samples had the lowest FFA values (~1.27% oleic acid). These values are not statistically ($P > 0.05$) different. The results of FFA of the two cricket species are lower than those of *Oryctes owariensis* larvae oil study (1.87% oleic acid) in Cote D'Ivoire [43]. These observations may be linked to the insect species. FFA content of crickets increased significantly ($P < 0.05$) during processing. The highest increase in FFA of oil samples was seen in fried samples (7.4 and 5.32% oleic acid respectively in *H. daganensis* and *P. tricolor* oil). Within the processing samples, bleached + fried and roasted *P. tricolor* presented a similar and the lowest FFA content (~ 2.35% oleic acid). In the case of *H. daganensis*, the lowest FFA was found in bleached + fried samples (4.43% oleic acid). In each cooking treatment, *H. daganensis* presented a higher FFA content compared to *P. tricolor*. The increase in FFA during processing is linked to heat. Heat is a factor that activates the cleavage of triglycerides and phospholipids present in food. FFA may be promoted by the reaction of oil with moisture. Previous studies have shown that FFA increases with heat treatment in many food and food products [44-45]. The acceptable limit for FFA in oil is reported to be 3.52-4% oleic acid [46]. Our results show that with *P. tricolor*, this limit was not exceeded after different cooking process except fried samples. However, with *H. daganensis*, the FFA of fried, soaked + fried and roasted samples exceeded the recommended acid value.

3.2.2 Effect on Iodine Value (IV)

The iodine value measurement is the test commonly used to quantify the amount of double bonds present in oil and fat. It is an indication of the lipid's potential to be oxidized. Iodine values of lipid help to predict lipid stability. The changes in IV of crickets during processing are shown in Table 2. As observed in that Table, the raw samples (controls) presented the highest IV. Raw *P. tricolor* compared to raw *H. daganensis* was found to have the highest IV (69.07 mgI₂/100g of oil). These values were lower than those noted by Assielou et al. [43] from *Oryctes owariensis* larvae oil (105.25 gI₂/100g of oil) and Ekpo and Onigbinde [47] reported for *Macrotermes bellicosus* oil (108 g I₂/100 g of oil).

However, they were higher than 48.35 gI₂/100g of oil reported by Mathew et al. [48] for *Rhynchophorus palmarum* L. larva. The IV noted in this study for raw samples are in some way lower than the range 80-106 gI₂/100 g of oil

specified by FAO/WHO [49] for edible oil. IV of the two cricket species were significantly reduced ($P < 0.05$) after cooking (Table 2). Those decreases were in accordance with the decrease in unsaturated fatty acids present in cricket oils. The fried samples in the two cases presented the highest IV, while bleached + fried samples presented the lowest IV. However, fried *P. tricolor* compared to fried *H. daganensis* had a higher IV (58.61 $\text{gI}_2/100\text{g}$ of oil). The decrease in IV during cooking can consequently be due to changes in cricket oil that occurred during processing. Indeed, at high temperature, molecular oxygen reacts with double bonds of unsaturated fatty acids and reduces their content [50]. The decrease in IV reduces the nutritive and healthy value of these crickets. According to the study of Orthofer et al. [51], heat treatments are responsible for lipid oxidation in oils.

3.2.3 Effect on Peroxide Value (PV)

Lipid oxidation has been found to be a major source of off flavours and decreased quality in fatty food and oil. An increase in the amount of double bonds in the oil makes them more susceptible to oxidation. Fatty acid oxidation can be assessed rapidly by measuring the hydroperoxides content. These compounds are generally unstable and may break down into secondary oxidation products of various molecular weights which decrease the nutritional value of oils [52]. The peroxide values of untreated and cooked crickets are shown in Table 2. In this Table, the PV of raw samples ranged from 6.18 meq O_2/kg of oil in raw *H. daganensis* to 12.90 meq O_2/kg oil in *P. Tricolor*. The PV noted in the raw samples study were lower than those obtained in raw Mealworm larvae (19 meq O_2/kg of oil; [3]), but still higher than those noted by Assielou et al. [43] in *Oryctes owariensis* larvae (0.96 meq O_2/kg of oil). A significant increase ($P < 0.05$) in PV was noticeable in all treated samples except roasted *P. tricolor*. In roasted *P. tricolor* a significant decrease in PV was observed. The fried samples in the two species and bleached + fried sample in the case of *H. daganensis* were found to have the highest PV (~24 meq O_2/kg of oil). The lowest PV (6.65 meq O_2/kg of oil) in *H. daganensis* was observed in soaked + fried sample while in *P. tricolor*, roasted sample presented the lowest PV (7.60 meq O_2/kg of oil). Accumulation of hydroperoxides during different treatment methods, in certain cases, are due to the reaction between free unsaturated fatty acids with molecular oxygen. These reactions are

accelerated by high temperature (heat) and moisture content of samples [51]. Hydroperoxides are highly unstable and can be converted to secondary products. This can then explain the decrease in PV observed in roasted *P. tricolor*. Oil becomes rancid when the values of their peroxides is between 20 and 40 meq O_2/kg of oil [53]. The data from this experiment clearly show that the lipids of roasted and bleached + fried samples in the two species are rancid. The PV of roasted samples in the two cases, and of raw and soaked + fried sample in the case of *P. tricolor* are in line with the standard specified by FAO/WHO [49] for fresh edible oil which is below 10 meq O_2/kg of oil.

3.2.3 Effect on Thiobarbituric Acid Reactive Substances (TBARS)

Hydroperoxides, which are the primary oxidative products, are formed during lipid oxidation in the early stage. Besides, due to their instabilities, they are rapidly transformed into both volatile and non-volatile secondary products. The TBARS test has been used to measure the amount of relative polar secondary reaction products, like malondialdehyde (MDA). It serves as an oxidative damage index. The high concentration of MDA in oil contributes to decreasing in the nutritive value of food and their organoleptic qualities [54]. The TBARS values of raw and different cooked crickets are presented in Table 2. TBARS formation in raw samples varies from 1.58 to 1.80 mg MDA/kg of oil, respectively, for *H. daganensis* and *P. tricolor*. During cooking processes, these values increased significantly ($P < 0.05$) and the fried samples in the case of the two species were found to have the highest TBARS content (9.10 and 7.04 mg MDA/KG of oil respectively for *H. daganensis* and *P. tricolor*). Within cooked crickets, soaked + fried samples in both species presented a lower TBARS value. The increase in TBARS during processing indicates the formation of secondary lipid oxidation products in cricket oils. During peroxidation, when the PV reaches a certain amount, they decompose in volatile and non-volatile aldehydes due to high temperature, thus, increasing malondialdehyde levels [55]. According to Al-Kahtani et al. [56], meat products can be considered in a good conservation state concerning oxidative changes, when they have less than 3 mg MDA/kg of oil. Hence, soaked + fried sample studied was suitable for consumption.

Table 1. Effects of frying and roasting on proximate composition of two species of crickets

Samples	Moisture (% wet weight)	Ash (g per 100 g dry weight)	Lipid (g per 100 g dry weight)	Protein (g per 100 g dry weight)	Carbohydrate (g per 100 g dry weight)	Crude fibre(g per 100 g dry weight)	Energy (Kcal)
Hieroglyphus daganensis							
Raw	58.20±2.32 ^a	3.49±0.17 ^c	15.80±0.08 ^g	41.69±0.58 ^e	18.00 ±0.70 ^a	17.54±0.11 ^a	381.10
Fried	26.80±1.45 ^d	4.14±0.18 ^b	27.63±0.40 ^a	46.43±0.08 ^d	15.56±1.30 ^b	14.22±0.11 ^b	496.63
Soaked + fried	25.78±1.20 ^d	4.50±0.31 ^b	23.80±0.17 ^d	51.42±0.35 ^c	9.87±0.15 ^d	11.02±0.34 ^c	459.63
Bleached + fried	27.94±1.90 ^d	4.14±0.18 ^b	26.28±0.40 ^b	46.85±0.27 ^d	11.37±0.60 ^d	12.63±0.53 ^c	473.00
Roasted	40.60±3.56 ^b	4.97±0.06 ^a	20.60±0.71 ^e	50.91±0.34 ^c	12.90±0.22 ^c	10.45±0.29 ^d	441.00
Parcinema tricolor							
Raw	54.68±0.20 ^a	3.17±0.07 ^c	18.10±0.22 ^f	48.59±0.08 ^g	11.98±0.10 ^c	17.50±0.06 ^a	405.30
Fried	26.99±3.30 ^d	3.69± 0.19 ^c	24.19±0.70 ^d	51.09±0.05 ^c	8.27±0.67 ^f	14.18±0.12 ^b	405.29
Soaked + fried	26.80±1.78 ^d	4.03±0.02 ^b	24.30±0.04 ^d	55.38±1.07 ^a	5.60± 0.28 ^g	12.05 ±0.38 ^c	463.02
Bleached + fried	34.01±1.20 ^c	3.52±0.08 ^c	23.88±0.40 ^c	52.68±0.60 ^b	6.72±0.12 ^e	13.29±0.46 ^b	452.44
Roasted	45.80±5.06 ^b	3.92±0.02 ^b	21.36±0.20 ^e	55.64±0.29 ^a	9.01±0.06 ^f	10.79±0.03 ^d	450.83

Values are mean ± standard deviation. Mean values in the same column with different superscript letters are significantly different ($p < 0.05$)

Table 2. Changes in acid, iodine, peroxide and TBARS values of cricket samples during frying and roasting

Samples	Free fatty acid value (% oleic acid)	Iodine value (g I ₂ /100 g of oil)	Peroxide value (meq O ₂ /kg of oil)	TBARS value (mg MDA/kg oil)
Hieroglyphus daganensis				
Raw	1.28±0.23 ^f	56.93±0.17 ^b	6.18±0.47 ^e	1.58±0.04 ^h
Fried	7.40±0.09 ^a	47.10±0.94 ^c	24.17±0.80 ^b	9.10±0.44 ^a
Soaked + fried	6.49±0.20 ^b	41.60±0.59 ^d	6.65±0.62 ^e	2.20±0.01 ^g
Bleached + fried	4.43±0.10 ^d	35.80±0.54 ^e	24.68±2.50 ^b	5.44±0.04 ^d
Roasted	5.43±0.20 ^c	38.04±0.03 ^d	9.30±0.73 ^d	3.35±0.03 ^f
Parcinema tricolor				
Raw	1.26±0.14 ^f	69.07±0.72 ^a	12.90±0.40 ^d	1.80±0.05 ^g
Fried	5.32±0.30 ^c	58.61±0.60 ^b	24.03±0.90 ^b	7.04±0.02 ^b
Soaked + fried	3.90±0.03 ^d	55.90±0.20 ^b	11.90±0.37 ^d	3.06±0.13 ^f
Bleached + fried	2.35±0.10 ^e	41.75±0.90 ^d	21.97±0.30 ^c	5.91±0.02 ^d
Roasted	2.80±0.01 ^e	48.58±0.57 ^c	7.60±0.12 ^e	4.49±0.20 ^e

Values are mean ± standard deviation. Mean values in the same column with different superscript letters are significantly different ($p < 0.05$)

4. CONCLUSION

The results obtained in this study indicate that the proximate composition of raw *H. daganensis* and *P. tricolor* commonly consumed in Far-North Cameroon is different. However, both edibles crickets are good sources of lipid, protein, and ash. Roasting and frying methods used have an influence on the proximate composition and oxidative parameters of these two species. During these processing method, lipid, protein and ash contents of crickets' increased while moisture, carbohydrate and crude fibre content decrease. The increase of these macronutrients enhanced the nutritional value of crickets and it could contribute significantly to reduce the malnutrition in the local population. Practically, all the cooking methods affect the quality of cricket lipids because PV decreased in *Parcinema tricolor* with roasting, and was significantly different from raw samples in soaked + fried samples of the two crickets' species. Soaking combined with frying appears in this study, to be the best cooking method of the both crickets' species, concerning calorie, protein content and oxidative stability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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