SHORT COMMUNICATION

Proximate composition and mineral content of five edible insects consumed in Korea

Soon-Kyung Kim¹, Connie M. Weaver¹ and Mi-Kyeong Choi ³

¹Department of Food Sciences & Nutrition, Soonchunhyang University, Asan, South Korea; ²Department of Nutrition Science, Purdue University, West Lafayette, IN, USA; ³Division of Food Science, Kongju National University, Yesan, South Korea

ABSTRACT
The objective of this study was to assess the nutritional value of edible insects with a focus on minerals. Proximate analysis and mineral content were analyzed for five types of dried edible insects currently sold in Korean markets including Tenebrio molitor, Oxya chinensis sinuosa, Bombyx mori, Protaetia brevitarsis seulensis, and Verlarifictorus aspersus. On a dry weight basis, the highest content of fat was in Tenebrio molitor and of protein in Oxya chinensis sinuosa. Energy content was highest in Tenebrio molitor at 23.9 MJ/kg dry weight. Protaetia brevitarsis seulensis had the highest concentration of calcium (349.2–2282.0 mg/kg dry weight), of phosphorus (5105.0–8875.1 mg/kg dry weight), and of magnesium (502.2–2522.9 mg/kg dry weight). Zinc and copper concentrations were highest in Verlarifictorus aspersus. Iron, manganese, and molybdenum concentrations were highest in Oxya chinensis sinuosa. Last, the concentration of boron was highest in Tenebrio molitor. Edible insects may be a source of mineral nutrition.

1. Introduction

FAO projected that the world population will exceed 9 billion around 2050 and there will be a food crisis due to a reduction in production rather than an increase in production to secure food for the increased population (FAO, 2009). Concern for the food crisis demanded new alternatives to our previous human food supply and one of the alternatives is to utilize edible insects (Van Huis et al., 2013). Edible insects are insects used for food. Much attention has been paid to insects as a future food source to combat the food crisis as they are rich in protein, minerals, and vitamins (Nowak, Persijn, Rittenschober, & Charrondiere, 2016).

Positive aspects of edible insects include the low possibility of environment contamination compared to current livestock food sources as much less greenhouse gas per serving is emitted (Oonincx et al., 2010). Also, there is less space required to produce a large quantity of insects than can be raised conveniently with animals. Furthermore, insects can be hygienically managed, raised under a relatively clean environment, and they are relatively safe from diseases such as mad cow disease, epidemic stomatitis, and other common diseases associated with livestock (Sachs, 2010; Van Huis, 2013; Van Huis et al., 2013). Despite these strengths of insects as a future food source, studies on their nutritional value are limited.

Insect consumption is increasing worldwide from tropical countries to Western societies (Gaston & Chown, 1999; Miček, Rop, Borkovcova, & Bednar, 2014). Edible insects are used as ingredients in many cooking recipes in Africa, Asia, South America, and Australia. Europe is taking active steps toward incorporation of edible insects into their future diet (European Commission, 1997).

Edible insects are reported to be a high-quality protein source. Other than that, it also contains a high crude fat concentration, a rich mineral concentration of 49–121 g/kg, and high vitamin concentrations (Bukkens, 1997). Rumpold and Schlüter (2013) analyzed 236 types of edible insects and found that most edible insects contain sufficient amounts of energy, protein, unsaturated fatty acid, and trace nutrients (cooper, iron, magnesium, manganese, biotin, and pantothenic acid).
In Korea, silkworm, *Oxya chinensis sinuosa* and *Bombyx mori* are consumed as representative edible insects (Ji et al., 2015). In order to enhance the marketability of edible insects as food industrialization materials through diverse development, it is critical to understand traits of edible insects, particularly their nutritional content. Since edible insects are used in addition to the foods rather than as a standalone food, it is important to measure their trace nutrient content. Therefore, the general composition and nine minerals were analyzed for five representative edible insects to assess the nutritive value of edible insects consumed in Korea.

2. Materials and methods

2.1. Edible insect selection and purchase

Edible insects currently permitted by Korea FDA are seven types including *Tenebrio molitor* (mealworm), *Oxya chinensis sinuosa* (grasshopper), *Bombyx mori* (pupa), *Protaetia brevitarsis seulensis* (grub), *Verlarifictorus aspersus* (cricket), silk-worm, and beetle larva. Among them, this study evaluated *Tenebrio molitor*, *Oxya chinensis sinuosa*, *Bombyx mori*, *Protaetia brevitarsis seulensis*, and *Verlarifictorus aspersus*. The five types of the dried edible insects were purchased from three vendors located in Chungnam, Korea.

2.2. General composition analysis

Proximate analysis on the five types of edible insects purchased was conducted according to AACC method (AACC, 1990). Briefly, an atmospheric heat drying at 105°C for 4 h was used for analysis of moisture content, a direct ashing method of 600°C for ash content, a Soxhlet extraction method for fat content, and a micro Kjeldahl method for protein content. All analyses of general composition were repeated twice.

2.3. Mineral content analysis

In order to conduct mineral content analysis for five types of edible insects purchased, wet digestion of edible insects was conducted. In other words, 2 g of specimen were put into 50 ml flask for digestion and digestion was conducted on a hot plate at 250°C until there was no light brown colored smoke after adding nitric acid 15 mL. Digestion was conducted again in a 50-mL mass flask until about 1 mL of digestion solution was left after adding 5 mL perchloric acid. Upon completion of digestion, the solution was cooled and hot distilled water added after a placing filter (No. 6) in the flask. Wet digestion was conducted in duplicate for each specimen. Mineral content analysis for digested specimen was conducted with the use of inductively coupled plasma optical emission spectroscopy (ICP-OES, Optima 5300 DV, PerkinElmer, MA, USA). Relative standard deviation acquired from three repeated analyses of the same specimen was within 3% reproducibility. Recovery rate of mineral analysis was calculated by conducting hot digestion and mineral analysis of rice flour NCS ZC73018 (Certified Reference Materials, MSC, Beijing, China) as its certified reference material. Analysis recovery rate of this method was ±5% for all minerals. Diluent standard solution for mineral weighing was manufactured with the purchase of 100 mg/kg standard solution (AnApex Co., Daejeon, Korea) and high-purity argon gas was used. In order to reduce contamination, all plastic apparatus used in the experiment, was soaked for 24 h in 0.4% EDTA solution and glassware was soaked in undiluted nitric acid solution before rinsing three times with secondary distilled water.

2.4. Statistical analysis

SAS (Ver. 9.4, SAS Institute Inc., Cary, NC, USA) was used for statistical processing and analysis of data. Means and standard deviations were calculated for all analysis data. Mean differences in mineral concentration among the five types of insects were determined with one-way ANOVA test and Duncan’s multiple range test. Verification on significance was conducted for all statistical analysis at level of \( p < 0.05 \).

3. Results and discussion

General composition of edible insects (Figure 1) is shown in Table 1. Comparing proximate composition of five types of edible insects as a dry weight basis, the highest ash content was in *Protaetia brevitarsis seulensis*, *Tenebrio molitor* had the highest fat and *Oxya chinensis sinuosa* the highest protein...
Concentration. Edible insects are considered a high protein source as its typical protein content is 500–600 g/kg (Bednárová, Borkovcová, Milček, Rop, & Zeman, 2013; Bukkens, 1997; Ramos-Elorduy, 1997). It also is a high-energy source with a fat content of 80–950 g/kg (Punzo, 2003). Protein concentration of some traditional livestock sources such as beef, pork, chicken, and others is 200–300 g/kg (Rural Development Administration, 2011; United States Department of Agriculture, 2015). By comparison, *Oxya chinensis sinuosa* with the highest protein at 742.8 g/kg dry weight had a much higher protein concentration. The insects tested in this study were dried. Protein concentration in five types of non-dried edible insects sold in India was 226–705 g/kg, still similar or higher than meat (Shantibala, Lokeshwari, Thingnam, & Somkuwar, 2012). Therefore, edible insects might be a valuable source of dietary protein or used as a protein supplement.

Mineral content on five types of edible insects is shown in Table 2. Calcium concentration ranged from 349.2 to 2282 mg/kg dry weight and was highest in *Protaetia brevitarsis seulensis* and lowest in *Tenebrio molitor*. Phosphorus ranged from 5105 to 8875.1 mg/kg dry weight, and was highest in *Protaetia brevitarsis seulensis* and lowest in *Verlarifictorus aspersus*. Magnesium ranged from 252.2 to 2522.9 mg/kg dry weight, and was highest in *Bombyx mori* and lowest in *Verlarifictorus aspersus*. Zinc content ranged from 75.6 to 189.1 mg/kg dry weight and was highest in *Bombyx mori* and lowest in *Protaetia brevitarsis seulensis*. Iron ranged from 49.5 to 99.7 mg/kg dry weight and was highest in *Oxya chinensis sinuosa* and lowest in *Bombyx mori*. Copper ranged from 9.4 to 27.3 mg/kg dry weight and was highest in *Verlarifictorus aspersus* and lowest in *Bombyx mori*. Manganese ranged from 7 to 48.2 mg/kg dry weight and was highest in *Oxya chinensis sinuosa* and lowest in *Tenebrio molitor*. Boron ranged from 14.6 to 22.3 mg/kg dry weight and was highest in *Tenebrio molitor* and lowest in *Bombyx mori*. Molybdenum ranged from 0.2 to 1.5 mg/kg dry weight and was highest in *Oxya chinensis sinuosa* and lowest in *Bombyx mori*.

Calcium, phosphorus, and magnesium are important constituents of bone. The calcium concentration of milk, the most common food source, is 900–1300 mg/kg (Rural Development Administration, 2011; United States Department of Agriculture, 2015). By comparison, *Protaetia brevitarsis seulensis* had the highest concentration of not only calcium, but also phosphorus and magnesium among five types of edible insects. The calcium concentration of non-dried *Lethocerus indicus*, *Laccotrophes maculatus*, *Hydrophilus olivaceus*, *Cybister tripunctatus* and *Crocothemis servilia* was reported to be 243–960 mg/kg (Shantibala et al., 2012).

Zinc is a component of about 100 enzymes which catalyze activation, cell division, and immune action (King, Shames, & Woodhouse, 2000). Copper is a component of various oxidizing enzymes which contributes to oxidation–reduction reactions (Halfdanarson, Kumar, Li, Phyliky, & Hogan, 2008). Major dietary sources of zinc and copper include oyster and beef, respectively. Zinc content of oyster is 132 mg/kg and copper content of beef liver is 53 mg/kg (Rural Development Administration, 2011). By comparison,
the zinc and copper content of *Verlarifictorus aspersus* was 189.1 mg/kg dry weight and 27.3 mg/kg dry weight, respectively, and the highest among the five types of edible insects tested. Zinc and copper concentrations of *Laccotrephes maculatus* used in India were 232 mg/kg and 137/kg, respectively; thus it was higher than that of oyster and beef liver (Shantibala et al., 2012).

Among the five types of edible insects in this study, iron, manganese, and molybdenum concentration were the highest in *Oxya chinesis sinuosa*. Iron is a component of hemoglobin and myoglobin which has oxygen carrier function and acts as a cofactor of various enzymes (Beard & Han, 2009). Manganese is component of various enzymes which contributes to activation (Watts, 1990). Molybdenum acts as cofactor of various oxidizing enzymes (Rajagopalan, 1987; Schwarz & Mendel, 2006). Considering the fact that iron content of edible insects, a good food source for iron, is 50–80 mg/kg (Rural Development Administration, 2015; United States Department of Agriculture, 2015), iron content of *Oxya chinesis sinuosa* was slightly higher at 99.7 mg/kg dry weight. Shantibala et al. (2012) reported that iron content of *Lethocerus indicus* and *Hydrophilus olivaceous* was 4100 mg/kg and 4610 mg/kg, respectively. Thus, some edible insects may be a main source of iron.

In this study, only five of the seven edible types permitted in Korea were tested. However, this study provided mineral content of representative edible insects and found that mineral content differed with type of edible insect. Edible insects may be a useful source of dietary protein and minerals.

4. Conclusions

Among five types of dried edible insects including *Tenebrio molitor*, *Oxya chinesis sinuosa*, *Bombbyx mori*, *Protaetia brevitarsis seuensis*, and *Verlarifictorus aspersus*, fat and energy concentrations were highest in *Tenebrio molitor* and protein concentration was highest in *Oxya chinesis sinuosa*. The highest concentrations of calcium, phosphorus, and magnesium were in *Protaetia brevitarsis seuensis*, the highest concentration of zinc and copper in *Verlarifictorus aspersus*, the highest concentration of iron, manganese, and molybdenum in *Oxya chinesis sinuosa*, and the highest concentration of boron was in *Tenebrio molitor*. Edible insects may be a useful source of dietary protein and minerals.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Mi-Kyeong Choi http://orcid.org/0000-0002-6227-4053

References

AAPC. (1990). Approved methods of the American association of cereal chemists. MN: Author.

Adamkova’, A., Koulimská, L., Borkovcová, M., Mlček, J., & Bednárová, M. (2014). Calcium in edible insects and its use in human nutrition. *Potravinarstvo – The Scientific Journal for Food Industry, 8*, 233–238.

Beard, J., & Han, O. (2009). Systemic iron status. *Biochimica et Biophysica Acta, 1790*, 584–588. doi:10.1016/j.bbadis.2008.09.005

Bednálová, M., Borkovcová, M., Mlček, J., Rop, O., & Zeman, L. (2013). Edible insects – Species suitable for entomophagy under condition of Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 61*, 587–593. doi:10.1111/actaun.2013.6030587

Bukkens, S.G.F. (1997). The nutritional value of edible insects. *Ecology of Food and Nutrition, 36*, 287–319. doi:10.1080/03670249.1997.9991521

European Commission. (1997). Regulation (EC) No 258/97 of the European Parliament and of the Council of 27 January 1997 concerning novel foods and novel food ingredients. Brussels: Author.

FAO. (2009). How to feed the world in 2050. Rome: Author.

Gaston, K.J., & Chown, S.L. (1999). Elevation and climatic tolerance: A test using dung beetles. *Oikos, 86*, 584–590.

Halfdanarson, T.R., Kumar, N., Li, C.-Y., Phyliky, R.L., & Hogan, W.J. (2008). Hematological manifestations of copper deficiency: A retrospective review. *European Journal of Haematology, 80*, 523–531. doi:10.1111/ ejh.2008.80.issue-6

Ji, S.-D., Kim, N.-S., Lee, J.-Y., Kim, M.-J., Kweon, H.Y., Sugn, G.B., ... Kim, K.-Y. (2015). Development of processing technology for edible mature silkworm. *Journal of Sericultural and Entomological Science, 53*, 38–43. doi:10.7852/jjes.2015.53.1.38

King, J.C., Shames, D.M., & Woodhouse, L.R. (2000). Zinc homeostasis in humans. *Journal of Nutrition, 130*, 1360S–1366S.

Mlček, J., Rop, O., Borkovcová, M., & Bednar, M.A. (2014). A comprehensive look at the possibilities of edible insects as food in Europe – A review. *Polish Journal of Food and Nutrition Sciences, 64*, 147–157. doi:10.2478/v10222-012-0099-8

Nowak, V., Persijn, D., Rittenschober, D., & Charondiere, U.R. (2016). Review of food composition data for edible insects. *Food Chemistry, 193*, 39–46. doi:10.1016/j.foodchem.2014.10.114

Oonincx, D.G., van Itterbeeck, J., Heetkamp, M.J., van den Brand, H., van Loon, J.J., & van Huis, A. (2010). An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PloS One, 5*, e14445. doi:10.1371/journal. pone.0014445

Punzo, F. (2003). Nutrient composition of some insects and arachnids. *Biological Sciences, 66*, 84–98.

Rajagopalan, K.V. (1987). Molybdenum-an essential trace element. *Nutrition Reviews, 45*, 321–328. doi:10.1111/1753-4887.1987.tb00981.x

Ramos-Elorduy, J. (1997). The importance of edible insects in the nutrition and economy of people of the rural areas of Mexico. *Ecology of Food and Nutrition, 36*, 347–366. doi:10.1080/03670249.1997.9991524

Rumpold, B.A., & Schlüter, O.K. (2013). Nutritional composition and safety aspects of edible insects. *Molecular Nutrition & Food Research, 57*, 802–823. doi:10.1002/mnfr.201200735

Rural Development Administration, National Institute of Agricultural Science. (2011). Food composition table. Seoul: Kwangmungpressing Press.

Sachs, J. (2010). Rethinking macroeconomics: Knitting together global society. *The Broker, 10*, 1–3.

Schwarz, G., & Mendel, R.R. (2006). Molybdenum cofactor biosynthesis and molybdenum enzymes. *Annual Review of Plant Biology, 57*, 623–647. doi:10.1146/annurev.plant.57.032905.105437

Shantibala, T., Lokeshwari, R., Thingnam, G., & Somkuwar, B.G. (2012). MEIMAN: Database exploring medicinal and edible insects of Manipur. *Bioinformation, 8*, 489–491. doi:10.6026/bioinformation United States Department of Agriculture, Agricultural Research Service. (2015). *USDA national nutrient database for standard reference, release 28*. Washington, DC: Department of Agriculture.

van Huis, A. (2013). Potential of insects as food and feed in assuring food security. *Annual Review of Entomology, 58*, 563–583. doi:10.1146/annurev-ento-120811-153704

Van Huis, A., van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., & Vantomme, P. (2013). Edible insects: Future prospects for food and feed security. Rome: Food and Agriculture Organization of the United Nations.

Watts, D.L. (1990). The nutritional relationships of mannikin. *Journal of Orthomolecular Medicine, 5*, 219–222.