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Productivity, Bioconversion Capacity, Protein and Fat Contents of Black Soldier Fly Larvae (*Hermetia illucens)* Fed with Jatropha Curcas Pressed Cake

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Abstract: The use of black soldier flies (BSF) for biofuel production and fish feeding is nowadays presented as an ecological alternative. Several biomasses have been used to nurture BSF, however *Jatropha curcas* pressed cake obtained from biofuel production using jatropha seeds is a nutrient-rich biomass that has not yet been fully used as feed for BSF, probably due to its toxicity (not used in animal feeding). The aim of this study was to assess the bioconversion of this cake by black soldier flies (*Hermetia illucens*) following different detoxification treatments. The study was conducted in a greenhouse. Three detoxification treatments were applied on *Jatropha curcas* pressed cakes (whitch was obtained by cold pressing of *Jatropha cusas* seeds with a residual oil content of 24.64±0.05%): the treatments consisted of a control, thermal, biological and thermo-biological treatments. Resulting cake samples were used to feed 4 treatments of 550 BSF larvae in each. Each treatment had 4 repetitions, making a total of sixteen repetitions. The BSF larvae were four-day-old and were fed with 90 g of cakes every 4 days during 15 days. Assessed parameters included survival rate of larvae, meal reduction rate, bioconversion rate, organic matter, fats, crude protein, and ash contents of larvae. Results showed that the highest ($p>0.05$) larval survival rate (98,42±1,22%) was obtained with the biological treatment. The best bioconversion rate (37.1±60.68%) was recorded with the control treatment. No significant difference was observed between treatments with regard to organic matter (94.25±0.13%), fats (32.08±0.25%), crude protein (45.33±0.14%) and in ash (5.75±0.13%) contents. It was concluded that *Jatropha curcas* cakes, although toxic for monogastric, are appropriate feed material for black soldier fly larvae and can be used without any prior detoxification treatment.

Keywords: Jatropha, Bioconversion, BSF, Larvae, Cake

1. Introduction

The constantly growing population is affecting human wellbeing resulting in food insecurity and energy crises amongst others. On the food level, this demographic growth increases the need for food rich in proteins and oil particularly soya and fish meal used for feeding cattle and even humans [1]. The intensive use of these two ingredients has a significant negative impact on the environment [2] notably; the destruction of forests for the establishment of new soybean plantations and enormous pressure on marine fauna for the production of fishmeal.

In the energy field, faced with the environmental problems caused by the use of conventional energy sources, a renewed interest is increasingly observed for renewable energy sources that are more environmentally benign. Among these sources, *Jatropha curcas* (whole seed) presents itself as a very promising raw material for the production of second-generation biodiesel. These *Jatropha cucas* pressed cakes are not edible by humans or animals because of their toxicity. Investigations are therefore being carried out with the aim of valuing these cakes.

Several techniques for the recovery of *Jatropha cucas* pressed cakes exists notably; biomethanation [3-5], combustion [6], pyrolysis [7] and bioconversion by black soldier fly larvae. Amongst these techniques, bioconversion by black soldier fly larvae seems to be a very promising alternative because of its triple applications: They do not only allow the production at a lower cost of a larval biomass very rich in protein that can replace fish meal and soybean [8] in livestock feed (poultry [9], pigs [10] and fish [11], but also provide a better compost (in terms of phosphorus, nitrogen and potassium) compared to that resulting from conventional composting systems [10]. This compost is very useful in organic farming and also allow efficient and ecological management of organic waste [1, 2, 13].

In view of the triple advantage provided by black soldier fly larvae, many bioconversions work by these larvae have been carried out with different substrates [8, 12]. Such as manure and organic waste [13], food waste, catering waste [14], fruit waste [15]; agricultural residues, in particular cassava skins [16]. These studies concluded that the growth performance and the physicochemical composition of the larvae are a function of the type of substrate provided. Despite this apparent potential of black soldier fly larvae in animal nutrition and in the treatment of organic waste, studies on feeding of black soldier fly larvae based on *Jatropha curcas* cakes has not been conducted. There is therefore a lack of knowledge on the ability of black soldier fly larvae to degrade Jatropha cakes despite their toxicity. As a result, several questions arise: are black soldier fly larvae sensitive to the toxic substances contained in Jatropha cakes? Do the various detoxification techniques proposed by the literature improve its bioconversion? Do they have an impact on the bromatological properties of the larvae (pre-pupa)? Thus, the aim of this study was to investigate the effect of treatment of Jatropha cakes on their bioconversion parameters and the quantity of protein and fats produced by black soldier fly larvae.

2. Materials and Methods

2.1. Presentation of the Area and Study Site

This study was conducted in a greenhouse at the renewable energy laboratory of the Department of Agricultural Engineering of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang, Cameroon.

2.2. Black Soldier Fly Colony

The pre-pupae (two weeks old black soldier fly larvae) were acquired from AgriBusiness vocational training Center (ABC), Dschang, Cameroon. These larvae were multiplied over 3 cycles of 45 days. At the end of this multiplication stage, the black soldier fly eggs were collected and incubated according to the method described by Dzepe, *et al.*, (2020a) [17]. After hatching, 2200 four-day-old larvae were collected and divided into 4 equal groups (550 larvaes/group) and used to test the different cakes that had undergone the treatments.

2.3. Jatropha Curcas **Cake Processing**

Three types of treatment were applied to the cakes of Jatropha; thermal treatment (TT), biological treatment (TB) and thermo biological treatment (TTB). The group without treatment (TO) was used as control. The purpose of these treatments was to reduce the toxicity of the cakes and to observe their influences on the bioconversion parameters and the bromatological properties of the larvae (prepupa).

1) Thermal treatment (TT): In accordance with the recommendations of Eroarome, *et al.*, (1998) [32] and taken up by Treboux, (2013) [33], the following parameters were retained: water content: 66%, heating temperature: 121°C and heating time 30 minutes. This treatment was carried out in a Fisher brand oven, the maximum temperature is 200°C. The water content of the meal was determined by the gravimetric method [18] and adjusted to 66% by adding a volume of water determined by the equation (1) given by Chung-Yiin *et al* (2020) [19].

$$V_{H_2O} = \frac{(\%_{H_2O})(M_S)}{1-\%_{H_2O}} - M_{H_2O} \quad (1)$$

Where V_{H_2O} represents the volume of water to added, $\%_{H_2O}$ the desired water content which is 66% in this study (0.66 was introduced in this equation), M_s the dry mass of the cake and M_{H_2O} the initial water content of the cake.

2) Biological treatment (TB): *Jatropha* cakes were treated by solid state fermentation. This fermentation took place in a plastic container (Ø30 × 12 cm). A mass of 1 kg of cake with a water content of 11.11% was weighed using a 1 g precision electronic scale. This mass of substrate was mixed with 0.85 kg of fresh water to have a humidity level of 70% (as recommended by Brand *et al* (2000) [20]) conducive to the development of microorganisms. The fermentation tanks were seeded by exposing the cake and water mixture to the open air outside for 24 hours. This fermentation took place away from light for a period of 7 days [21] at a temperature between 28 and 30°C [20]. The fermentation was interrupted by drying at a 70°C temperature of for 12 hours [21] in an electric dehydrator.
3) Thermo-biological treatment (TTB): This treatment consisted of combining biological treatments and heat treatment. The cakes having undergone a heat treatment were submitted directly after cooling to the biological treatment using Aspergellus niger.

2.4. Characterization of Substrates and Pre-Pupae from Treatments

The cakes and pre-pupae from the different treatments were analyzed in the animal production and nutrition laboratory of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang. These analyses made it possible to determine the bromatological composition (dry matter, ash, organic matter, crude protein and fat contents) of each type of cake as well as of the pre-pupae from each treatment following the method described by AOAC (1990) [22]. The determination of fibers in the meals was carried out by the protocol developed by Van *et al* (1991) [23] for the determination of Neutral Detergent Fiber, Acid Detergent Fiber, Acid Detergent Lignin, Cellulose and Hemicellulose.

2.5. Experimentation

The circular plastic containers (Ø 30 × 12 cm) were used to carry out the experimentations. Those containers were covered with mosquito nets to prevent black soldier fly larvae predators and to avoid the presence of housefly larvae in the containers as shown in *Figure 1*.

Figure 1. *Experimental set up.*

Four seeded containers of 550 four-day-old larvae (0.0018 g mean weight) each were used for each organic substrate sample. The different containers were supplied every four days with 90 g of their respective substrates. Each treatment was repeated four times and the experimental period was determined according to the required time of BSF larvae to reach maturity which was approximately 15 days. The experiment was stopped when 40% of larvae reached the pre-pupe stage as reported by Zhenghui (2019) [24]. Table 1 summarizes the different treatments performed in this study.

Table 1. *Description of the different treatments performed during the study.*

Treatment	Control (TO)	Biological (TB)	Thermic (TT)	Thermo-biological (TTB)
Number of lavae (n)	550	550	550	550
Quantity of substrate (g)	90	90	90	90
Feeding occasions (n)	Every 4 days	Every 4 days	Every 4 days	Every 4 days
Treatment replicates	4	4	4	4

2.6. Parameters of the Bioconversion of J Curcas Cakes

From each treatment, the larvae were harvested on the 15th day in the containers, counted and weighed using an electronic balance with precision 0.01 g, after washing with fresh water. Residual substrates were also collected from the containers and weighed using an electronic scale of precision ±0.1 g. Residual substrate was dried in an electrical dryer at 45°C for 24 hours. Outlet was weighed using an electronic scale of precision ±0.1 g to determine the dry weight. To take into account both the sustainable organic waste recycling and the larval biomass production, the efficacy of Black Soldier Fly larvae to thrive in the *Jatropha curcas* Cake which undergone each treatments was assessed using parameters such as Larvae total weight gained (1), waste reduction rate (3), Residual mixed organics (5), larval survival rate (10), larval bioconversion rate (6) … Those all parameters were calculated using the formulas on *Table 2*:

Table 2. *Parameters of bioconversion and calculated formulas.*

N°	parameter	unit	Formula of calculation
1	Larvae total weight gained	g	Final larval dry weight (g) – Initial larval dry weight (g)
2	Growth rate	g/j	$\frac{Larvae\ total\ weight\ gained\ (g)}{rearing\ duration\ (day)}$
3	waste reduction rate (WR)	%	$\frac{dry\ feed\ served\ (g) - dry\ residue\ remained(g)}{dry\ feed\ served(g)} \times 100$
4	Waste reduction index (WRI)	%/day	$\frac{dry\ feed\ served(g) - dry\ residue\ remained(g)}{dry\ feed\ served(g) \times rearing\ duration\ (day)} \times 100$
5	Residual mixed organics	%	$\frac{dry\ residue\ remained(g)}{dry\ feed\ served(g)} \times 100$
6	Bioconversion rate	%	$\frac{Larvae\ total\ weight\ gained\ (g)}{dry\ feed\ served(g)} \times 100$
7	Metabolic loss of mix organics	%	$\frac{dry\ feed\ served(g) - (dry\ residue\ remained(g) + Larvae\ total\ weight\ gained\ (g))}{dry\ feed\ offered(g) - dry\ residue\ remained(g)} \times 100$
8	Mixed organics removal rate	%	$\frac{dry\ feed\ offered(g) - dry\ residue\ remained(g)}{rearing\ duration\ (day)}$
9	Bioconversion Yield	%	$\frac{Larvae\ total\ weight\ gained\ (g)}{dry\ feed\ served(g) - dry\ residue\ remained(g)} \times 100$
10	Survival Rate	%	$\frac{Number\ of\ larvae\ harvested}{Number\ of\ four\ days\ old\ larvae\ added} \times 100$

Like the waste reduction index, a high bioconversion rate indicates good bioconversion efficiency.

2.7. Statistical Analysis

Statistical analysis was conducted using the software I IBM SPSS Statistics 20. Means from each treatment were submitted to a one-way ANOVA after prior confirmation of homogeneity of variance and normality. If significant differences were detected at p < 0.05, then a Tukey's post-hoc test was performed to identify differences among the treatments. All data are presented as means ± standard deviation.

3. Results and Discussion

3.1. Characterization of Substrates

Dry matter content of the different substrates varied between 94.52% for pressed cakes that had undergone thermo-biological treatment and 95.16% for pressed cakes that had undergone heat treatment. The dry matter content was influenced by these two treatments ($p < 0{,}05$). But on the other hand, for the other treatments there was no significant difference.

The organic matter content varied from 92.24% for TTB to 93.61% for TO. Although the values were very close, there are significant differences between the organic matter contents between the different treatments except between TB and TTB ($p > 0{,}05$).

The highest protein content was recorded from the TB treatment (24.02%) and the lowest was recorded from TT (20.93%) while the meal that had not undergone any treatment had a protein content of 22.16%. There were significant differences on crude protein content between the different treatments except for TO and TTB ($p < 0{,}05$). The biological treatment had the highest crude protein content (24.02%) i.e. an increase of 1.96% compared to the untreated cake which was 22.06% and very close to 24.54% obtained by Silva and Hesselberrg (2020) [3] and 24.3% obtained by Kongkasawan *et al* (2016) [27]. This increase in protein content could be due to the development of fungi, in particular *Aspergillus niger,* with which the cake was seeded for the biological treatment. This increase in protein content is less than the 7.5% obtained by NESSEIM (2014) [25]. This difference is mainly due to the type of pressed cake used in the experiment. In this study, the cake of the whole seed (almond+shell) was used while NESSEIM (2014) [25] used an almond cake devoid of the shell. The jatropha sheaths used in this study has a mass of 61.25% almond very rich in protein and 38.75% shell rich in lignin close to those obtained by Becker (2009) [26] which is 65% almond and 35% hull. This also explains the low crude protein content close to 24.3% obtained by Kongkasawan *et al* (2016) [27] and partly the high residual fat content of the pressed cakes used in this study in comparison with those obtained by Sogang *et al* (2021) [28] which is 22.47% for the press cakes at 25°C and at a pressure of 422.06 bars. The presence of shells, which are essentially made up of lignin, contributes in lowering the crude protein content and during trituration, it fixes the oil particles and contributes to increasing the residual oil content in the meal.

In terms of residual fat in pressed cakes, TO recorded highest content (24.64%) meanwhile TB the lowest (16.91%). There was a significant ($p < 0{,}05$) difference between the fat contents between the different treatments. This significant difference between the different treatments was recorded on crude fiber contents (between 59.35% for TO and 50.07% for TTB), lignin (between 19.99% for TTB and 24.92% for TT), cellulose (between 17.18% for TT and 25.24% for TTB) and hemicellulose (between 4.85% for TTB and 19.93% for TO). Figure 2 resumes the characterization results of the substrate.

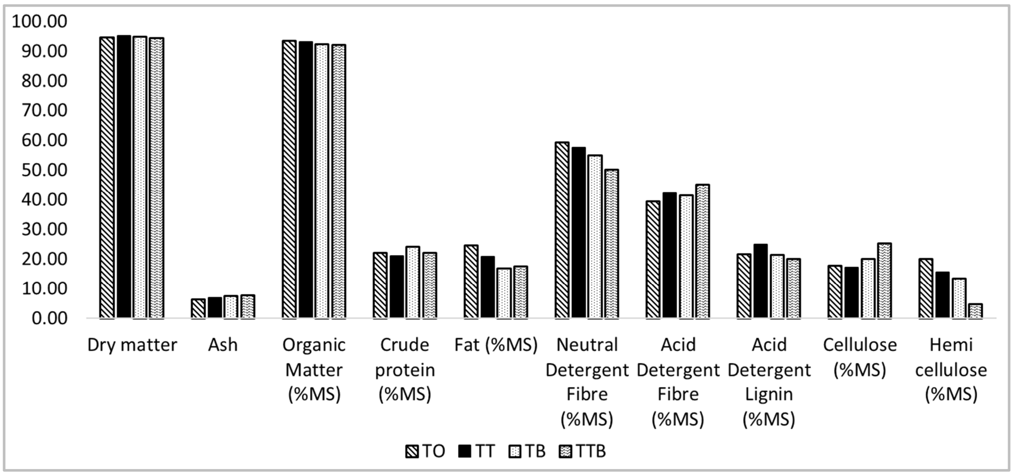

Figure 2. *Comparative study of the bromatological properties and analysis of the fibers of the various pressed cakes from jatropha having undergone various treatments.*

All the treatments contributed to reducing the residual fat content in the meals. It went from 24.64% in the untreated pressed cakes to 20.62%, 16.91% and 17.48% in the pressed cakes having undergone heat treatment, biological treatment and thermo-biological treatment respectively. There was a reduction of 4.02%, 7.73% and 7.16% respectively for these treatments. This can be explained by the fact that the fungi which developed in the pressed cakes during the biological treatment operation consumed the fat for their growth.

According to the statistical analyses carried out using the IBM SPSS Statistics 20 software, there was no significant difference between the different treatments with regards to the dry matter except between heat treatment and the thermo-biological treatment. As for the ash and organic matter contents, there existed a significant difference at 5% between the treatments except between the biological and thermo-biological treatments. With regard to the crude proteins, there was a significant difference between the treatments, except between the themo-biological treatment and the control which did not present any significant difference. There was equally a significant difference between the treatments for fat, crude fiber (NDF), ADF, cellulose and hemi-cellulose content at the 5% probability level. Moreover, a significant difference in lignin content was observed between all the treatments except between the control and the biological treatment.

3.2. Larval Growth Parameters

At the end of the bioconversion, the biological treatment had the greatest mass of fresh pre-pupa ($100.33 \pm 2.19\ g$) while the thermo-biological treatment had the lowest mass (82.67±7.33 g) (*Table 3).* Consider a mass of dry pre-pupa of $35.00 \pm 0.88\ g$ and $29.00 \pm 2.51\ g$ for the biological and thermo-biological treatments respectively. With an average water content of $64.67 \pm 0.26\%$, the total weight gain of the larvae at the end of bioconversion is $34.49 \pm 0.69\ g$ and $28.46 \pm 2.43\ g$ for biological and thermo-biological treatments respectively. Thus, according to Tukey's post-hoc test, there was no significant ($p > 0{,}05$) difference between the treatments. In terms of mass of larval biomass, the biological treatment seemed more interesting although no significant differences were obtained between TB, TO and TT.

Although the survival rate of the larvae was highest ($98{,}42 \pm 1{,}22\%$) in the meal that had undergone the biological treatment, and lowest ($90{,}30 \pm 4{,}82\%$) in the thermo-biological treatment, it was not affected by the treatment ($p > 0{,}05$). BSF larvae are very voracious and have the ability to degrade several types of organic waste [12]. In this study, the survival rate of the larvae was not influenced by the different treatments carried out. It was 98.42% maximum for cakes that had undergone biological treatment, and 90.30% minimum in the thermo-biological treatment. This suggests that jatropha cake, although toxic for monogastrics [25] and [29], is not toxic for black soldier fly larvae. The questions therefore arise as to whether the black soldier fly larvae are bio-accumulators of the toxin present in the jatropha pressed cake, or if they are capable of digesting them, or do they pass through their digestive system?

With an initial mass of 270 g of meal and 1g of fresh larva for each of the treatments, the greatest mass of fresh pre-pupa was obtained with the biological treatment (100.65g or 34.85g dry) against 82.72g or 28.81g dry for the thermo-biological treatment which had the lowest mass. In addition, the TB presented the lowest metabolic losses ($62{,}79 \pm 0{,}85\%$) compared to $65.98 \pm 0.92\%$ to the TO. TB presented the best characteristics in terms of metabolic loss although there was no significant difference between the different treatments.

Table 3. *Larval growth parameters.*

Setting	Untreated	Biological treatment	Heat treatment	Thermo-biological treatment	P ANOVA
Mass of fresh pre-pupa (g)	97.00±3.51	100.33±2.18	91.67±2.03	82.67±7.33	0.085
Pre-pupal dry mass (g)	34.33±0.33	35.00±0.56	33.67±0.88	29.00±2.51	0.054
Total weight gain (g)	33.75±0.46	34.39±0.69	32.90±0.87	28.46±2.43	0.052
Daily growth (g/d)	2.41±0.033	2.46±0.05	2.34±0.06	2.03±0.17	0.052
Metabolic losses (%)	66.33±0.91	63.16±0.84	65.87±1.23	65.54±2.09	0.416
Larval survival rate (%)	92.12±1.49	98.42±1.21	93.81±1.81	90.66±1.48	0.265

These different larval survival rates for the treatments applied to Jatropha cake in this study are higher than those obtained by [30]) using household waste (47%) and fruit and vegetable waste (77%) and comparable to those obtained by Lalander *et al* (2019) [12] using chicken feed (93.0±2.9%), chicken droppings (92.7 ± 33%) and human faeces (91.8±4.5%). According to some authors, the survival rate of the larvae is a function of the access of the larvae to the source of food and the type of food [31].

In general, with regard to statistical analyses (ANOVA) with all probabilities less than 5% (*Table 3*), it can be said without risk of being mistaken that the growth parameters of black soldier fly larvae in *Jatropha curcas* cakes are not affected by the treatments applied to it.

3.3. Meal Bioconversion Parameters

The rate of conversion of Jatropha pressed cake by the larvae was higher (37.16±0.68%) in the untreated pressed cakes and lower (30.49±0.80%) in the pressed cakes that had undergone thermo-biological treatment (*Table 4*). This range of conversion rate was less than 48.41% obtained by Zhenghui *et al* (2019) [24] with corn straw and those of Chung-Yiin *et al* (2020) [19] which varried between 48% and 53% with coconut flesh waste. This observed difference can be explained by the fact that the meal which was used in this study was a whole seed meal. The hulls, representing 35% of these whole seeds, are difficult to degrade by the larvae and thus contribute to reducing the rate of bioconversion. The thermo-biological treatment presented a significant ($p < 0{,}05$) difference compared to the 3 other treatments.

The result of the analysis of variance (ANOVA) showed that there was a significant difference between the treatments for the conversion rate, the conversion index and the residual material content of the different cakes from the different treatments. This suggests that the black soldier fly larvae in this study had difficulty consuming the meal resulting from this treatment.

The treatments applied to the meal influenced the biomass conversion rate by BSF larvae. In terms of biomass conversion rate, there was no difference between the untreated meals and those having undergone thermal and biological treatments ($p > 0{,}05$).

Thus, of the 4 treatments applied to the Jatropha cakes, the biological treatment presented the best bioconversion parameters. Indeed, it had the highest bioconversion rate

(37.28%), the highest bioconversion efficiency and yield of 12.91% and 37.21% respectively. This treatment equally presented the lowest metabolic losses of 62.79%.

The conversion index followed the same trend as that of the conversion rate because they are strongly linked (r=1). After the LMSN bioconversion operation, the highest residual material content (69.50±0.80%) was recorded with cakes having undergone the thermo-biological treatment while the lowest content (62.84±0.68%) was observed with untreated pressed cakes. The analysis of variance test (ANOVA) showed that there is a significant difference between the treatments for the three preceding parameters. Despite the high conversion rate for the untreated cakes, the highest bioconversion rate (37.28±0.84%) was obtained with the pressed cakes having undergone the biological treatment and the lowest (30.63±2.70%) was obtained for the thermo-biological treatment. With regard to the analysis of variance (ANOVA) test, there was no significant difference between the treatments in terms of bioconversion rate, yield and efficiency of the bioconversion because the probability threshold was greater than 5% and the correlation was strong between these two parameters.

Table 4. *Meal bioconversion parameters.*

Setting	Untreated	Biological treatment	Heat treatment	Thermo-biological treatment	P ANOVA
Material conversion rate (%)	37.16±0.68	34.69±0.12	35.80±1.74	30.49±0.80	0.009
Conversion index (%/d)	2.65±0.05	2.48±0.01	2.56±0.12	2.17±0.59	0.008
Residual material content (%)	62.84±0.68	65.30±0.12	64.20±1.74	69.50±0.80	0.009
Bioconversion rate (%)	35.91±1.30	37.28±0.84	33.96±0.71	30.63±2.70	0.81
Bioconversion yield (%)	33.67±0.88	36.67±0.88	34.00±1.15	34.33±2.18	0.45
Bioconversion efficiency (%)	12.50±0.17	12.78±0.25	12.18±0.32	10.54±0.90	0.52

3.4. Effect of Treatments on the Bromatological Composition of Larvae

At the end of the various treatments, although the highest organic matter content (94.66±0.33%) was recorded for the thermal treatment and the lowest (94.00%) for the biological and thermobiological treatment, the analysis of variance (ANOVA) showed that the organic matter content (the average of which is 94.25±0.13%) of the larvae (pre-pupae) from different treatments were statistically identical. The same was true for the ash, crude protein and fat contents, the average values of which are 5.75±0.13%, 45.33±0.14% and 32.08±0.25% respectively. The Table 5 presents the average bromatological compositions of the jatropha pressed cakes having undergone treatments and that of the larvae (pre-pupae) resulting from the bioconversion of these cakes.

Table 5. *Average bromatological compositions of Jatropha cakes having undergone treatment and that of the larvae (pre-pupae) resulting from the bioconversion of these cakes.*

Substrate	Dry matter (%)	Organic matter (%)	Ash (%)	Crude protein (%)	Fat (%)
Jatropha pressed cake	94.83±0.08	92.86±0.17	7.14±0.17	22.29±0.34	19.91±0.93
Larvae from jatropha pressed cakes	95.42±0.15	94.25±0.13	5.75±0.13	45.33±0.14	32.08±0.25

The investigations of Purkayastha and Sarkar (2021) [10] showed that the bromatological composition of soldier fly larvae varies greatly depending on the feed they received. In this study, the treatments applied to the meal did not affect the bromatological composition of the larvae. This comes to reinforce the idea that the toxic substances (ester of phorbol and antinutritional) from the jatropha pressed cakes have no influence on black soldier fly larvae (BSFL). According to these observations, the high crude protein (45.33±0.14%) and fat contents (32.08±0.25%) from these larvae is an alternative source of protein in animal nutrition [9, 15] and a very cheap raw material for the production of biofuels.

4. Conclusion

At the end of this study, the main objective of which was to study the bioconversion parameters of *Jatropha curcas* pressed cakes by black soldier fly larvae, it can be concluded that the waste treatment technology by black soldier fly larvae is very promising in the reduction and recycling of jatropha pressed cakes responsible for insalubrities and environmental pollution. This recycling makes it possible to transform jatropha pressed cakes into useful products such as fats for biodiesel production, a biomass rich in protein for animal feed and an interesting fertilizer for organic farming. The best bioconversion rate (37.16±0.68%) was recorded from Jatropha pressed cakes that had not undergone any treatment. Thus, showing that the toxic substances found in Jatropha has no influence on the black soldier fly larvae. The fats and crude protein contents BSFL resulting from this bioconversion were 32.08 ± 0.25% and 45.33 ± 0.14% respectively. Due to this composition, these larvae constitute an alternative source of protein for animal nutrition and a very cheap raw material for the production of biofuels.

5. Recommendations for Follow up

Future studies could focus on the questions whether the black soldier fly larvae are bio-accumulators of the toxins present in the *Jatropha curcas* pressed cake, or if they are capable of digesting them, or do they pass through their digestive system. This will permit to know if the black soldier larvae fed with *Jatropha cucas* pressed cake can be safely use to feed animals.

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