ISSN 2664-4150 (Print) & ISSN 2664-794X (Online)
South Asian Research Journal of Engineering and Technology
Abbreviated Key Title: South Asian Res J Eng Tech

| Volume-4 | Issue-5 | Sept-Oct- 2022 | DOI: 10.36346/sarjet.2022.v04i05.007

Original Research Article

Chemical Characterization of Some Fruits and Vegetables Used as Substrates for the Production of Black Soldier Fly Larvae

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Article History
Received: 30.08.2022
Accepted: 05.10.2022
Published: 18.10.2022

Abstract: Black soldier fly larvae feed on different organic materials. The nutritional composition of these larvae depends on the feeding substrate. The objective of this study is to determine the composition of macronutrients and micronutrients of fruits and vegetables used as substrate for the production of larvae. To do this, various fruits and vegetables were obtained from fruit and vegetable retailers of Carena in the commune of Plateau (Abidjan). These are the releases of sweet banana, watermelon, avocado, cucumber, papaya and orange. They were packed in a cooler, closed and transported to the experiment site. Samples of these fruits and vegetables were taken and chemically analyzed. It was determined metabolizable energy, the content of moisture, protein, fat, carbohydrate, cellulose, ash, minerals (potassium, phosphorus, calcium, sodium, and magnesium) and vitamin C. The results showed that sweet banana and watermelon are rich in protein respectively 2.20% ± 0.00 and 1.93% ± 0.00. The sweet banana is also rich in ash (4.80% ± 0.00) and mineral elements such as sodium (17.35 mg ± 3.68) and magnesium (30.8 mg ± 4.40). Avocado is energetic (161 ± 1.02 kcal). It is rich in fat (43.5% ± 0.01), potassium (339 mg ± 22.3) and phosphorus (52 mg ± 3.02). Orange and papaya are rich in vitamin C respectively 70 mg ± 3.00 and 64 mg ± 2.00. Watermelon and cucumber have a high water respectively 93.91% ± 1.00 and 91.4% ± 1.01. The have also a high cellulose content respectively 11.41% ± 0.01 and 11.1% ± 0.01. This study has shown that the fruits and vegetables used are excellent substrates. They are rich in macronutrients and micronutrients useful for the growth of black soldier fly larvae.

Keywords: Black soldier fly larvae, larvae, fruits and vegetables, Chemical composition.

INTRODUCTION

Protein consumption is an important parameter for poultry feeding. Indeed, proteins have economic implications and a significant role in the physiology of nutrition (Beghoul, 2015). The use of raw materials which are rich in protein (soya and fish meal) for animal feed is a rather delicate situation. Supplying animals with high-protein feed has become a real problem for breeders. Protein sources such as soybean cake and fish meal available in Côte d'Ivoire are very expensive (Ouattara *et al*., 2016).

In the search for new sources of economically supportable proteins, many studies have shown the alternative role that insects could provide for animal feed (Kelemu S *et al*., 2015). The studies of Bouafou (2011) and Janssen *et al*., (2017), demonstrated that insect larvae provide a source of protein that can replace fish meal and soybean meal. Henry *et al.*, (2018), made an inventory of insects as a substitute in animal feeding and found that certain Diptera, Coleoptera and Orthoptera had better fatty acid content and a high protein content compared to fishmeal. Of all these insects, black soldier fly larvae (*Hermetia illucens*) are of particular interest. They have the ability to be reared on a wide range of organic materials. Also, their life cycle is relatively short (Li *et al.*, 2011) and their content is high in protein and fat (Wang and Shelomi, 2017). The black soldier fly is often bred on substrates composed of agricultural co-products or residues of agri-food processing (Parra *et al.*, 2015; Paul *et al.*, 2015). These include vegetable and restaurant waste

(Parra *et al.*, 2015), beet molasses, potato peelings, cereals, brewer's yeast, leftover bread and biscuits (Parra *et al.*, 2015), alfalfa flour, wheat bran, maize flour, brewers spent grain (Armel *et al.*, 2020), fish offal (Nguyen, 2013) and waste fruits and vegetables.

In Côte d'Ivoire, fruits and vegetables provide an opportunity for rearing of the black soldier fly. They are available at any time of the year on the market and easily accessible. Indeed, they constitute a considerable part of waste and losses (FAO, 2004). Fruits and vegetables have an important nutritional value (Tassadit, 2010). These fruits include sweet banana, watermelon, avocado, cucumber, papaya and orange. However, before using them as substrates for the production of black soldier fly, it is important to know the nutritional potential of each fruit and vegetable in order to better understand its impact. It is to this aim that this work has been devoted. This involves determining the macronutrient and micronutrient composition of these fruits and vegetables (sweet banana, watermelon, avocado, cucumber, papaya and orange).

MATERIAL AND METHODS

Fruits and Vegetables

The fruits and vegetables used for the study consist of discards of papaya, cucumber, avocado, sweet banana, watermelon and orange collected from the fruit and vegetable markets of Plateau (Abidjan).

Technical Material

A cooler with a capacity of 10 liters was used to transport the fruits and vegetables collected to the Laboratory for chemical analyses. An electronic scale with a capacity of 5 kg (Kitchen Scale; Model: SH-131) and a precision of 0.1 g was used for weighing the different samples. A blender with a capacity of 3 liters was used to grind the different substrates. Basins with capacities of 20 liters were used for the storage of fruits and vegetables. A kitchen knife was used for cutting the substrates.

Methods

Collection of Fruits and Vegetables

The fruits and vegetables were collected from fruit and vegetable retailers of *Carena* in the commune of Plateau (Abidjan). These are sweet banana, watermelon, avocado, cucumber, papaya and orange. These fruits and vegetables are all ripe but cannot be marketed. They are stored in bags ready to throw away. They were packed in a cooler which was closed and transported to the analysis site.

Pretreatment of Fruits and Vegetables

The pre-treatment operations varied according to the type of substrate used.

The papaya was cut up, the pulp and the seeds were ground to obtain a ground material. The ground material was then used for chemical characterization.

The cucumber was cut into small pieces with the skin and crushed to obtain a crushed material which was used for the chemical characterization.

The avocado was pitted, cut into small pieces and then crushed. The ground material was used for chemical analysis.

As for the banana, it was crushed with all the skin and pulp. The ground material obtained was used for the chemical characterization.

The watermelon was cut up and crushed. The ground material was used for chemical analysis.

The orange was cut into several slices with the skin. Finally, the slices were ground. The ground material was used for chemical analysis.

Determination of Chemical Composition

For each substrate a quantity of 100 g was taken.

Metabolizable Energy

The value of the metabolizable energy (ME) is obtained by calculation from the fat, the cellulose and the ash content of the sample. This value is determined from the equation of Sibbald (1980). This equation is presented as follows:

$$ME\ (kcal/kg) = 3.951 + 54.4 \times F - 88.7 \times CA - 40.8 \times CF$$

ME= Metabolizable energy (kcal/kg DM)
F= Fat (% DM)
CA= Crude Ash (% DM)
CF= Crude Fiber (% DM)

Protein

The total nitrogen content is determined by KJEDAHL according to the method of AOAC (2005). The nitrogen content obtained affected by the conversion coefficient 6.25 made it possible to estimate the total protein content.

Crude fiber

The dosage of the cellulose is carried out according to the method of Van Soest *et al.*, (1991).

Fat

The determination of the fat was done using soxhlet according to AOAC (2005).

Ash

Ash content is determined by subtracting from the dry matter (DM) rate, the organic matter (OM) content.

Carbohydrate content

Carbohydrate content is determined using the method of AOAC (2005).

Minerals

The quantification of the minerals was done by Atomic Absorption Spectrometry in accordance with the instructions of AFNOR (1991).

Vitamin C

The extraction and the assay were carried out according to the method described by Stevens *et al.*, (2006) on a microplate and by spectrophotometry.

RESULTS

Table 1 presents the chemical composition of the six different substrates. The nutritional values vary from one substrate to another. These values show significant differences at the 5% level. It emerges from this table that the sweet banana and the watermelon have higher protein contents respectively 2.20% ± 0.00 and 1.93% ± 0.00. The sweet banana also has a high content of ash (4.80% ± 0.00), carbohydrate (20.5 ±0.1) and mineral elements such as sodium (17.35 mg ± 3.68) and magnesium (30.8 mg ± 4.40). Watermelon has the lowest carbohydrate content (1.80% ±0.00). Avocado is energetic (161 ± 1.02 kcal). It has the high content of fat (43.5% ± 0.01), potassium (339 mg ± 22.3) and phosphorus (52 mg ± 3.02). As for the orange and the papaya, they have high contents of vitamin C respectively 70 mg ± 3.00 and 64 mg ± 2.00. Watermelon and cucumber have high water contents (respectively, 93.91% ± 1.00 and 91.4% ± 1.01). Cucumber and avocado have the lowest levels of vitamin C (respectively 1.2 mg ±0.00 and 1 ±0.00).

Table 1: Chemical composition of fruits and vegetables

Constituents	Banana	watermelon	Avocado	Cucumber	Papaya	Orange
Humidity (%)	73.8^{d} ±0.50	93.91^{a} ±1.00	70.8^{d}±1.00	91.4^{a} ±1.01	87.1^{ba} ±0.10	85^{cb} ±1.00
ME (kcal)	93.6^{b} ±1.00	29^{c}±0.05	161^{a} ±1.02	3^{d}±0.00	32^{c} ±0.05	62^{b}±1.00
Protein (%)	2.20^{a} ±0.00	1.93^{ab} ±0.00	1.82^{b}±0.00	1.27^{c}±0.00	0.5^{e} ±0.00	1^{d} ±0.00
Fat (%)	0.10^{b}±0.00	0.18^{b}±0.00	43.5^{a}±0.01	0.11^{b}±0.00	0.1^{b}±0.00	0.19^{b}±0.00
Carbohydrate (%)	20.5^{a}±0.1	1.80^{e}±0.00	4.8^{d}±0.00	4.06^{d}±0.00	7.8^{c}±0.00	15^{b}±0.05
Cellulose (%)	9.10^{d}±0.00	11.41^{b}±0.01	6.9^{e}±0.00	11.1^{b}±0.01	10.2^{c}±0.01	12.3^{a}±0.02
Ash (%)	4.80^{a}±0.00	0.81^{d}±0.00	1.77^{c}±0.00	3.17^{b}±0.00	0.5±0.00	1.2^{d}±0.00
Potassium (mg/100g)	318.95^{b}±28.20	143.91^{e}±7.40	339^{a}±22.3	38^{f}±1.01	214^{d}±17.00	237^{c}±15.01
Phosphorus (mg/100g)	21.7^{b} ± 2.40	17.4^{c}±0.01	52^{a}±3.02	6^{f}±0.01	11^{d}±1.02	18^{c}±0.05
Calcium (mg/100g)	4.9^{e}± 1.00	10.43^{d}±0.01	12^{c}±0.05	4^{e}±0.00	20^{b}±0.05	52^{a}±1.00
Sodium (mg/100g)	17.35^{a}± 3.68	1.25^{d}±0.00	7^{b}±0.02	1^{d}±0.00	3^{c}±0.00	0^{e}±0.00
Magnesium (mg/100g)	30.8^{a}± 4,40	11.31^{c}±0.05	29^{a}±2.01	3^{d}±0.00	13^{b}±0.03	13^{b}±0.05
Vitamin C (mg/100g)	4.5^{d}±0.30	8.6^{c}±0.01	1.2^{e}±0.00	1^{e}±0.00	64^{b}±2.00	70^{a}±3.00

The different letters a, b, c, d, e, f on the same line mean that there is a significant difference at the 5% threshold between the values.
ME: Metabolizable Energy

DISCUSSION

The differences between the chemical compositions of fruits and vegetables could be linked to several phenomena. According to Ahmad *et al.*, (2010) and Ana *et al.*, (2013), the physico-chemical and nutritional compositions of fruits and vegetables depend on the fruit or vegetable, the cultivation practice, the climatic conditions of the region of origin, the maturity and the storage conditions. The energy and lipid values obtained for avocado are different from those of Patricia *et al.,* (2016). The latter found 140-228 kcal and 13.5-24% respectively for energy and lipids. While in this present study, it was found 161 kcal for energy and 43.5% for lipid content. These observed differences would be related to the mass of the fruit, the variety of avocado, the drying process and the extraction method. This remark was made by Santos *et al.*, (2013). These authors demonstrated that the lipid content in avocado is between 25 and 33% when the fat is extracted by cold pressing. The content is between 45 and 57% when proceeding by the method of solvent extraction. The potassium and phosphorus contents of avocado for the present study are similar to those found by Dembitsky *et al.*, (2011) respectively 339 mg and 48 mg per 100 g of DM.

The vitamin C content obtained in papaya differs from Jin-Sik *et al.*, (2018). These authors reported 0.98 mg/100 g of DM, whereas in the present study, 64 mg/100 g was found. This difference would be attributable to the maturity of the fruit. Indeed, when the papaya is more mature, its nutrient content is high (Wurochekke *et al.*, 2013).

The vitamin C content of the orange in the present study is significantly higher than that reported by Ciqual (2016). The latter obtained a vitamin C content of 57 mg/100 g whereas in the present study, it is obtained 70 mg/100 g. This difference would be related to the variety of orange, to the storage temperature. According to Aurélie *et al.*, (2016), the storage temperature decreases the vitamin C level from 18% to 39% after two months of storage.

The water content of cucumber agrees with the values found by Roggatz *et al.*, (2016) and Barreira *et al.*, (2017).

Water contents of watermelon reported by Duduyemi *et al.*, (2013) and Olayinka and Etejere (2018), 91.5% and 93.65-96.79% respectively are similar to the water content of the present study (92%). This high water content has the consequence of the rapid deterioration of this fruit (Oziama *et al.*, 2013).

The protein and sodium contents obtained for sweet bananas are different from those of Aurore (2009). The latter found a value of 1.1% for protein and 1 mg for sodium, while in the present study, it was obtained 2.2% for protein and 17.35 mg for sodium. This difference would certainly be linked to the degree of ripening of the fruit, to the variety of the fruit, to the culture medium. Indeed, these different factors determine the nutritional composition of the fruit. According to Bugaud *et al.*, (2009), the chemical composition of the sweet banana is influenced by its variety, the cultivation area and the cultivation practices. These authors showed that during ripening, enzymes (amylases and catalases) transform polysaccharides into disaccharides, then into monosaccharides. During this phenomenon, the monosaccharide and disaccharide phase characterize the phases whose sugar contents are high in sweet banana. However, the protein and magnesium values found in the present study for the sweet banana are similar to the results of Mohapatra *et al.*, (2010). These authors reported a protein level of 2.20% and a magnesium content of 30 mg. As a general rule, bananas have a high carbohydrate content (20 to 23%) and are almost devoid of lipids (0.2 to 0.3%), sodium chloride, hence their use in salt-free diets (Aurora, 2009).

CONCLUSION

Chemical characterization made it possible to determine the macronutrients and micronutrients contained in sweet banana, watermelon, avocado, cucumber, papaya and orange. Sweet banana and watermelon have higher protein contents. The sweet banana also has a high content of ash and mineral elements (sodium and magnesium). Avocado is rich in lipids, potassium and phosphorus. Orange and papaya are rich in vitamin C. Watermelon and cucumber is rich in water. This study showed that the fruits and vegetables used would be excellent substrates rich in macronutrients and micronutrients for the growth of black soldier fly larvae.

ACKNOWLEDGEMENTS

We would like to thank the company Labograin Africa for facilitating the collection and the transport of fruits and vegetables.

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