Food Chemistry 193 (2016) 39–46

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Analytical Methods

Review of food composition data for edible insects ☆

Verena Nowak, Diedelinde Persijn, Doris Rittenschober, U. Ruth Charrondiere *

Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla 1, 00153 Rome, Italy

ARTICLE INFO

Article history:
Received 25 February 2014
Received in revised form 19 October 2014
Accepted 20 October 2014
Available online 15 November 2014

Keywords:
Edible insects
Food composition data
Tenebrio molitor
Nutrient variation
Biodiversity
Underutilised
INFOODS
FAO

ABSTRACT

Edible insects are considered rich in protein and a variety of micronutrients, and are therefore seen as potential contributors to food security. However, the estimation of the insects' contribution to the nutrient intake is limited since data are absent in food composition tables and databases. Therefore, FAO/INFOODS collected and published analytical data from primary sources with sufficient quality in the Food Composition Database for Biodiversity (BioFoodComp). Data were compiled for 456 food entries on insects in different developmental stages. A total of 5734 data points were entered, most on minerals and trace elements (34.8%), proximates (24.5%), amino acids (15.3%) and (pro)vitamins (9.1%). Data analysis of *Tenebrio molitor* confirms its nutritive quality that can help to combat malnutrition. The collection of data will assist compilers to incorporate more insects into tables and databases, and to further improve nutrient intake estimations.

1. Introduction

The UN projected the world population to reach 9.6 billion people in 2050 (United Nations, Department of Economic and Social Affairs, Population Division, 2013) which will require increased food and feed outputs. Edible insects are traditionally consumed in many parts of the world (DeFoliart, 1997) and are considered as having potential to contribute to the world's food security (van Huis, 2013). It is estimated that at least 2 billion people eat insects on a regular basis (van Huis et al., 2013), not only because of their nutritive value but also because of their taste (Nonaka, 2009). However, especially in urban and Western societies, insects are rarely eaten or consumption is even perceived as culturally inappropriate (FAO Regional Office for Asia, 2010; van Huis, 2013) and disgusting (Nonaka, 2009). But consumer perceptions can be changed as it was recognised in Thailand: entomophagy was mainly common in Northern and Northeastern regions but in recent years, it occurs more frequently nationwide and is no longer seen as a habit of poor and rural people (FAO Regional Office for Asia, 2013).

Insects are considered food with satisfactorily energy and protein content, good amino acid and fatty acid profiles and high contents of a variety of micronutrients such as the minerals copper, iron, magnesium, manganese, phosphorous, selenium, and zinc and the vitamins riboflavin, pantothenic acid, biotin, and in some cases folic acid (Rumpold & Schlüter, 2013). Beside those characteristics that can improve the nutrition status directly, insects also have positive effects on the environment. They play an important role in waste biodegradation and as pollinators in plant reproduction. Furthermore, they have a high feed conversion efficiency and their production is less land-dependent than conventional livestock, which makes them resource-saving food and feed, and it is probable that they produce less greenhouse gases and use significantly less water than conventional livestock (FAO Regional Office for Asia & the Pacific, 2010; Nakagaki & DeFoliart, 1991). Finally, increasing the production and consumption of edible insects is suspected to have an impact on livelihood and social conditions. Gathering and farming of insects can be done with a minimal input of technical or capital resources which gives also the poorest members of society a possibility to acquire income (FAO Regional Office for Asia & the Pacific, 2010).

Up to now, about 2000 edible insect species are known (Jongema, 2013). Compared to this huge variety, only little is known about the nutrient composition and contribution. In a recent review, chemical composition of 236 edible insects have been published (Rumpold & Schlüter, 2013). However, those data are presented on a dry matter basis only, which cannot directly be used for the assessment of human nutrition and for food composition databases (FCDBs), as foods are consumed on a fresh weight basis and, therefore, data are presented on a fresh weight basis in FCDBs.

☆ The views expressed in this publication are those of the author(s) and do not necessarily reflect the views or policies of the Food and Agriculture Organization of the United Nations.

* Corresponding author. Tel.: +39 06 570 56 134; fax: +39 06 570 53 879.
E-mail address: ruth.charrondiere@fao.org (U.R. Charrondiere).

http://dx.doi.org/10.1016/j.foodchem.2014.10.114
0308-8146/

INFOODS (International Network of Food Data Systems), since its establishment in 1984, aims to stimulate and coordinate efforts to improve the quality and availability of compositional data globally. INFOODS in collaboration with the Food and Agriculture Organization of the United Nations (FAO) published in 2010 the first version of the FAO/INFOODS Food Composition Database for Biodiversity (BioFoodComp) (Charrondiere & Burlingame, 2011; FAO/INFOODS., 2013b) according to INFOODS guidelines and standards (FAO/INFOODS, 2012a, 2012b, 2012c, 2012d). This database is a growing repository of solely analytical data. Since version 2.0, published in 2012, data on edible insects are part of the compiled food entries (Charrondière et al., 2013). FAO actively promotes the conservation and sustainable use of biodiversity for nutrition and agriculture and was explicitly requested in 2013 by the Commission on Genetic Resources for Food and Agriculture (CGRF) to regularly update the BioFoodComp (FAO, 2013).

To the best of our knowledge, no comprehensive compilation on the nutritional values on a fresh weight basis of insects was published so far. Information on food composition is fundamental and useful for nutrition-based programmes, projects and policies, as well as for optimising feed. Therefore, the objective of this review is to give a general overview of the available nutrient values on edible insects found in the scientific literature and to express, evaluate, and compare the species similarities and differences based on their nutrient composition. The mealworm (*Tenebrio molitor*) will serve as an example for detailed information on nutrient data and discussion of results.

2. Materials and methods

2.1. Data sources

An extensive literature search was performed from January to March 2012 through Scopus and Science Direct. The following key words were used: edible insects/grasshopper/beetle/cricket/bug/ant/silkworm/fly/moth, nutritional value, proximate, protein/fat/carbohydrate/fibre/mineral. The compositional data were collected from scientific papers, research articles, short communications, reports and scholars research. The papers were screened for food composition data. The bibliography of the identified articles led to further relevant articles. Additionally, relevant unpublished data were directly provided by scientists, e.g. through the INFOODS discussion list (http://www.fao.org/infoods/infoods/discussion-list/en/). Furthermore, an internal database on edible insects of FAO and the Wageningen University and Research centre including 1911 references was screened for food composition data. Out of those, only 7 articles provided compositional data that fit our purpose. When information was not clear or missing in the publication, the authors were contacted for clarification.

The compositional data on edible insects in the ASEAN Food Composition Table (Puwastien, Mahidon, & System, 2000) and the West-Africa Food Composition Table (Stadlmayr et al., 2012) were used for comparison and plausibility checks.

2.2. Inclusion and exclusion of data and data quality

Foods included in BioFoodComp are foods described at cultivar/variety/breed level as well as wild and underutilised foods. Detailed criteria for biodiverse foods have been described elsewhere (INFOODS., 2013). Insects are considered underutilised foods according to the INFOODS List of underutilised species contributing to the Nutritional Indicators for Biodiversity Version 1.2 (INFOODS, 2013) and are, therefore, eligible to be included, even if they are described at species level or above. Only primary analytical data with sufficient documentation on raw, dried and processed single foods were included, which either were expressed as per edible portion on fresh weight basis (EP) or which could be transformed into this data expression.

Exclusion criteria were defined prior to data compilation (Table 1). Reasons for exclusion included, i.e. imprecise food and value description and inconsistent or implausible data. Furthermore, selected checks from the FAO/INFOODS Guidelines for Checking Food Composition Data prior to the Publication of a User Table/Database – Version 1.0 (FAO/INFOODS, 2012a) were applied. Those checks concerned mainly the consistency and plausibility of the data, for example: the sum of proximates (water, carbohydrate, fat, protein, ash, and alcohol) was within the acceptable range; the sum of amino acids corresponded to the protein value; the sum of fatty acids corresponded to the total fat content; the energy content and vitamin equivalents were calculated correctly; and outliers were identified. In case a problem was identified, values were either marked by putting them into brackets or excluded, depending on the amount of deviation from mean values and availability of data for comparison. No universe exclusion criteria was applied for all species as often no data for comparison were available because of the wide diversity within the animal class of insects. As data on insects are rarely reported and the natural variation might be high, it was decided to keep as much data as possible and put them preferably into brackets as indication of low quality instead of excluding them from the database. Reasons for such decisions were documented in the database.

In this article, data in brackets were considered for the description of the database, e.g. the number of data points, but they were excluded from the calculation of nutrient content values.

2.3. Standardisation and compilation

Standardisation of data is necessary as data expressions and definitions vary substantially throughout different publications. The standard used for the present work was based on the FAO/INFOODS compilation tool, which is a simple food composition database management system based on Microsoft Excel (Charrondiere & Burlingame, 2011; FAO/INFOODS, 2013b). Data were expressed as per 100 g EP. For an unequivocal identification of food components, the system of the INFOODS food component identifiers (tagnames) was used (FAO/INFOODS, 2012d; Klensin, Feskanich, Lin, Truswell, & Southgate, 1989). Conversions of units and denominators were done according to the FAO/INFOODS Guidelines for Converting Units, Denominators and Expressions – version 1.0 (FAO/INFOODS, 2012b). One of the most important conversions was from data presented as per dry matter to per fresh weight of edible portion (EP). The conversion was possible when either the percentage of dry matter or the water content was given in the publication or was provided by authors via personal communication using the following equation:

$$\frac{\text{Nutrient value}\,(\text{g}/100\,\text{g dry matter})}{100} \times (100 - \text{water content}\,(\text{g}/100\,\text{g EP})) = \text{nutrient value}\,(\text{g}/100\,\text{g EP})$$

All data that fulfilled the quality criteria and could be expressed as per 100 g EP were compiled in the FAO/INFOODS Food Composition Database for Biodiversity (version 2.1) (FAO/INFOODS, 2013a) which is freely available from http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/.

2.4. Nutrient reference values to determine if the food is 'source' of a nutrient or has 'high' content according to Codex Alimentarius

According to the definitions for food labelling by Codex Alimenatrius (WHO, 2007), a solid food product is a source of protein, when the protein content is at least 10% of the Nutrient Reference