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Use of house cricket to address food security in Kenya: "Nutrient and chitin composition of farmed crickets as influenced by age"

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House cricket is currently introduced for scaled-up production in farming systems in Kenya and other parts of the world, as an alternative source of animal proteins. The aim of this study was to assess the nutritional composition in farmed cricket as influenced by age in order to ascertain the optimal harvesting time for possible utilization of crickets in improving child nutrition in Kenya. Sampling was carried out between weeks 4 and 13. The moisture content was analysed by drying method, chitin by sodium hydroxide digestion, protein content by estimation of total nitrogen, crude fat by soxhlet extraction method, ash by muffle furnace incineration, available carbohydrates by subtraction, and energy by calculation method. The crude protein mean ranged from 36.00 to 60.00 g/100 g, chitin 2.20 to 12.40 g/100 g, total lipids 12.00 to 25.00 g/100 g, over the 13 weeks period. Minerals concentration was optimum at week 9, with magnesium 1.30 to 11.30 mg/100 g, calcium 1.40 to 19.70 mg/100 g, and zinc 0.20 to 16.60 mg/100 g. Findings from this study indicate that farmed cricket would be best harvested between weeks 9 and 11, when the protein and mineral content is optimum. Nutrients available in farmed crickets show that farmed crickets can be used in child food ingredients to improve child nutrition.

Key words: Farmed crickets, proximate, protein, fatty acid, omega 3, omega 6, minerals, child nutrition.

INTRODUCTION

Food security in Kenya is still a challenge and there is need for agriculture diversity to help Kenyan population get sufficient food (Mburu et al., 2016; Kimiti et al., 2016). Food and nutrition security affects most countries in the world and is directly linked to other problems such as human health and poverty (Pritchard, 2016).

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Millions of children in the world are currently affected by acute malnutrition (Bliss et al., 2016; Bartz et al., 2014; Black et al., 2013), with half of the deaths in children below 5 years being caused by under nutrition or nutrition related complications (Black et al., 2013). High prevalence of malnutrition, characterised by stunting early in life has been demonstrated in the Kenyan population by studies done recently, and lack of proteins is rated high in Kenyan children (Kimani-Murage et al., 2015; M'Kaibi et al., 2015). There has also been increased cases in morbidity and mortality due to poverty and food insecurity (Cohen et al., 2015).

While the major source of protein for human consumption is plant and animal proteins (meat, pork, fish, milk and eggs) which is rated higher in quality, and therefore preferred by many people (Ertl et al., 2016; Martens et al., 2013; Cook and Monsen, 1976). These animal proteins are however expensive and not easily available (Van Huis, 2013). The high cost of animal protein is partly contributed by increasing demand for animal protein directly attributed to sharp population rise (Konyole, 2014). This has prompted search for alternative sources which include insects.

Insect consumption has been practiced among Kenyan communities since ancestral times, and more so, when there was food insufficiency (Evans et al., 2015). In the recent years, there is great interest in insect consumption all over the world, since they have been found to contain high nutrient content (van Huis, 2015; Halloran et al., 2015). The only difference in the past and present in relation to edible insects, is that in the past, insects as food was considered a hobby where people in few communities would go to the forest to collect them when the season allowed for non-commercial home consumption compared to the recent times where they are increasingly sold in the markets and on the streets (Durst and Hanboonsong, 2015).

In Kenya, use of insect for food is an ancient tradition in many communities, and currently a more sort after delicacy in the western region of Kenya, (Ayieko et al., 2012; Kinyuru et al., 2009; Christensen et al., 2006). People are used to collecting insects in the wild, this was largely carried out by women and children, and insect farming is thus a new idea among the Kenyan population (Rumpold and Schlüter, 2013; Kinyuru et al., 2012; Bukkens, 1997).

Insects have a varied biochemical composition of both macronutrients and micronutrients (Finke, 2016). Crickets in particular, offer a highly economical protein source (Caparros Megido et al., 2016), and therefore, sustainable solution to existing and looming issues of malnutrition. Better nutrition can be achieved by production and distribution of high quality protein (Kelemu et al., 2015). To help meet growing demands of quality nutrition as the world population grows, insects are good for children especially undernourished children, due to high protein and fatty acid content (Acosta and Fanzo, 2012), and plenty of minerals such as iron, selenium, copper, magnesium and zinc. Cricket farming is a feasible venture and has demonstrated success in other countries for example in Thailand (Hanboonsong et al., 2013).

Cricket rearing requires simple locally available raw materials, which includes egg trays, which is importance if the local community will adopt rearing of crickets in an easy affordable way. Currently, cricket farming is still under small-scale production in most parts of the world (Halloran et al., 2016), but people are slowly adopting to cricket rearing largely for cash at the local markets and this is why there is increased interest in cricket rearing.

Cricket rearing has been shown to be economical in water and feed consumption, since they consume little water and food. Cricket rearing is also time efficient and an environmentally safe way of alternative protein generation as they produce less greenhouse gases (Caparros Megido et al., 2016). Crickets have a high feed conversion rate, therefore providing high quality nutrients, which in turn are cheaper, efficient and environmentally sound protein source when compared with traditional livestock protein sources, which are expensive to maintain (Payne et al., 2015). Crickets could therefore be used to curb food insecurity and malnutrition in developing countries. For this to happen, they should be incorporated in the day to day diet. However, to improve widespread utilization, they have to be reared in large-scale and in a sustainable manner in order to supply a wider population (Van Huis et al., 2015).

The aim of this study was to assess the nutritional and chitin composition of farmed cricket as influenced by age in order to ascertain the optimal harvesting time for maximum nutrient content in an effort to incorporate them in the diets to improve child nutrition. Crickets' rearing was preferred for this study since crickets are easier and cheaper for mass produce.

METHODOLOGY

Cricket production

This study was carried out at Jomo Kenyatta University of Agriculture and Technology (JKUAT). The rearing was carried out in simple fabricated cages that mimicked the crickets natural environment (Hanboonsong, 2013; Loranger and Bertram, 2016). The nymphs were fed on 21 g/100 g protein feed, commercially available as a starter diet. After two weeks, the diet was alternated with commonly available vegetables and weeds such as pumpkins leaves, cassava leaves, morning glory leaves, black jack and sukuma wiki depending on the availability of the green leaves since crickets are known to be herbivores (Lundy and Parrella, 2015). At four weeks, the 21 g/100 g protein commercial feed was replaced with 14 g/100 g protein commercial feed and supplemented with green leaves for their life span.

For this study, one pen was used to breed crickets under the same structure to minimize variations in environmental conditions and feeding. All crickets were fed on the same diet and maintained under similar conditions with average temperature of 25°C throughout the study period.

Sample collection and preparation

Sampling was done every week from week four to week 13. Three independent samples were collected weekly on days 1, 3 and 5 of the week. One kilogram of harvested cricket yielded three samples which formed samples representing the week.

After collection, the crickets were frozen at -20°C overnight, then washed in tap water and rinsed in distilled water. The crickets were then oven dried at 50°C for 72 h. When the crickets were dried with moisture content 4.00 to 6.00g/100g, the crickets were crushed to very small fine particles (250 mm), to get the cricket powder. When 1 kg of the harvested crickets was oven dried, approximately 400 g of dry weight was obtained. The cricket powder was stored at -20°C and during analysis only the required amount was taken from the freezer. All analysis was carried out in triplicate.

Proximate analysis

Standard methods for proximate analysis were adopted in this study. To determine crude proteins, total nitrogen obtained by micro-Kjeldahl method was used; percentage nitrogen was multiplied by 6.25 N factors to obtain crude protein content in crickets (AOAC, method 990.03). Crude fat was obtained by Soxhlet extraction method (AOAC, method 920.39). AOAC, method 940.28 was used to determine fatty acid profile, and calculation of omega 3 and 6 fatty acid in the crude fat.

Ash determination was done by 550°C muffle furnace incineration (AOAC, method 920.48). To determine the available minerals in the sample, AOAC method 984.27 was used. Mineral analysis was determined by dry ashing and measured by flame atomic absorption spectrophotometry (Shimadzu 6300 AAS AA/AE Spectrophotometer) (AOAC, 2005). Quantification of minerals was done using commercial standards (Sigma-Aldrich Chemie, Steinheim, Germany). In-house controls were also used by using a vacuum packed controlled sample stored at -20°C.

Available carbohydrate content was calculated from the proximate values by subtraction method. Energy levels from the proximate analysis, was obtained by Energy content = (Crude protein × 4) + Crude fat × 9) + (Available carbohydrate × 4) (AOAC, 2005).

Chitin extraction

To extract chitin from crickets, 150 g of ground cricket powder was placed in 1000 ml beaker containing 4% boiling sodium hydroxide and the mixture was boiled for 2 h for the powder to undergo deproteinization to remove sugar and protein components (Toan, 2009; Lertsutthiwong et al., 2002). The content was allowed to cool for 30 min, followed by centrifuging at 10000 revolutions per minute, for 10 min to separate the solid part containing chitin from the liquid part containing sodium hydroxide, sugar and proteins components (Galed et al., 2005).

To dissolve minerals from the centrifuged residue, 600 ml of 1% hydrochloric acid was added and the residue placed in a rotor shaker (Sanyo electric company limited, Japan) rotating at 40 rpm for 24 h at room temperature (Trung et al., 2006). The content was then subjected to centrifugation and the liquid part disposed while the remaining residue was treated with 500 ml of 2% boiling sodium hydroxide for 1 h to decompose albumin (Puvvada et al., 2012). The content underwent centrifugation and the liquid part that contained albumin was discarded. The brown solid residue was washed three times with boiled distilled water to remove the remaining polysaccharides and sodium hydroxide, and then dried at 70°C for 60 h after which the extracted chitin was kept in zip lock bags at -20°C until use.

Amino acid analysis

Approximately, 2.00 g of the cricket flour sample was used for amino acid analysis. The sample was defatted using methanol before hydrolysing using 6 M hydrochloric acid. Amino acid analysis was done using ion exchange chromatography, the hydrolysed sample was injected into the amino acid analyser (Technicon Instrumentation Corporation, Dublin, Ireland.), for separation and characterization of amino acids, using the Technicon sequential multi sample amino acid analyser (Ertingshausen et al., 1969).

RESULTS

Figure 1, shows the nutrient and energy content of cricket based on harvesting age. Cricket which were four weeks old were chosen as the starting point for cricket harvesting since crickets which were less than four weeks old were too small to be handled, and this would mean harvesting so many crickets to obtain the required mass. Protein content was on a staggering rise from week 4 to 11 and dropped at weeks 12 and 13. The protein content in cricket increased as the cricket aged, though the increase is not linear and maximum protein content was seen between week 9 (58.30 g/100 g), week 10 (59.74 g/100 g) and week 11 (60.40 g/100 g). The rise in total lipids is slow when compared with cricket protein content rise (Figure 1), the lowest lipid content was seen at week 13 (12.00 g/100 g), while the highest was at weeks 9 and 10 at 25 g/100 g. Cricket chitin content was on steady rise as the crickets aged and at week 13 chitin content was at maximum 12.33 g/100 g, of the total cricket content. Ash content was almost constant across all ages with approximate composition of between 4.00 g/100 g and 5.00 g/100 g content; there was no defined rise in ash content. Initially, available carbohydrate was high at 39.23 g/100 g at four weeks, then drops drastically to 14.60 g/100 g at week 6, before increasing again at week 7 (Figure 1). Energy levels were high between 1827.03 kJ/100 g at week 4 and rose to 1807.49 kJ/100 g at week six. Optimum energy content is seen at week nine, 1774.02 kJ/100 g.

Table 1 shows mineral content in farmed crickets; mineral content starts at a higher level and slightly drops as the crickets aged and finally rose at weeks 11, 12 and 13. There is no defined rise or drop in mineral contents: magnesium optimum levels of 12.00 mg/100 g was seen at week 12, calcium 11.33 mg/100 g at week 13, copper 10.67 mg/100 g at week 12, iron at 0.04 mg/100 g at week 13, and zinc 19.33 mg/100 g at week 11.

Figure 2 outlines the major fatty acid fractions of cricket

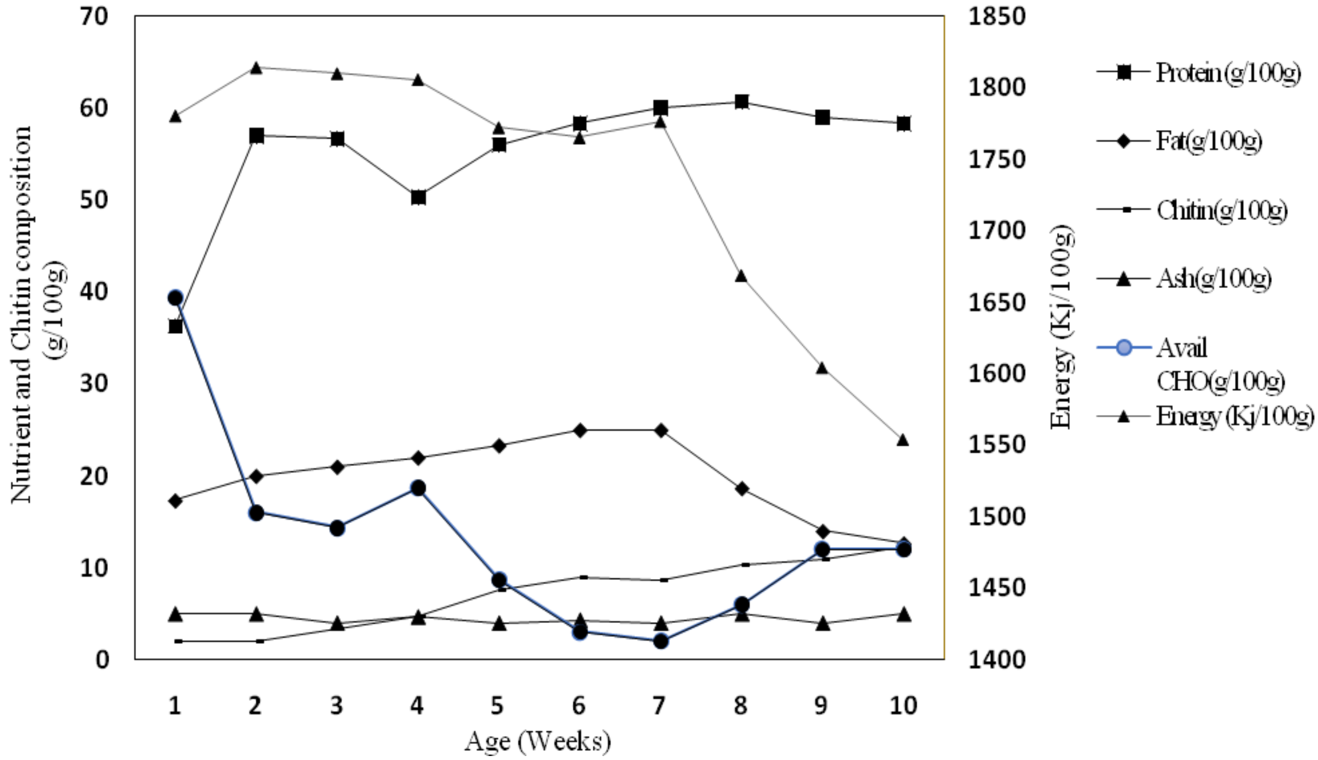

Figure 1. Proximate,chitin and energy content of crickets harvested at different ages.

Table 1. Mineral composition (mg/100 g) of cricket harvested at different ages.

Age in weeks	Magnesium	Calcium	Copper	Iron	Zinc
4	11.33	5.67	8.67	0.03	15.00
5	9.00	2.67	3.67	0.01	12.33
6	10.33	1.67	9.33	0.02	17.00
7	9.33	1.67	6.00	0.01	15.00
8	9.00	1.33	4.67	0.03	14.67
9	9.67	11.00	5.67	0.03	15.33
10	9.33	1.67	4.33	0.01	14.33
11	9.33	2.00	5.67	0.02	19.33
12	12.00	8.00	10.67	0.03	14.67
13	9.67	11.33	5.33	0.04	15.67

oil, which clearly show that cricket fat is rich in good fats which includes omega 6 and 3. Crickets had polyunsaturated fatty acids (PUFAs) ranging from 2.00 to 5.00 g/100 g, the PUFAs increased from week 4 to reach a maximum of 5.00 g/100 g at week 7 and drops again to 3.00 g/100 g at week 13 (Figure 2). Saturated fatty acid (SATU's) increased as the cricket aged from 48.29 g/100 g at week 4 to 63.88 g/100 g at week 6 and then drops to 46.12 g/100 g at week 13. Mono-unsaturated fatty acid (MUFAs) increased from week 4 to 12 and slightly reduces at week 13.

Table 2 shows the fatty acid composition of cricket oil at different ages. When cricket fatty acid profile is further grouped into omega 3 and 6 and the ratio between omega 6 and 3 calculated, the ratio ranged from 0.33 to 2.40.

Table 3 shows the amino acid content of cricket protein in mg/g protein. Out of the total amino acids, 13 amino

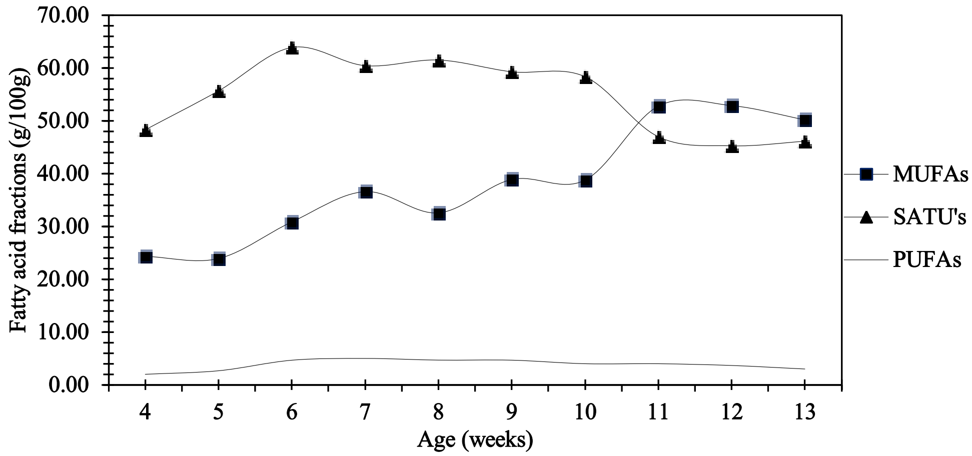

Figure 2. Fatty acid fractions in cricket oil with age in weeks. SATU's, Saturated fats; MUFAs, monounsaturated fats; PUFAs, polyunsaturated fats.

Table 2. Fatty acid composition of cricket oil at different ages.

Age (weeks)	Fatty acid g/100 g							
	Palmitic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid	EPA	DHA	Omega 6/Omega 3 ratio
4	18.05	23.95	2.08	1.00	1.00	1.00	1.00	1.04
5	18.74	23.00	6.40	1.00	1.00	1.00	1.67	2.40
6	19.96	29.58	5.97	1.00	1.00	1.33	3.33	1.28
7	32.19	35.39	1.63	1.00	1.00	2.00	3.00	0.33
8	28.15	31.26	5.47	2.00	1.67	2.00	2.68	1.17
9	24.97	37.45	8.30	2.00	1.33	1.67	3.00	1.78
10	25.04	37.06	5.00	3.00	2.00	1.00	3.00	1.25
11	27.78	51.17	3.00	3.00	1.33	1.00	3.00	0.75
12	28.00	51.52	3.00	3.00	1.33	1.00	2.67	0.82
13	26.69	48.89	3.33	3.00	2.00	1.00	2.00	1.11

Table 3. Amino acid contained in cricket protein in mg/g protein.

Compound	Amount	Recommended mg/g protein (3-10) years
Histidine	ND	16.00
Arginine	67.23	-
Lysine	ND	48.00
Glutamine	ND	-
Serine	ND	-
Glutamic acid	ND	-
Proline	15.83	-
Valine	12.47	40.00
Methionine	11.32	22.00
Tyrosine	11.32	22.00
Isoleucine	ND	31.00
Leucine	17.27	61.00
Phenylalanine	13.68	22.00

(Ricardo et al., 2015).

acids were analysed and 7 out of the 13 had detectable values.

DISCUSSION

This study has demonstrated that house cricket has high protein content up to about 60.67 g/100 g of the total nutrient content, based on daily value in 8368.00 kJ diet for children above four years and adults (Krauss et al., 2000; Mann and Truswell, 2012); 100 g of cricket serving per day would provide the required 50 g protein. Since the crickets were fed on locally available diets, it is clear that the high protein content can be achieved by local farmers who would like to adopt the simple diet and this makes cricket rearing for protein supplementation a venture worth exploitation in Kenya and other part with similar setups as Kenya. Most children suffer from malnutrition due to insufficient or lack of proteins and therefore crickets provide an opportunity to help these children.

The results correlated well with other studies that have shown high protein content in insects (Kinyuru et al., 2015; Collavo et al., 2005). Since protein content declined in weeks 12 and 13, it would be of importance to consider weeks 9, 10 and 11 have the optimal time for cricket harvesting if the target is to get the highest protein content. In a study carried out by De Foliart et al. (1982), in the earlier decades, crickets were found to contain high protein content of 54.00 g/100 g, this study has demonstrated that cricket protein content can be higher than 54 g/100 g.

Crude fat content of between 12.67 and 25.00 g/100 g in house cricket, is within the range observed by Narzani and Sarmah (2015) where crude fat content in insect seemed to vary from 1.00 g/100 g to 40.00 g/100 g (Narzari and Sarmah, 2015). If children would be given 100 g serving of crickets per day, the crude fat content would provide about 38% of the total daily requirements (65 g/100 g). Other studies have shown low fat content in crickets, when compared with fat content in termites (Payne et al., 2015). Low fat content in cricket would be of importance for industrial exploitation of cricket, since high fat content hinders procesability and shelf life of food products, hence reduce its mass production and market potential (Kinyuru, 2014). Crickets therefore demonstrate high market potential and extended shelf life when compared with termites in relation to the overall fat content and their inclusion in food to supplement protein and fat especially in complementary food.

Insects are known to contain chitin as the major fibre, and therefore, in the current study, chitin was quantified from crickets. Chitin content in insects has been found to range from 4.00 g/100 g to 21.00 g/100 g (Finke, 2015). In the current study, the chitin content ranged between 2.00 g/100 g and 12.00 g/100 g which is the lowest at the tender age and increases as cricket age. This would be the highest contributor of hardened wings as the crickets' age increase. Cricket harvested at weeks 12 and 13 with the highest chitin content were hard to process since the cuticle was rigid and therefore the powder obtained was rough 510 mm as compared to 250 mm in weeks 4 to 11. Rough cricket flour would greatly affect the end products made from cricket powder and therefore it would be better to harvest crickets before too much hardening of the cuticle between weeks 9, 10, and 11. Chitin also did not contribute to energy content and the content rises, while the energy content declined, and this is why at weeks 12 and 13 the energy content was low.

Ash content was below 10.00 g/100 g in the current study, recent studies on insects have indicated that the ash content in insect is less than 10.00 g/100 g (Rumpold and Schlüter, 2015). In the past, studies have demonstrated that crickets having varied in nutrient content (Belluco et al., 2013), with content of available carbohydrates ranging from 1.00 g/100 g to 47.00 g/100 g (Narzari and Sarmah, 2015). In the current study, carbohydrate content was within this range, and as the age increased, the carbohydrate levels steadily decrease over time especially when protein levels and chitin content increased. At week 7, there is a drop in most nutrients which seem to be the lowest at this age; it would be of importance for future scientist to find out if the drop has any correlation with start of egg laying in cricket.

Previous studies have shown insects to be energy dense with up to 2418.35 kJ/100 g of energy (Finke, 2013). The energy content fluctuates, which is attributed majorly to the fluctuations in other proximate contents. The energy levels in cricket started off at a high level and when fat content drops the energy content also drop. As much as the energy contents drops, the drop is not much since the overall energy content ranges from 370.01 kJ/100 g and 1807.49 kJ/100 g. This study shows crickets are energy dense food source, and can easily be an option to curb malnutrition in energy deficient children in developing world where malnutrition rates are still high (Black et al., 2013), as long as the crickets are harvested at the right age to ensure a balance of proximate nutrients, minerals and energy.

Cricket mineral composition shows that crickets are not just energy dense food, they are also good for curbing high mineral deficiency in Kenyan children, since past studies have indicated high mineral deficiency in children (Duong et al., 2015). The data obtained from this study compared well with other studies that have analysed mineral content of crickets (Rumpold and Schlüter, 2015; Payne et al., 2016; Taufek et al., 2016).

Crickets oil contains lauric acid 1.5% which is found in breast milk and coconut oil and is converted to monolaurins which protects children from disease (Dayrit, 2015). Crickets contain myristic acid 3% which is also contained in cow milk (Mazhitova et al., 2015). Poly unsaturated fatty acid (PUFAs) content in crickets is an advantage especially in human nutrition since PUFAs in diet has been linked to anti-obesity and increased activity in children (Średnicka-Tober et al., 2016). Cricket meal would provide higher percentage of saturated fatty acid at 46 g/100 g when compared with 33 g/100 g in beef and 34 g/100 g in chicken (Ton et al., 2015), while PUFAs was at 5 g/100 g in crickets which is the same as PUFAs percentage in beef (Ton et al., 2015; Średnicka-Tober et al., 2016). Supplementing children diet with cricket would give the children the needed lipids which would ensure more health and increased activity in children.

Oil containing omega 3 and 6 fats has been rated positive in child's diet. The oil found in cricket has omega 3 and 6 fatty acid which clearly indicates that feeding children with cricket would boost their good fat content. Past studies have indicated that fatty acid is more desirable when the ration of omega 6:3 is lower or almost equal to one (Yang et al., 2006); human beings are believed to have evolved on omega 6:3 balanced diet of 1:1 (Oddy et al., 2004) and increase ratio of omega 6:3 promotes obesity in children (Simopoulos, 2016). Growing children need sufficient amounts of omega 3 and 6 (Brenna et al., 2015). Therefore, cricket meal is important if adopted to feed children to improve child nutrition.

There is need for higher protein content in children to be able to meet the required amino acid patterns. Malnourished children require slightly higher protein intake, to enable them get required amino acids (Ricardo et al., 2015). Since cricket contain high protein content, its use in improving child nutrition is likely to boost the amino acid requirements in moderately malnourished children. Farming of crickets can be achieved in drought stricken areas, because cricket requires small amount of space and water. Since drought is a major constrain in Kenyan agriculture (Huho and Mugalavai, 2010), exploitation of crickets can address food security.

CONCLUSION AND RECOMMENDATIONS

The optimum age for farmed cricket harvesting would be between week 9, 10, and 11, when the protein, total lipids and mineral content is optimum. At this age chitin content is slightly lower hence better procesability and finer flour which would greatly enhance the end product made from cricket. Cricket omega 6 to 3 ratio makes cricket oil good for child nutrition. This study recommends the rearing of crickets and the use of cricket in child nutritional interventions for its high protein content, which is often the major cause of child under nutrition.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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