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# Nutrient composition of *Blaptica dubia* (Order: Blattodea) as an alternative protein source

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## Abstract

*Blaptica dubia* is a cockroach that used as feed for most reptiles and amphibians because of it nutritive value. Its alternative protein sources can replace the current high priced imported animal feed such as fishmeal, soybeans and meat. It has potential as an animal feed and minimize high livestock farming cost of the farmers. A study was conducted to determine the nutritional composition (moisture, ash, crude protein, chitin and fat) of *B. dubia* in different growth stages. Moisture and ash determine using AOAC protocol, protein using Kjeldahl method, chitin using chemical treatment and fat analysis using soxhlet extraction method. The proximate analysis of adults and nymph of *B. dubia* contained 59.06-62.70% moisture, 2.47-4.17% ash, 47.50-54.32% crude protein, 3.83-5.58 % chitin and 35.49-44.22% fat on dry weight. Thus, the tested feed pellets could be an alternative protein source as the animal feed especially in pet industry.



## 1. INTRODUCTION

In 2050, the world population is predicted to reach 9 billion people and minimum 70% risen of global harvested yields are required to provide sufficient food sources (Finley & Seiber, 2014). The increasing world population bring up the issues of food insecurity due to the production of food sources are unable to support for human and livestock consumption. Sustainable food and feed sources are needed to produce adequate food supply continuously for the growing population. Insects will be a newly alternative choice. Entomophagy which means insects eating is becoming economic importance for feed and food sources due to the nutritive components, low costing and the fast reproduction rate of the insects (Anankware et al., 2015).

Insects can be used as food because of its absolute protein levels and protein quality (Yi et al., 2013). Insects give a high food conversion efficiency when compared with conventional livestock due to its shorter life cycle. The production of protein sources from insects will cause less environmental effects than the breeding of livestock, which producing greenhouse gas and ammonia emissions. Thus, the culturing of insects can be introduced as a sustainable farming of protein production.

Dubia cockroach (*Blaptica dubia*) also known as South-American Dubia cockroach and Orange-spotted cockroach, is a large, sexually dimorphic blaberid cockroach. The wings are fully developed in the males adults but they have a poor development of arolium between their claws which make them unable to climb on smooth surfaces; neither nymph nor adult stages (Wu et al., 2013). This species is reared as feed for most of the reptiles and amphibians. *Blaptica dubia* consists of higher protein content compared to other insect sources such as crickets which are commonly used. Its rearing method is easy to be maintained with minimum smell compared to other cockroaches. Low-technique is required in rearing the insects as they are easily feed on organic waste materials and convert it into protein (van Huis et al., 2013).

Dubia cockroach can be a good alternative source of protein with less environmental impact, short life cycle and able to be reared in a huge production. Malaysia is a tropical country which provides a suitable climate in term of temperature and humidity for the breeding of Dubia cockroach. However, far too little attention has been paid to culture and convert its protein content into animal feed in this country. In this scenario, our aim is to determine the nutrient composition of B. dubia at adults and nymph stages.



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## 2. MATERIALS AND METHODS

### 2.1. Rearing

*Blaptica dubia* colonies were reared at a mean room temperature of 26.16 ± 2.5˚C with about 75.34 ± 6.98% of relative humidity. They were maintained in the plastics box [35(h) x45(w) x60(l) cm]. The plastics boxes were covered with netted lids (Ø ≈ 2mm) to provide air circulation for the colony. The egg cardboards were provided and stacked horizontally inside the plastics box to act as shelter, hiding and breeding sides. The colonies were supplied with kitchen waste and water sources in the corners directly on the container floor.

### 2.2. Nutrition analysis

*Blaptica dubia* which are adult male, adult female and nymph (Figure 1) were sampled and analysed for moisture, ash, protein, chitin and fat content. The moisture content was determined by drying 2g sample at 135°C for two hours (AOAC, 2005b; Undersander, et al., 1993). The ash content was determined by burning 5g sample in a muffle furnace at 550°C for three hours (AOAC, 2005a). Analysis of protein content was done using Kjeldahl method (FOSS, 2003). Chitin extraction was using chemical treatment method suggested by Majtán et al. (2007). Soxhlet extraction method was used to analyse fat content (Anderson, 2004). All of the analysis conducted for five replicates.

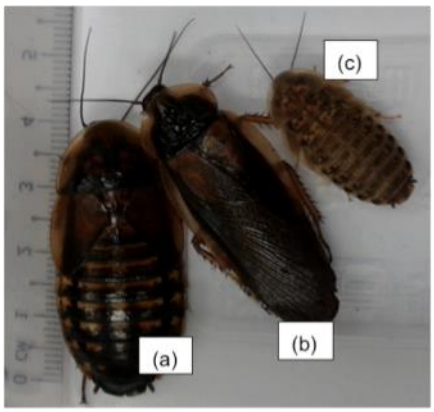


**Figure 1**: Appearance of *Blaptica dubia*. (a) Female adult, (b) Male adult, (c) Nymph

### 2.3. Statistical analysis

One-way analysis of variance (ANOVA) was used to measure the significance of the differences between the nutrient contents in nymph and adult stages of *B. dubia*. All statistical test was performed using SPSS (IBM SPSS Statistics Version 22). For graphical representation of nutritional value, a radar chart was develop using Microsft Excel 2012.

## 3. RESULTS AND DISCUSSION

Table 1 shows the proximate nutrient composition of *B. dubia* for male, female and nymph that determined on dry matter basis. Male had the higher moisture content of 62.70% while nymph had the lower moisture content which is 59.06%. The study found that no significant difference in the moisture content between male, female and nymph (*p*-values >0.05).

The result in Table 1 show higher ash content (4.17%) in male compared with female and nymph which are 3.69% and 2.47%, respectively. However, significant difference was found in between ash content of male, female and nymph ($F_{(2,12)}$ = 3012.665, p = .000).

Male consist of the highest protein content which was 54.32% follow by female (52.87%) and the least in nymph which was 47.50% (Table 1 & Fig. 2). The protein content in male showed significant difference compare with female and nymph of B. *dubia* though($F_{(2,12)}$ = 37.984, p = .000). However, no significant difference was found in between female and nymph (post hoc Tukey test, p = 0.227).

**Table 1**: Proximate nutrient composition of *Blaptica dubia* in male, female and nymph.

| | Moisture (%) | Ash (%)* | Protein (%)* | Chitin (%)* | Fat (%)* |
|---|---|---|---|---|---|
| **Male** | 62.70 ± 1.08[a] | 4.17 ± 0.03[a] | 54.32 ± 2.00[a] | 4.38 ± 0.79[a] | 35.51 ± 0.71[a] |
| **Female** | 61.46 ± 3.45[a] | 3.69 ± 0.05[b] | 52.87 ± 1.01[b] | 5.58 ± 0.23[a] | 35.49 ± 3.68[a] |
| **Nymph** | 59.06 ± 1.00[a] | 2.47 ± 0.02[c] | 47.50 ± 0.23[b] | 3.83 ± 0.36[b] | 44.22 ± 1.05[b] |

Result represent the Mean ± SD of the five estimations.
*The percentage of Ash, Protein, Chitin and Fat are based on the dry basis of the sample.
[a b c] represents the significant different (p<0.05) of respective composition among the male, female and nymph.

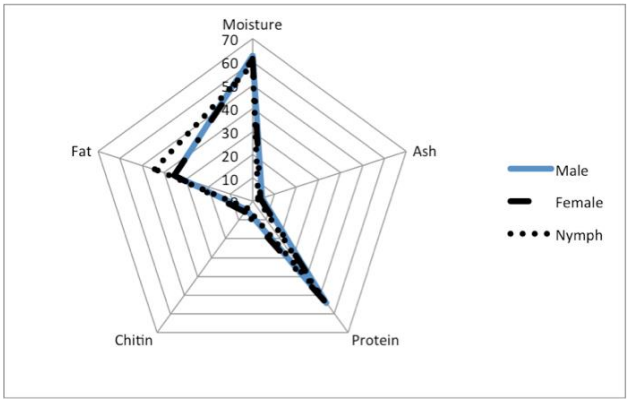


**Figure 2**: Radar chart of nutritional value of *B. dubia* according to the male, female and nymph.

The chitin content observed in female was 5.58% which was higher than male (4.38%) and nymph (3.83%). There are significant difference of chitin value among the adults and nymph($F_{(2,12)}$ = 14.961, p = .001). .

The nymph had high amount of fat (44.22%) than male and female which were similar of 35%. Significant difference was found in fat content between male to nymph and female to nymph.

Insects are being used for its multiple purposes, such as human food and animal feeds as an alternative nutritional sources. *Blaptica dubia* is increasing popularity among western countries to use as feeder insects for



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reptiles and amphibians or even able to act as additive value for broiler chicken feeds as stated by Bildan et al. (2012). The nutritive value in cockroach can be act as healthy food and feed materials, also the food safety evaluation have confirmed that cockroach is not poisonous to animals and human Feng et al. (2014).

The ranges of moisture content of *B. dubia* in this study were similar with the moisture of Argentinean cockroach (59.63%) and American cockroach (61.30%) as stated by Young (2010). The moisture content found in the study also match with the general moisture presented in raw insects (55 to 85%) and low moisture content in whole insects usually indicated high fat composition (Finke, 2008). Similarly, the nymph of *B. dubia* shown lower moisture content when compare with adults but highest value of crude fat. The moisture content found in other insects are 3.63% in adult *Holotrichia parallela* (beetle) (Yang et al., 2014) and 56.82% in *Rhychophorus phoenicus* (weevil) (Amadi et al., 2014). Higher moisture content may increase the microbial activities and caused deterioration during storage (Siulapwa et al., 2014).

The lower of ash content in *B. dubia* was indicated that there was lacking of minerals it contains which lower than other insects like the larva of *Cirina forda* (10.26 ± 0.01%) that considered minerals-rich insect (Omotoso, 2006). Ash content of *B. dubia* in this study also lower than the great minerals source of cricket (*Brachytrupes membranaceus*) that consist of 6.4% (Paiko et al., 2013).

Significant difference found in protein value between *B. dubia* adults (male and female) and nymph stage is due to the adult has high crude protein content (54.32% and 52.87%) than the nymph (47.50%). Bigger sized adults have form harden cuticle than the smaller nymph stage which have a less nitrogenous soft cuticle. The reason is the adult stages are covered with a nitrogen-hydrogen bonded chitin layer that increase the N content in the calculation of protein content (Pretorius, 2011), due to the analysis method used (Kjeldahl method (FOSS, 2003)). Besides, Mayer (2014) stated that adult insects of crickets, houseflies, fruit flies, hissing cockroaches and Turkestan cockroaches consist of higher protein content than the juvenile cockroaches and nymph crickets. Mbah and Elekima (2007) found that the *Componotus* sp. (carpenter ants) could be used as feed in livestock supplement as it consists of high crude protein (40.10%) whereby, *B. dubia* probably is more suitable for the feed production due to a higher protein content. Longvah et al., (2011) also suggested that the protein content from defatted eri silkworm (*Samia ricinii*) pupae was suitable to use as animal nutrition in pet food or poultry industry.

When comparing to other protein sources (Pretorius, 2011), the protein content of common housefly (*Musca domestica*) larvae (60.38%), pupae meal (76.23%) and fish meal (69.13) are higher than the *B. dubia* while protein content in soya oil cake meal (49.44%) is slightly lower. *Blaptica dubia* also has a higher protein content than the long-horned grasshopper (*Ruspolia differens*) which has a value of 37.1% for green coloured grasshopper and 35.3% for brown coloured grasshopper stated in Kinyuru et al. (2011). Higher protein content are available in insects when comparing to lean red meat sources of beef (23.2%), veal (24.8%) and mutton (21.5%) (Kinyuru et al., 2011). Although livestock by-products such as chicken offal which consists of 65.8% crude protein are lower prices than fish meals (Omole et al., 2008), this cheap protein sources are lacking of essential biological values of amino acids (Shariff & Mona, 2013). Therefore, *B. dubia* could be used to replace the meat protein sources as it is easy to maintain in the small area of farm because rearing of this insects are inside the storage boxes that can be piled one above another.

The result shown in Table 1 and Figure 2 was against with Oonincx and Dierenfeld (2012) stated that higher protein and lower fat content in nymph stage of development as nymph had the least protein and highest fat percentages when compared with the adult stage of the same species. However, the protein content in male, female and nymph of *B. dubia* still remain in the ranges of cockroach species which was 38% to 76% dry matter that stated in the literature (Oonincx & Dierenfeld, 2012).

Higher chitin contents were found in adults of B. dubia than the nymph (3.83 ± 0.36%) but the female (5.58 ± 0.23%) was higher than male (4.38 ± 0.79%) in this study. However, the larval and pupal cuticles of the tobacco hornworm (*Manduca sexta*) consist of higher (14% and 25%) chitin content than the adult cuticles (7%) (Kramer & Muthukrishnan, 2009). Lower chitin also was found in *B. dubia* when compared with adult *Holotrichia parallela* which was 10.47 ± 0.53% (Yang et al., 2014) and 9.1% crude chitin from housefly larvae (Zhang et al., 2011). Although high yield of chitin can get from crustacean shells such as crab (13 to 26%), shrimp (14 to 42%) and krill (34 to 49%), the chitin extraction process from them is expensive (Tajik et al., 2008; Zhang et al., 2011). Thus, the chitin value available in insects can be another alternative source for extraction.

The fats available in diets play important roles to enhance the palatability of food, function of the cells and transportation of the vitamins (Omotoso, 2006). The crude fat content in nymph of the *B. dubia* was quite high, 44.22 ± 1.05%, when compared with the adults. Higher crude fat content also found in *B. dubia* when compared with Argentinean cockroach (34.88%) and American cockroach (28.4%) (Young, 2010). The nymph of *B. dubia* was similar to six-spotted cockroach nymph (*Eublaberus distanti*) in the past study of Oonincx and Dierenfeld (2012) which had more fat value and less protein content that could provide higher calorie as animal feed. Mayer (2014) also stated that the juvenile stage of beetles and



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cockroaches have higher fat value than the adult stage. Since the nymphs are younger than adults, the higher fat content in the nymph could be used as cheaper animal fat and oil-based products from insects (Mbah & Elekima, 2007).

However, the result in this study shown is diversed from Yi et al. (2013) which stated that *B. dubia* consist of 67.4 ± 2.1% moisture content, 19.3 ± 0.9% crude protein and 7.7 ± 0.1% fat content. This might due to different stages of *B. dubia*, segment of the insects' body, feeding materials and growing environment of the insect will affect the composition of the analysis.

Digestibility is important to determine the utilization of protein which provide the actual amount of nutrients consumed and absorbed by the animals as poor quality of protein and diets will give low digestibility (Badina, 2012). Low quality of protein will cause poor absorption in the animal and may influence health of the animals (Shariff & Mona, 2013). According to Oonincx and Dierenfeld (2012), the nutritional content that available in insects are able to achieve the domestic carnivores feeding requirements. However, the invertebrate cuticle or exoskeleton of various insect consist certain amount of chitin that can decrease the digestibility of the whole insect diet (Arbuckle, 2009).

Generally, 80% or higher protein digestibility was found in pet foods which will closely meet the amino acid and protein quality required by the animals (Buffington, 1991). The apparent digestibility of B. dubia feed pellets was consider high that having an average of 81.57%. However, it was similar to the apparent crude protein digestibility of high-protein extruded (81.6%) in cats but lower than the raw beef-based and cooked beef-based diet which were 93.3% and 92.9% Kerr et al. (2012). Schiavone et al. (2014) suggested that *Hermetia illucens* and *Tenebrio molitor* meals are suitable to use in feed for broiler chicken as alternative protein source due to their significant values of apparent digestibility of crude protein (69.1% and 66.1%). Finke (2008) indicated rats, chickens and fish which were fed with insects, such as flies, crickets and mealworms have been found to grow healthily due to the good palatability and absent of anti-nutritional factor.

There is limited reports on the essential requirement of amino acids, fatty acids and its composition in the insects that could be use as feed (Oonincx & Dierenfeld, 2012). Further research to be conducted to identify the specific nutrients elements in *B. dubia* as the additive value or alternative protein source that suitable for animal consumption.

## 4. CONCLUSION

Dubia cockroaches were found to have higher protein content when compared with other feeding sources. This enables to support the growing demand of protein sources for animal feed requirement. Insect farming has the advantages of low costing and fast reproduction rate if compared to animal livestock farming. *Blaptica dubia* also easy to maintain than the shorter lifespan crickets rearing that will make noise, smell and escape from the rearing colonies easily. In fact, the manufacture of animal feed from by-products of the livestock such as internal organs and bones which consist of less amount of nutrients that might not sufficient to support the diet of the rearing animals. Besides, the halal issues on the animal feed also being questionnaire on the sources of the raw materials. Thus, it could be an alternative way to get another protein sources to replace the livestock meat or by-products in animal feed. Insects have been becoming more and more economic important in other countries as they are more profitable compared with imported feed or raw materials that built up higher cost of production.

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## REFERENCES

Amadi, E. N., Kiin-Kabari, D. B., Kpormon, L. B., Robinson, V. K. K. (2014). Microbial flora and nutritional composition of adult Palm-Wine Beetle (*Rhychophorus phoenicus*). International Journal of Current Microbiology and Applied Sciences, *3*(11), 189-192.

Anderson, S. (2004). Soxtec: Its principles and applications In D. L. Luthria (Ed.), Oil extraction and analysis: critical issues and comparative studies. Champaign, Illinois: AOCS Press.

Anankware, P.J., Fening, K.O., Osekre, E., & Obeng-Ofori, D. (2015). Insect as food and feed: A review. *Agricultural Research and Review*, *3*(1), 143-151.

AOAC. (2005a). Official methods of analysis of AOAC International (18 ed.) Official method 942.05 - Ash of animal feed (pp. 8). Gaithersburg, Maryland: AOAC International.

AOAC. (2005b). Official methods of analysis of AOAC International (18 ed.) Official method 930.15. Gaithersburg, Maryland: AOAC International.

Arbuckle, K. (2009). Influence of diet on mineral composition of crickets used as prey for captive amphibians, specifically hylidae. (Master of Science), University of Glasgow.

Badina, A. I. (2012). Protein evaluation of dog food using mink (*Neovison vison*) as a model for ileal protein digestibility in dogs *(Canis familiaris).* (Masters of Science in feed manufacturing technology), University of Life Sciences Ås, Norway, Norwegian.

Bildan, D. M., Elli, M. V. C., Muldong, G. C., Leon, L. F. D., Dorig, R. J., Cruz, M. E. D. (2012). *Blaptica dubia (Dubia cockroach) as an additive for broiler chicken feeds.*, Tarlac State University Collage of Education Laboratory High School, Lucinda Campus, Tarlac City.

Buffington, C. A. (1991). Nutrition and Nutritional Disorders. In N. C. Pedersen (Ed.), Feline husbandry: diseases and management in the multiple-cat environment (pp. 330): American Veterinary Publications.

Feng, Y., Chen, X. M., Zhao, M. (2014). The rearing and utilization of cockroach in Yunnan, China. Book of Abstracts of Conference on Insects to Feed The World, The Netherlands 14-17 May 2014.

Finke, M. D. (2008). Nutrient content of insects. In Encyclopedia of Entomology (pp. 2623-2646). Springer Netherlands.

Finley, J. W., Seiber, J. N. (2014). The nexus of food, energy, and water. Journal Of Agricultural and Food Chemistry, *62*(27), 6255-6262.



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FOSS. (2003). The determination of nitrogen according to Kjeldahl using block digestion and steam distillation. *FOSS Analytical AB Sweden*, 1-12.

Kerr, K. R., Boler, B. V., Morris, C. L., Liu, K. J., Swanson, K. S. (2012). Apparent total tract energy and macronutrient digestibility and fecal fermentative end-product concentrations of domestic cats fed extruded, raw beef-based, and cooked beef-based diets. Journal Of Animal Science, 90(2), 515-522.

Kinyuru, J. N., Kenji, G. M., Muhoho, S. N., Ayieko, M. (2011). Nutritional potential of longhorn grasshopper (Ruspolia differens) consumed in Siaya District, Kenya. Journal of Agriculture, Science and Technology, *12*(1).

Kramer, K. J., Muthukrishnan, S. (2009). Chitin Metabolism in Insects. In L. I. Gilbert (Ed.), Insect development: Morphogenesis, molting and metamorphosis (pp. 498): Academic Press.

Longvah, T., Mangthya, K., Ramulu, P. (2011). Nutrient composition and protein quality evaluation of eri silkworm (*Samia ricinii*) prepupae and pupae. Food Chemistry, *128*(2), 400-403.

Majtán, J., Bíliková, K., Markovič, O., Gróf, J., Kogan, G., Šimúth, J. (2007). Isolation and characterization of chitin from bumblebee (*Bombus terrestris*). International journal of biological macromolecules, *40*(3), 237-241.

Mayer, J. (2014). Nutrition, An Issue of Veterinary Clinics of North America: Exotic Animal Practice (Vol. 17, No.3): Elsevier Health Sciences.

Mbah, C. E., Elekima, G. O. V. (2007). Nutrient composition of some terrestrial insects in Ahmadu Bello University, Samaru Zaria Nigeria. Science World Journal, *2*(2).

Omole, A. J., Iji, O. T., Soetan, A., Makanjuola, B. A. (2008). Nutritional value of chicken offal as replacement for local fish meal in growing snails. Journal of Central European Agriculture, *9*(3), 393-397.

Omotoso, O. T. (2006). Nutritional quality, functional properties and anti-nutrient compositions of the larva of Cirina forda (Westwood)(Lepidoptera: Saturniidae). Journal of Zhejiang University Science B, *7*(1), 51-55.

Oonincx, D. G. A. B., Dierenfeld, E. S. (2012). An investigation into the chemical composition of alternative invertebrate prey. Zoo Biology, *31*(1), 40-54.

Paiko, Y. B., Dauda, B. E. N., Suleiman, M. A. T., Akanya, H. O., Jacob, J. O. (2013). Physico-chemical properties and metal ions content of oil extracted from cicket (*Brachytrupes membranaceus*) in Bosso Local Government Area of Niger State, Nigeria. Asian Journal of Science and Technology, *4*(5), 008-012.

Pretorius, Q. (2011). The evaluation of larvae of *Musca domestica* (common house fly) as protein source for boiler production. (Doctoral dissertation), University of Stellenbosch, Stellenbosch.

Schiavone, A., De Marco, M., Rotolo, L., Belforti, M., Martinez Mirò, S., Madrid Sanchez, J., Gasco, L. (2014). Nutrient digestibility of *Hermetia illucens* and *Tenebrio molitor* meal in broiler chickens. Book of Abstracts of Conference on Insects to Feed The World, The Netherlands 14-17 May 2014. .

Shariff, A. H. M., Mona, Z. (2013). Raw ingredients in cat food manufacturing: palatability, digestibility and halal issues in Malaysia. Journal of Tropical Resources and Sustainable Sciences, *1*(1), 1-15.

Siulapwa, N., Mwambungu, A., Lungu, E., Sichilima, W. (2014). Nutritional Value of Four Common Edible Insects in Zambia. International Journal of Science and Research, *3*(6), 876-884.

Tajik, H., Moradi, M., Rohani, S. M. R., Erfani, A. M., Jalali, F. S. S. (2008). Preparation of chitosan from brine shrimp (Artemia urmiana) cyst shells and effects of different chemical processing sequences on the physicochemical and functional properties of the product. *Molecules*, *13*(6), 1263-1274.

Undersander, D. J., Mertens, D. R., Thiex, N. J. (1993). Dry matter determination. Forage analyses procedures.

van Huis, A., Itterbeeck, J. V., Klunder, H., Mertens, E., Halloran, A., Muir, G., Vantomme, P. (2013). Edible insects: future prospects for food and feed security. FAO Forestry Paper (FAO), 1-2.

Wu, H., Appel, A. G., & Hu, X. P. (2013). Instar determination of *Blaptica dubia* (Blattodea: Blaberidae) using Gaussian mixture models. Annals of the Entomological Society of America, *106*(3), 323-328.

Yang, Q., Liu, S., Sun, J., Yu, L., Zhang, C., Bi, J., Yang, Z., 14(1), 139. (2014). Nutritional Composition and Protein Quality of the Edible Beetle *Holotrichia parallela*. Journal of Insect Science, *14*(139). doi: 10.1093/jisesa/ieu001

Yi, L., Lakemond, C. M., Sagis, L., Eisner-Schadler, V., van Huis, A., van Boekel, M. A. (2013). Extraction and characterisation of protein fractions from five insect species. Food Chemistry, *141*(4), 3341-3348.

Young, C. E. (2010). Proximate and mineral composition of selected whole invertebrates and nutritional effects of different diets on the field cricket, *Gryllus bimaculatus*. (Bachelor), Nottingham Trent University

Zhang, A. J., Qin, Q. L., Zhang, H., Wang, H. T., Li, X., Miao, L., Wu, Y. J., 29, . (2011). Preparation and characterisation of food-grade chitosan from housefly larvae. Czech Journal Food Sciences, 29(6), 616-623.



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