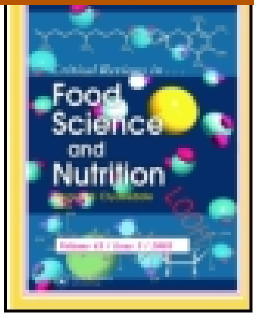

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Ugly but tasty: a systematic review of possible human and animal health risks related to entomophagy

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BACKGROUND

"All flying insects that walk on all fours are to be regarded as unclean by you. There are, however, some flying insects that walk on all fours that you may eat: those that have jointed legs for hopping on the ground. Of these you may eat any kind of locust, katydid, cricket or grasshopper. But all other flying insects that have four legs you are to regard as unclean" Leviticus 11:20-23.

The Old Testament is the old written document, which has been found so far, documenting the historical human habit of eating insects (Belluco, 2009). However, entomophagy (*éntomon*, "insect", and *phagein*, "to eat") has even deeper roots in human evolutionary history. Based on primates food habits, it is easy to infer that insects, and other invertebrates, were part of the diets of our earliest human ancestors (Tommaseo-Ponzetta and Paoletti, 2005; Fontaneto et al., 2011). For instance, isotope analysis of Australopithecine bones indicates a diet largely composed of animals such as insects foraging on graminaceae (Fontaneto et al., 2011; Klein, 2009).

In addition to this evidence, there are several other sources -- including a book collecting Leonardo Da Vinci's cooking experiments -- indicating that insects have been part of the human diet and are still widespread in many parts of the world (Tommaseo-Ponzetta and Paoletti, 2005; Routh and Routh, 2005).

In addition to looking at them as nutritional resources, humans have historically taken advantage of insects as producers of honey, silk, and natural coloring agents, as well as for pollination or biological control. Nonetheless, insects have long produced a sense of disgust in people from most Western countries. Unsurprisingly, as we are increasingly interested in finding new sources of protein and reconsidering food resources that are ignored in the modern diet, insects have attracted the interest of scientists, chefs and businessmen. As stated by the Food and Agricultural Organization (FAO) and other international organizations, mini-livestock (insect) food and feed might have considerable economic, environmental and nutritional advantages.

From a nutritional point of view, problems related to high levels of meat consumption have increased scientific interest in analyzing new sources of protein, and insects have been considered candidates for substituting meat for several reasons (Collavo et al., 2005; Payne et al., 2016).

It is difficult to generalize across the 2,000 insect species being consumed worldwide; however, compared to beef, pork and chicken, insect protein content is, on average, similar.

Insect essential amino acid scores range from 46 to 96%, although the majority of insects have limited levels of either tryptophan or lysine. In addition to protein, insects seem to contain more polyunsaturated fatty acids (although content varies significantly depending on the species and their diet) and higher levels of minerals, such as iron and zinc, and of vitamins B_1, B_2, and B_3 compared to other livestock animals that are of particular interest for women and children's diets, especially in developing countries (Belluco et al., 2015; van Huis et al., 2013).

Beside the nutritional aspects, preliminary environmental impact analyses estimated that livestock production consumes 30% of crops, 8% of freshwater resources, produces as much as 18% of greenhouse gas (GHG) emissions, and greatly contributes to global misallocation of reactive nitrogen (N) (Lundy and Parrella, 2015). Insects being farmed as mini-livestock result in lower GHG emissions and ammonia compared to the production of conventional livestock. An analysis conducted by Oonincx et al. in 2010 also suggests that less land area is required to farm mealworms compared to conventional livestock (Oonincx et al., 2010).

Preliminary economic impact analyses note the minimal technical or capital expenditures required for basic harvesting and rearing equipment. Insects can be easily breed, processed for food and feed and sold by all members of society including disadvantaged individuals, such as women and landless people in urban and rural areas (van Huis, 2013).

For the multiple potential advantages mentioned above, the European Commission is currently co-financing a research project to explore the feasibility of using insect protein for feed. The Commission is also considering how to develop policies that reflect the potential use of insects as novel foods and animal feed. Considering the lack of evidence related to this issue, the aim of our paper is to study the possible risks to human and animal health that are correlated with consumption of edible insects and to analyse the possible implementation of insect derivates as in the pharmaceutical field.

METHODS

Eligibility criteria

The types of studies included are original experimental and observational articles; reviews were excluded. No limits for language or year of publication were applied during the search. The sample included all edible insects used as human or animal foods or drugs. Studies of any follow-up length were included. Settings included any country, state and community size. The interventions described in the articles included different type of risks.

Any type of control or comparison group not exposed to insects eating during the study period was considered. Studies without comparison groups were also included. Primary outcomes included risks of singular or prolonged consumption of edible insects. Secondary outcomes included pharmacological risks.

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Search strategy

The following computerized databases were used for the basic search: PubMed/MEDLINE, Scopus, CAB Direct (the last searches were conducted on 16 November 2015).

To standardize and make the searches reproducible, the following search syntaxes were developed:

1) PubMed/MEDLINE: entomophagy [All Fields] OR “Insects”[Mesh] AND (“Nutritional status”[MeSH Terms] OR “Nutritive value”[Mesh] OR “Diet”[Mesh] OR “Dietary proteins”[Mesh] OR “Dietary Fats”[Mesh] OR edible [All Fields] OR eatable [All Fields]), using MeSH terms when supported.
2) Scopus: ALL (entomophagy OR insects AND (nutritional status OR nutritive value OR diet OR dietary protein* OR dietary fat* OR edible OR eatable)) AND SUBJAREA (mult OR medi OR nurs OR vete OR dent OR heal) AND (EXCLUDE (DOCTYPE, “ch”) OR EXCLUDE (DOCTYPE, “bk”) OR EXCLUDE (DOCTYPE, “cp”)).
3) CAB Direct: subject: (“insects as food”) OR (entomophagy) -- refine by journal article.

Inclusion and exclusion criteria

Inclusion criteria:

All articles clearly stating in title or abstract the intention to analyze the following topics were included:

- Risk of allergy: reported allergic reaction or laboratory confirmation of known allergens.
- Microbiological risk: reported microbiological contamination during any phase of production (collection, storage, transportation) or specific insect microbiological contamination.

- Chemical risk: reported presence of insect contamination with any known risky chemical substance or anti-nutrient factors.
- Malabsorption risk: reported risk of pathological nutrient malabsorption associated with the consumption of edible insects.
- Growth alteration risk: reported risk of pathological growth alteration associated with the consumption of edible insects.
- Hematic and qualitative meat alteration risk: reported risk of pathological hematic and qualitative meat alteration associated with the consumption of edible insects.
- Any other relevant risk related with edible insect consumption.
- Pharmacological effects: any reported pharmacological effects associated with the consumption of edible insects.

Case reports, qualitative studies or studies assessing clinical samples were included.

Exclusion criteria:

No limits for date of publication, authors, affiliation and language were applied.

All articles whose main objectives were not clearly stated in title or abstract were excluded.

Systematic and narrative reviews were excluded.

Study selection

The reviewers independently examined the titles, abstracts and key works of citations extracted from electronic databases for eligibility. For studies that appeared to meet the inclusion criteria, or when a definite decision could not be made based on the title or abstract alone, the full text articles were obtained to assess the inclusion criteria in detail. Studies were excluded if they did not meet one or more criteria. For any disagreements arising between the authors, that study was discussed until a consensus was reached. The full text of all articles matching the inclusion criteria was reviewed. The reasons for exclusion were recorded.

Data collection process and data items

For each selected study, the data have been extracted using a standard form. Extracted data items included authors, year of publication, type of insect, human or animal consumer, type of consumption (singular or prolonged), primary outcomes (acute/chronic, allergic, chemical, microbiological, hematic, malabsorption and growth failure risks), and secondary outcomes such as pharmacological effects.

RESULTS

A total of 6,026 articles were retrieved from all databases; after deduplication of findings, 5,308 articles were targeted for analysis. Screening the titles and abstracts allowed the selection of 341 studies addressing the entomophagy-related risks and pharmacological properties of insects. A second screening, conducted in accordance with the study inclusion and exclusion criteria, allowed us to select 70 original articles that were eligible for the final analysis (flowchart).

We reviewed 70 studies, 26 of which studied insects as possible sources of human foods or drugs, 30 of which analyzed the use of insects in animal feed (23 poultry, 1 rats and 6 fish), and 14 considered edible insects as both food and feed.

The most studied insects were *Musca domestica L*, silkworm pupae and crickets in general, but the full list is available in Table 1.

Possible risks of prolonged consumption of insects were analyzed in 37 articles, while 23 studies did not specify the duration of consumption and 6 focused on possible risks of singular consumption of edible insects.

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To provide more detailed findings, we decided to split the results into two main groups. The first takes into account all articles whose outcomes could be directly or indirectly linked to human health, including studies on rats and oil laboratory analysis. All insects analyzed in this group are commonly consumed by humans.

The second one includes all studies addressing edible insects as animal feed.

Humans

A total of 40 articles analyzed possible risks of health or drug effects caused by edible insect consumption by humans; 5 studies showed possible risks of allergy due to the presence of cross-reactive allergens in insects, suggesting that it is wise to advise individuals with known allergies to shellfish or mollusks to avoid eating edible insects. (Barre et al., 2014; Verhoeckx et al., 2014; Barennes et al., 2015; Broekman et al., 2015; Srinroch et al., 2015).

Microbiological contamination risk was analyzed in 4 studies, 3 of which suggested possible fungal or bacterial contamination due to poor sanitation and inadequate collection, drying, transportation, storage and marketing conditions (Klunder et al., 2012; Simpanya et al., 2000; Braide and Nwaoguikpe, 2010; Hernandez-Flores et al., 2015).

Possible chemical contamination, presence of anti-nutritional factors and oxidative potential of edible insects were analyzed in 9 articles, only 3 of which could exclude, given the current state of the art, a risk for human health (Braide and Nwaoguikpe, 2010; Adeduntan, 2005; Hyun et al., 2012; Memis et al., 2013; Koc et al., 2014; Musundire et al., 2014; Shantibala et al., 2014; Turkez et al., 2014; Omotoso, 2015).

Health risks related to the malabsorption of nutrients derived from edible insect consumption were studied in 16 articles; 10 studies excluded such a risk while the others stressed the need for additional efforts to better understand the role of the specific anti-nutrients, such as tannin and phytate, contained in edible insects and how processing methods could affect the nutrient potential of edible insects (Adeduntan, 2005; Hyun et al., 2012; Musundire et al., 2014; Omotoso, 2015; Adebowale, 2005; Omotoso, 2006; Zhou and Han, 2006; Omotoso and Afolabi, 2007; Kinyuru et al., 2010; Ekpo, 2011; Longvah et al., 2011; Longvah et al., 2012; Xia et al., 2012; Enghoff et al., 2014; Assielou et al., 2015; Bauserman et al., 2015).

In 8 articles, possible hematic and growth alterations due to edible insect consumption were studied. One study focused on cholesterol content of *Imbrasia belina*, suggesting that the adverse effects of a high concentration of cholesterol could be mitigated by the presence of substantial amounts of β-sitosterol and campesterol in the insect. The others concluded that insect consumption does not have detrimental hepatic, renal or hematologic effects and that infants who consumed caterpillar have higher hemoglobin concentrations and fewer cases of anemia, suggesting that caterpillar cereal might have some beneficial effects (Zhou and Han, 2006; Longvah et al., 2012; Xia et al., 2012; Bauserman et al., 2015; Ogunleye, 2006; Yeboah and Mitei, 2009; Ekpo, 2011; Igwe et al., 2014).

In a study conducted in 1994, B. I. Adamolekun et al. reported a human epidemic of seasonal ataxia in Ikare (Western Nigeria) associated with the consumption of *Anaphe venata Butler*. The study described 34 patients who developed cerebellar ataxia, nystagmus and varying levels of impaired consciousness after consuming this insect (Adamolekun and Ibikunle, 1994).

Finally, 8 articles presented data on the possible pharmacological effects of edible insect consumption. Apart from antioxidant and integrator potential due to their nutrient and anti-nutrient composition, protein content and high calcium density, many insects have shown specific properties that can be developed in the pharmaceutical sector nevertheless, possible risks for human health must be considered (Shantibala et al., 2014; Azad Thakur and Firake, 2012; Adámková et al., 2014). Two articles studied the possible use of edible insects (*Momordica charantia L., Myrmeleon sp.* and *Clanis bilineata)* as blood glucose--lowering agents for diabetic patients, confirming their potential as suitable alternative hypoglycemic agents for humans (Mujahid et al., 2013; Xia et al., 2013), while Cheso et al. showed the potential of the desert locust, *Schistocerca gregaria*, as an unconventional source of dietary and therapeutic sterols (Cheseto et al., 2015). Enghoff et al. suggest that Diplopoda defensive secretions, hydrogen cyanide and benzoquinones, may act as insect repellents and that sub-lethal cyanide ingestion may enhance human's innate resistance to malaria, while Tang confirmed that Chinese black ants (*Polyrhachis dives*) contain compounds that display anti-inflammatory, immunosuppressive, and renoprotective activities (Enghoff et al., 2014; Tang et al., 2015),.

Animals

The majority of studies considering edible insects as feed for animals focus on three main risks: growth alteration, nutrient malabsorption and hematic and qualitative meat alteration.

Of the 30 articles reviewed in this group, 23 analyzed insects as possible feed for poultry, 3 for fish and 1 for rats.

Poultry

In 19 articles, the risk of growth alteration from poultry feed including various insect derivates was studied. In one work, the incorporation of silkworm pupae meal into broiler diets at 5%, which replaced one-half of the fishmeal, significantly depressed growth rate and final body weight at 6 weeks old (Sudhakara Reddy et al., 1991). In all other studies reviewed, no

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differences in growth rate or egg production were observed, and some authors even suggest significantly better growth of broilers (Gawaad and Brune, 1979; Ocio et al., 1979; Dhaliwal et al., 1980; Joshi et al., 1980; Virk et al., 1980; Sujatha and Rao, 1981; Gado et al., 1982; Nakagaki et al., 1987; Chrappa et al., 1990; Chrappa et al., 1990; Kumar et al., 1992; Atteh and Ologbenla, 1993; Despins and Axtell, 1995; Pro M. et al., 1999; Hwangbo et al., 2009; Aigbodion et al., 2012; Sun et al., 2012; Jadalla et al., 2014; Bovera et al., 2015).

Similar results were observed for malabsorption risk. Of the 17 studies analyzing the issue, only one suggested a slight decrease in feed efficiency due to the lower caloric density of diets containing dried pupae compared with those containing soybean oil meal (Koo et al., 1980). The majority of authors observed no difference, and in some cases, chickens fed larvae meal had higher average concentrations of calcium and lower serum concentrations of total lipids, glucose, cholesterol and inorganic phosphorus compared with controls (Gawaad and Brune, 1979; Ocio et al., 1979; Dhaliwal et al., 1980; Joshi et al., 1980; Virk et al., 1980; Sujatha and Rao, 1981; Gado et al., 1982; Kumar et al., 1992; Atteh and Ologbenla, 1993; Pro M. et al., 1999; Hwangbo et al., 2009; Sun et al., 2012; Jadalla et al., 2014; Bovera et al., 2015; Virk et al., 1980; DeFoliart et al., 1982).

In 6 articles, possible hematic or meat alterations in broilers fed insect-based diets were assessed, and none observed significant alterations (Gado et al., 1982; Kumar et al., 1992; Atteh and Ologbenla, 1993; Hwangbo et al., 2009; Sun et al., 2012; Bovera et al., 2015).

Other animals

Only 6 articles analyzed the risks associated with the replacement of traditional fish feed with insect-based feed (maggots, termites, grasshoppers, silkworm pupae and May flies). They did not

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state specific risks but suggested a careful analysis of the anti-nutrients provided by such an insect-based diet (Fasakin et al., 2003; Sogbesan and Ugwumba, 2008; Tamale et al., 2010; Alegbeleye et al., 2012; Lee et al., 2012; Ji et al., 2015).

One article studied the effects of supplemental methionine and lysine on the nutritional value of housefly larvae meal (*Musca domestica*) fed to rats, concluding that housefly larvae meal seemed deficient in methionine and that supplementation with this amino acid was of tremendous benefit to the animals (Onifade et al., 2001).

DISCUSSION AND CONCLUSION

The vast heterogeneity of edible insects analyzed by studies deeply affects the output of this review.

It is clear that most recently, researchers have shifted their focus, moving away from the possible use of edible insects in animals feed to a protein and nutrient source for humans.

Humans

The risks to human health proposed and analyzed in the scientific literature are mainly related to allergy, microbiological and chemical contamination, malabsorption, and hematic alteration caused by edible insect consumption. The risk of allergic reaction due to the presence of allergens in insects is the only aspect showing overall concordance among authors, who identify a need for specific studies to investigate the existence of cross-reactive allergens. Nevertheless, such a risk is limited to the group of allergic persons and does not seems to be of higher impact compared to other more common foods, such as shellfish or mollusks. The second element noted by the results of this review is the need for more comprehensive studies on the role of the anti-nutrient factors often isolated from edible insects. In fact, their implications for human health are

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still under discussion, especially in terms of concentrations, interactions with nutrient assimilation and potential pharmaceutical applications.

Studies on microbiological contamination risk showed considerable heterogeneity in the conclusion reached by authors. An important factor seems to be poor sanitation and inadequate collection, drying, transportation, storage and marketing conditions. A possible interpretation, considering the countries and counties wherein those studies were conducted, is that microbiological contamination is strictly area specific, presenting a higher risk in lower-resources settings, a common feature of many products from low-income countries. Other risks, such as malabsorption, hematic alteration and growth alterations, linked with insect consumption did not present major concerns, and many author suggested a potential role for edible insects in efficiently fighting famine and lack of protein availability in low-resources settings and stressed the use of insects in most traditional cuisines.

Animals

Most of the articles reviewed suggested that edible insects derivatives represent efficient and safe substitutes for other animal protein products. On the one hand, many authors suggested that insect-based feed for poultry affect neither the quality of the meat nor the growth rate or the egg size. On the other hand, it is often stressed that insect-based meal can increase the concentration of nutrients and decrease the concentration of cholesterol in broiler meat. The same consideration could apply to fish feed, although the small number of studies reviewed underlines the need for more specific analyses.

As with studies on humans, many authors noted the need for ad hoc studies to determine the roles of anti-nutrients and their possible implications for animal health.

Finally, one of the most interesting finding is the use of insects as a starting point to develop drugs. Potential hypocholesterolemic and hypoglycemic agents derived from some insects will probably require additional efforts to determine their possible uses for human health, and the antioxidant characteristic exhibited by some insects needs in-depth research to standardize their use in many therapies.

In conclusion, this review shows that the use of insects as food and feed appears to have many positive aspects from the economic, environmental and nutritional points of view. However, considerable research still needs to be conducted, in particular, on the aspects of allergy, nutritional and anti-nutritional composition and pharmaceutical use of edible insects.

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REFERENCES

Adámková A., Kouřimská L., Borkovcová M., Mlček J., Bednářová M. (2014). Calcium in edible insects and its use in human nutrition. Potravinarstvo: Scientific Journal for Food Industry, 8: 233-38

Adamolekun B., Ibikunle F. R. (1994). Investigation of an epidemic of seasonal ataxia in Ikare, western Nigeria. Acta neurologica Scandinavica, 90: 309-11

Adebowale Y. A., Adebowale K.O., Ogentokun M.O.,. (2005).Evaluation of nutritive properties of the large African cricket (Gryllidae sp). Karachi, PAKISTAN, Pakistan Council of Scientific and Industrial Research

Adeduntan S. A. (2005). Nutritonal and antinutritional characteristics of some insects foragaing in Akure forest reserve Ondo State, Nigeria. *Journal of Food Technology,*, **3**: 563-67

Aigbodion F. I., Egbon I. N., Erukakpomren E. (2012). A preliminary study on the entomophagous response of Gallus gallus domesticus (Galliformes: Phasianidae) to adult Periplaneta americana (Blattaria: Blattidae). *International Journal of Tropical Insect Science*, **32**: 123-25

Alegbeleye W. O., Obasa S. O., Olude O. O., Otubu K., Jimoh W. (2012). Preliminary evaluation of the nutritive value of the variegated grasshopper (Zonocerus variegatus L.) for African catfish Clarias gariepinus (Burchell. 1822) fingerlings. *Aquaculture Research*, **43**: 412-20

Assielou B., Due E. A., Koffi M. D., Dabonne S., Kouame P. L. (2015). Oryctes owariensis larvae as good alternative protein source: nutritional and functional properties. *SCIENCEDOMAIN International*, **8**: 1-9

Atteh J. O., Ologbenla F. D. (1993). Replacement of fish meal with maggots in broiler diets: effects on performance and nutrient retention. *Nigerian Journal of Animal Production*, **20**: 44-49

Azad Thakur N. S., Firake D. M. (2012). Ochrophora montana (Distant): a precious dietary supplement during famine in northeastern Himalaya. *Current Science* **102**: 845-46

Barennes H., Phimmasane M., Rajaonarivo C. (2015). Insect Consumption to Address Undernutrition, a National Survey on the Prevalence of Insect Consumption among Adults and Vendors in Laos. *PloS one*, **10**: e0136458

Barre A., Caze-Subra S., Gironde C., Bienvenu F., Bienvenu J., Rougé P. (2014). Entomophagie et risque allergique. *Revue Française d'Allergologie*, **54**: 315-21

Bauserman M., Lokangaka A., Gado J., Close K., Wallace D., Kodondi K. K., Tshefu A., Bose C. (2015). A cluster-randomized trial determining the efficacy of caterpillar cereal as a locally available and sustainable complementary food to prevent stunting and anaemia. *Public health nutrition*, **18**: 1785-92

Belluco S. (2009). Insetti per uso alimentare umano: aspetti nutrizionali e igienico-sanitaried.^eds. Facoltá di Medicina Veterinaria, Università degli studi di Padova

Belluco S., Losasso C., Maggioletti M., Alonzi C., Ricci A., Paoletti M. G. (2015). Edible insects: a food security solution or a food safety concern? *Animal Frontiers*, **5**: 25-30

Bovera F., Piccolo G., Gasco L., Marono S., Loponte R., Vassalotti G., Mastellone V., Lombardi P., Attia Y. A., Nizza A. (2015). Yellow mealworm larvae (Tenebrio molitor, L.) as a possible alternative to soybean meal in broiler diets. *British poultry science*, **56**: 569-75

Braide W., Nwaoguikpe R. N. (2010). Microbiological and nutritional status of an edible caterpillar (Rhynchophorus phoenicis). *Current Trends in Microbiology*, **6**: 61 - 68

Broekman H., Knulst A., den Hartog Jager S., Monteleone F., Gaspari M., de Jong G., Houben G., Verhoeckx K. (2015). Effect of thermal processing on mealworm allergenicity. *Mol Nutr Food Res*, **59**: 1855-64

Cheseto X., Kuate S. P., Tchouassi D. P., Ndung'u M., Teal P. E., Torto B. (2015). Potential of the Desert Locust Schistocerca gregaria (Orthoptera: Acrididae) as an Unconventional Source of Dietary and Therapeutic Sterols. *PloS one*, **10**: e0127171

Chrappa V., Peter V., Straznicka H., Sabo V., Abelova H., Strozyk Z. (1990). Production effects of feeding housefly (Musca domestica L.) larvae and pupae to broiler chicks. *Scientia agriculturae bohemoslovaca*, **22**: 201-8

Chrappa V., Peter V., Stróžyk Z., Slámečka J. (1990). The effects of the feeding of poultry dung cultured by housefly (Musca domestica L.) larvae on the efficiency of broiler chicks. *Scientia Agriculturae Bohemoslovaca*, **22**: 131-38

Collavo A., Glew R. H., Huang Y. S., Chuang L. T., Bosse R., Paoletti M. G. (2005). House cricket small-scale farminged.^eds. Ecological implications of minilivestock: potential of insects, rodents, frogs and snails. Enfield, Science Publishers, Inc., 519-44

DeFoliart G. R., Finke M. D., Sunde M. L. (1982). Potential value of the mormon cricket (Orthoptera: Tettigoniidae) harvested as a high-protein feed for poultry. *Journal of economic entomology*, **75**: 848-52

Despins J. L., Axtell R. C. (1995). Feeding behavior and growth of broiler chicks fed larvae of the darkling beetle, Alphitobius diaperinus. *Poultry science*, **74**: 331-6

 ACCEPTED MANUSCRIPT

Dhaliwal J. S., Virk R. S., Atwal A. S. (1980). The use of house fly (Musca domestica Linnaeus) pupae meal in broiler mash. *Indian Journal of Poultry Science*, **15**: 119-22

Ekpo K. E. (2011). Effect of processing on the protein quality of four popular insects consumed in Southern Nigeria. *Archives of Applied Science Research*, **3**: 307-26

Ekpo K. E. (2011). Nutritional and biochemical evaluation of the protein quality of four popular insects consumed in Southern Nigeria. *Archives of Applied Science Research*, **3**: 428-44

Enghoff H., Manno N., Tchibozo S., List M., Schwarzinger B., Schoefberger W., Schwarzinger C., Paoletti M. G. (2014). Millipedes as food for humans: their nutritional and possible antimalarial value-a first report. *Evidence-based complementary and alternative medicine : eCAM*, **2014**: 651768

Fasakin E. A., Balogun A. M., Ajayi O. O. (2003). Evaluation of full-fat and defatted maggot meals in the feeding of clariid catfish Clarias gariepinus fingerlings. *Aquaculture Research*, **34**: 733-38

Fontaneto D., Tommaseo-Ponzetta M., Galli C., Risé P., Glew R. H., Paoletti M. G. (2011). Differences in Fatty Acid Composition between Aquatic and Terrestrial Insects Used as Food in Human Nutrition. Ecology of Food and Nutrition. *Ecology of Food and Nutrition*, **50**: 351-67

Gado M. S., El Aggory S. M., Abd El Gawaad A. A., Mahmoud A. K. (1982). The possibility of applying insect protein in broiler rations. *Research Bulletin - Ain-Shams University*

Gawaad A. A. A., Brune H. (1979). Insect Protein as a Possible Source of Protein to Poultry1. *Zeitschrift für Tierphysiologie Tierernährung und Futtermittelkunde*, **42**: 216-22

ACCEPTED MANUSCRIPT

Hernandez-Flores L., Llanderal-Cazares C., Guzman-Franco A. W., Aranda-Ocampo S. (2015). Bacteria Present in Comadia redtenbacheri Larvae (Lepidoptera: Cossidae). *J Med Entomol*, **52**: 1150-8

Hwangbo J., Hong E. C., Jang A., Kang H. K., Oh J. S., Kim B. W., Park B. S. (2009). Utilization of house fly-maggots, a feed supplement in the production of broiler chickens. *Journal of environmental biology / Academy of Environmental Biology, India*, **30**: 609-14

Hyun S.H., Kwon K. H., Park K.-H., Jeong H. C., Kwon O., Tindwa H., Han Y. S. (2012). Evaluation of nutritional status of an edible grasshopper, Oxya Chinensis Formosana. *Entomological Research*, **42**: 284-90

Igwe C. U., Ojiako A. O., Okwara J. E., Emejulu A. A., Nwaoguikpe R. N. (2014). Biochemical and haematologic effects of intake of Macrotermes nigeriensis fortified functional diet. *Pakistan journal of biological sciences : PJBS*, **17**: 282-6

Jadalla J. B., Habbani A. M. H., Bushara I., Mekki D. M. (2014). Effects of inclusion of different levels of watermelon bug meal in broiler rations on feed intake, body weight changes and feed conversion ratio in North Kordofan, Sudan. *Scientific Journal of Animal Science* **3**: 8-14

Ji H., Zhang J., Huang J., Cheng X., Liu C. (2015). Effect of replacement of dietary fish meal with silkworm pupae meal on growth performance, body composition, intestinal protease activity and health status in juvenile Jian carp (Cyprinus carpio var. Jian). *Aquaculture Research*, **46**: 1209-21

Joshi P. S., Rao P. V., Mitra A., Rao B. S. (1980). Evaluation of deoiled silkworm pupae-meal on layer performance. *Indian Journal of Animal Sciences*, **50**: 979-82

 ACCEPTED MANUSCRIPT

Kinyuru J. N., Kenji G. M., Njoroge S. M., Ayieko M. (2010). Effect of Processing Methods on the In Vitro Protein Digestibility and Vitamin Content of Edible Winged Termite (Macrotermes subhylanus) and Grasshopper (Ruspolia differens). *Food Bioprocess Technol*, **3**: 778-82

Klein R. G. (2009).The human career. Human biological and cultural origins. 3rd ed. Chicago and London, The University of Chicago Press

Klunder H. C., Wolkers-Rooijackers J., Korpela J. M., Nout M. J. R. (2012). Microbiological aspects of processing and storage of edible insects. *Food Control*, **26**: 628-31

Koc K., Incekara U., Turkez H. (2014). Biomonitoring of the genotoxic effects and oxidative potentials of commercial edible dung beetles (Onitis sp.), grasshopper (Caelifera sp.) and mole crickets (Gryllotalpa sp.) in vitro. *Toxicol Ind Health*, **30**: 683-9

Koo S. I., Currin T. A., Johnson M. G., King E. W., Turk D. E. (1980). The Nutritional Value and Microbial Content of Dried Face Fly Pupae (Musca autumnalis (De Geer)) When Fed to Chicks. *Poult Sci*, **59**: 2514-18

Kumar A., Hasan S. B., Rao R. J. (1992). Studies on the performance of broilers fed on silkworm moth meal. *International Journal of Animal Sciences*, **7**: 227-29

Lee J., Choi I. C., Kim K. T., Cho S. H., Yoo J. Y. (2012). Response of dietary substitution of fishmeal with various protein sources on growth, body composition and blood chemistry of olive flounder (Paralichthys olivaceus, Temminck & Schlegel, 1846). *Fish physiology and biochemistry*, **38**: 735-44

 ACCEPTED MANUSCRIPT

Longvah T., Manghtya K., Qadri S. S. (2012). Eri silkworm: a source of edible oil with a high content of alpha-linolenic acid and of significant nutritional value. *J Sci Food Agric,* **92**: 1988-93

Longvah T., Mangthya K., Ramulu P. (2011). Nutrient composition and protein quality evaluation of eri silkworm (Samia ricinii) prepupae and pupae. *Food Chem*, **128**: 400-3

Lundy M. E., Parrella M. P. (2015). Crickets are not a free lunch: protein capture from scalable organic side-streams via high-density populations of Acheta domesticus. *PloS one*, **10**: e0118785

Memis E., Turkez H., Incekara U., Banjo A. D., Fasunwon B. T., Togar B. (2013). In vitro biomonitoring of the genotoxic and oxidative potentials of two commonly eaten insects in southwestern Nigeria. *Toxicol Ind Health*, **29**: 52-9

Mujahid M. Z., Agistia D. D., Sa'adah M., Nugroho A. E. (2013). A combination of bitter gourd ethanolic extract with ant lion larvae aqueous extract for a blood glucose-lowering agent. *International Food Research Journal*, **20**: 851-55

Musundire R., Zvidzai C. J., Chidewe C., Samende B. K., Manditsera F. A. (2014). Nutrient and anti-nutrient composition of Henicus whellani (Orthoptera: Stenopelmatidae), an edible ground cricket, in south-eastern Zimbabwe. *International Journal of Tropical Insect Science,* **34**: 223-31

Nakagaki B. J., Sunde M. L., Defoliart G. R. (1987). Protein Quality of the House Cricket, Acheta domesticus, When Fed to Broiler Chicks. *Poult Sci*, **66**: 1367-71

Ocio E., Viñaras R., Rey J. M. (1979). House fly larvae meal grown on municipal organic waste as a source of protein in poultry diets. *Animal Feed Science and Technology,* **4**: 227-31

 ACCEPTED MANUSCRIPT

Ogunleye R. F. (2006). Biochemical implications of the consumption of Zonocerus variegatus, (Orthoptera: Notodontidae) and Cirina forda Westwood (Lepidoptera: Saturnidae). *Journal of Food Agriculture and Environment*, **4**: 23-25

Omotoso O. T., Afolabi O. (2007). Nutritional evaluation, functional properties and anti-nutritional factors of Macrobrachium rosenbergii, an underutilized animal. *Pakistan Journal of Scientific and Industrial Research*, **50**: 109-12

Omotoso O. T. (2015). Nutrient composition, mineral analysis and anti-nutrient factors of Oryctes rhinoceros L. (Scarabaeidae: Coleoptera) and winged termites, Marcrotermes nigeriensis Sjostedt. (Termitidae: Isoptera). *British Journal of Applied Science & Technology*, **8**: 97-106

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**: 51-5

Onifade A. A., Oduguwa O. O., Fanimo A. O., Abu A. O., Olutunde T. O., Arije A., Babatunde G. M. (2001). Effects of supplemental methionine and lysine on the nutritional value of housefly larvae meal (Musca domestica) fed to rats. *Bioresource technology*, **78**: 191-4

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

 ACCEPTED MANUSCRIPT

Payne C. L. R., Scarborough P., Rayner M., Nonaka K. (2016). A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values. *Trends in Food Science & Technology*, **47**: 69-77

Pro M. A., Cuca G. M., Becerril P. C., Bravo M. H., Bixler C. E., Pérez H. A. (1999). Estimation of metabolizable energy and utilization of fly larvae (Musca domestica L.) in the feeding of broilers. *Archivos Latinoamericanos de Producción Animal*, **7**: 39-51

Routh S., Routh J. (2005). Note di cucina di Leonardo da Vinci. Roma, Voland

Shantibala T., Lokeshwari R. K., Debaraj H. (2014). Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India. *Journal of insect science*, **14**: 14

Simpanya M. F., Allotey J., Mpuchane S. F. (2000). A mycological investigation of phane, an edible caterpillar of an emperor moth, Imbrasia belina. *J Food Prot*, **63**: 137-40

Sogbesan A. O., Ugwumba A. A. A. (2008). Nutritional evaluation of termite (Macrotermes subhyalinus) meal as animal protein supplements in the diets of Heterobranchus longifilis (Valenciennes, 1840) fingerlings. *Turkish Journal of Fisheries and Aquatic Sciences*, **8**: 149-57

Srinroch C., Srisomsap C., Chokchaichamnankit D., Punyarit P., Phiriyangkul P. (2015). Identification of novel allergen in edible insect, Gryllus bimaculatus and its cross-reactivity with Macrobrachium spp. allergens. *Food chemistry*, **184**: 160-6

 ACCEPTED MANUSCRIPT

Sudhakara Reddy P., Nakahari D., Talukdas J. K., Sundararasu V. (1991). Effect of mineral supplementation on the nutritive value of silkworm pupae meal in broiler feeds. *Cheiron*, **20**: 106

Sujatha K. R., Rao B. S. (1981). Feasibility of substituting fishmeal by alternative protein sources in layer rations. *Indian Journal of Poultry Science*, **16**: 350-57

Sun T., Long R. J., Liu Z. Y., Ding W. R., Zhang Y. (2012). Aspects of lipid oxidation of meat from free-range broilers consuming a diet containing grasshoppers on alpine steppe of the Tibetan Plateau. *Poultry science*, **91**: 224-31

Tamale A., Sifuna T., Mwangi K., Ayieko M., Ndonga M. (2010). Use of mayflies as total replacement of Rastrineobola argentea in diets for catfish, Clarias gariepinus in Lake Victoria basined.^eds. Ethnobotany and Health Proceedings of the Cluster Workshop. Entebbe, Uganda, Inter-University Council for East Africa Lake Victoria Research Initiative, 178-84

Tang J.J., Fang P., Xia H.-L., Tu Z.-C., Hou B.-Y., Yan Y.-M., Di L., Zhang L., Cheng Y.-X. (2015). Constituents from the edible Chinese black ants (Polyrhachis dives) showing protective effect on rat mesangial cells and anti-inflammatory activity. *Food Research International*, **67**: 163-68

Tommaseo-Ponzetta M., Paoletti M. G. (2005). Lessons from Traditional Foraging Patterns in West Papua (Indonesia). Ecological implications of minilivestock: potential of insects, rodents, frogs and snails. Enfield, Science Publishers, Inc., 441-57

Turkez H., Incekara U., Guner A., Aydin E., Dirican E., Togar B. (2014). The cytogenetic effects of the aqueous extracts of migratory locust (Locusta migratoria L.) in vitro. *Toxicol Ind Health*, **30**: 233-7

van Huis A. (2013).Edible insects : future prospects for food and feed security. Rome, Food and Agriculture Organization of the United Nations

Verhoeckx K. C. M., van Broekhoven S., den Hartog-Jager C. F., Gaspari M., de Jong G. A. H., Wichers H. J., van Hoffen E., Houben G. F., Knulst A. C. (2014). House dust mite (Der p 10) and crustacean allergic patients may react to food containing Yellow mealworm proteins. *Food and Chemical Toxicology*, **65**: 364-73

Virk R. S., Lodhi G. N., Ichhponani J. S. (1980). Deoiled silk worm pupae meal as a substitute for fish meal in White Leghorn laying ration. *Indian Journal of Poultry Science*, **15**: 149-54

Virk R. S., Lodhi G. N., Ichhponani J. S. (1980). Nutritive value of untreated, water and acid treated deoiled silk worm pupae meal for broiler chicks. *Indian Journal of Poultry Science*, **15**: 155-61

Xia Z., Chen J., Wu S. (2013). Hypolipidemic activity of the chitooligosaccharides from Clanis bilineata (Lepidoptera), an edible insect. *International journal of biological macromolecules*, **59**: 96-8

Xia Z., Wu S., Pan S., Kim J. M. (2012). Nutritional evaluation of protein from Clanis bilineata (Lepidoptera), an edible insect. *Journal of the science of food and agriculture*, **92**: 1479-82

ACCEPTED MANUSCRIPT

Yeboah S. O., Mitei Y. C. (2009). Further Lipid Profiling of the Oil from the Mophane Caterpillar, Imbrasia belina. *J Am Oil Chem Soc*, **86**: 1047-55

Zhou J., Han D. (2006). Safety evaluation of protein of silkworm (Antheraea pernyi) pupae. *Food and chemical toxicology*, **44**: 1123-30

Table 1: Articles included for final review

	Authors	**Year**	**Title**	**Type of insect**	**Human/animal**	**Type of consumption**	**Main risks analyzed** *	**Specific risk y/n**	**Pharmacological effect**	**Main results**
1	A. A. A. Gawad et al.	1979	Insect protein as a possible source of protein to poultry. 1. Introduction and statement of the problem	*Musca domestica L.* and *Phormia terraenovae R.-D*	Animal (poultry)	Prolonged	Malabsorption risk Growth alteration	n	-	Larval meal could be a suitable feedstuff for broiler production.

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							ris k			
2	E. Ocio et al.	1979	House fly larvae meal grown on municipal organic waste as a source of protein in poultry diets	*Musca domestica L*	Animal (poultry)	Prolonged	Malabsorption risk Growth alteration risk	n	-	Results showed no significant differences in body weight gain or food conversion efficiency.
3	J. S. Dhaliwal	198	The use of house fly	*Musca domest*	Animal (poultr	Prolonged	Malabsor	n	-	50 per cent replaceme

	et al.	0	(Musca domestica Linnaeus) pupae meal in broiler mash	*ica L*	y)		ption risk Growth alteration risk			nt of fish meal by house fJy pupae in the poultry ration may be adopted without any adverse effect on the performance of the birds.
4	P. S. Joshi et al.	1980	Evaluation of deoiled silkworm	Silkworm pupae	Animal (poultry)	Prolonged	Malabsorpti	n	-	Egg size was not affected by insect

			pupae-meal on layer performance				on risk Growth alteration risk			based feed.
5	S. I. Koo et al.	1980	The nutritional value and microbial content of dried face fly pupae	*Musca autumnalis*	Animal (poultry)	Prolonged	Malabsorption risk	y	-	Dried pupae of M. autumnalis could be used to extract nutrients in dung

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			(Musca autumnalis (De Geer)) when fed to chicks							and could be used as a feed extender and protein source.
6	R. S. Virk et al.	1980	Deoiled silk worm pupae meal as a substitute for fish meal in White Leghorn laying ration	Silkworm pupae	Animal (poultry)	Prolonged	Malabsorption risk	n	-	SWP had no significant effect on egg production.
7	R. S. Virk	19	Nutritive value of	Silkworm	Animal	Prolonged	Malab	n	-	The effects of

		80	untreated, water and acid treated deoiled silk worm pupae meal for broiler chicks	pupae	(poultry)		sorption risk Growth alteration risk			SWP on growth and in production performance are good.
8	K. R. Sujatha et al.	1981	Feasibility of substituting fishmeal by alternativ	Silkworm pupae	Animal (poultry)	Prolonged	Malabsorption risk	n	-	There was no significant difference among treatment

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			e protein sources in layer rations				Growth alteration risk			groups in egg production, feed intake, egg weight, bodyweight or financial returns.
9	G. R. DeFoliart et al.	1982	Potential value of the mormon cricket (Orthoptera: Tettigoniidae) harvested	Mormon cricket	Animal (poultry)	Prolonged	Malabsorption risk	n	-	Diets based on maize and crickets produced significantly better growth of broiler chicks

			as a high-protein feed for poultry							than a conventional diet based on maize and soyabean.
10	M. S. Gado et al.	1982	The possibility of applying insect protein in broiler rations	*Musca domestica*	Animal (poultry)	Prolonged	Malabsorption risk Growth alteration ris	n	-	Chickens given larvae meal had higher average concentrations of calcium and lower concentrations of total lipids, glucose,

								k Hematic and qualitative meat alteration risk			cholesterol and inorganic phosphorus in blood serum compared with controls; total protein was not affected. Birds given larvae meal had greater weights of edible and

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										inedible parts of the carcass, giblets and body fat, and lower weight of feathers compared with control birds.
11	B. J. Nakagaki, et al.	1987	Protein quality of the house cricket, Acheta domesticus, when	House cricket (*Acheta domesticus*)	Animal (poultry)	Prolonged	Growth alteration risk	n	-	There were no significant differences in weight

			fed to broiler chicks							gain between chicks fed on maize/soyabean meal diets and those fed on maize/cricket diets.
12	V. Chrappa et al.	1990	The effects of the feeding of poultry dung cultured by housefly (Musca	*Musca domestica L.*	Animal (poultry)	Prolonged	Growth alteration risk	n	-	Results indicated that 3 or 5% dried poultry manure containing housefly larvae

			domestica L.) larvae on the efficiency of broiler chicks							was a suitable feed for broiler chicken.
13	V. Chrappa et al.	1990	Production effects of feeding housefly (Musca domestica L.) larvae and pupae to broiler chicks	*Musca domestica L.*	Animal (poultry)	Prolonged	Growth alteration risk	n	-	Results indicated that when feeds of animal origin are replaced by housefly pupae and/or larvae, there are no

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										negative effects on chick growth efficiency, nor on the quality and taste of the meat of the birds reared on these diets.
14	P. Sudhakara Reddy et al.	1991	Effect of mineral supplementation on the nutritive	Silkworm pupae	Animal (poultry)	Prolonged	Growth alteration risk	y	-	Incorporation of silkworm pupae meal (SWPM)

			value of silkworm pupae meal in broiler feeds								in broiler diets at 5%, replacing half of the fish meal, significantly depressed growth rate, and final body weight at 6 weeks old, leading to poorer feed efficiency, higher cost of productio

										n and lower broiler farm economy index
15	A. Kumar et al.	1992	Studies on the performance of broilers fed on silkworm moth meal	Silkworm	Animal (poultry)	Prolonged	Malabsorption risk Growth alteration risk	n	-	Silkworm moth meal can be successfully used as a source of animal protein in broiler feeds.

							k He ma tic an d qu alit ati ve me at alt era tio n ris k			
16	J. O. Atteh et al.	199	Replacement of fish meal	*Musca domestica*	Animal (poultr	Prolonged	Malabsor	n	-	Maggots could replace

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		3	with maggots in broiler diets: effects on performance and nutrient retention		y)		ption risk Growth alteration risk Hematic and qualitative			33% of dietary fish meal without compromising performance and are an economical replacement

							me at alt era tio n ris k			
17	B. Adamolekun et al.	1994	Investigation of an epidemic of seasonal ataxia in Ikare, western Nigeria	*Anaphe venata Butler*	Human	Singular	Risk of developing ataxia after consumption	y	-	Consumption of the roasted larvae of Anaphe venata Butler could cause cerebellar ataxia, nystagmus and

										varying levels of impaired consciousness.
18	J. L. Despins et al.	1995	Feeding behavior and growth of broiler chicks fed larvae of the darkling beetle, Alphitobius diaperinus	*Alphitobius diaperinus*	Animal (poultry)	Prolonged	Growth alteration risk	n	-	The body weight of chicks feeding on starter feed and larvae was significantly greater than the weight of chicks consuming feed only.

19	M.A. Pro et al.	1999	Estimation of metabolizable energy and utilization of fly larvae (Musca domestica L.) in the feeding of broilers	*Musca domestica L*	Animal (poultry)	Prolonged	Malabsorption risk Growth alteration risk	n	-	Protein and energy supplied by the dry fly larvae support animal performance similar to that of chicks fed a conventional diet
20	M. F. Simpanya et al.	2000	A mycological investigation of	*Imbrasia belina*	Non specific	Prolonged	Microbiologica	y	-	Risk of recontamination of phane during

			phane, an edible caterpillar of an emperor moth, Imbrasia belina				l contamination risk			drying and storage.
21	A. A. Onifade et al.	2001	Effects of supplemental methionine and lysine on the nutritional value of housefly larvae meal (Musca	*Musca domestica L*	Animal (rats)	Non specific	Hematic and qualitative meat altera	y	-	Housefly larvae meal seemed deficient in methionine and it benefited the rat tremendously to suppleme

			domestica) fed to rats				tion risk			nt with this amino acid
22	E. A. Fasakin et al	2003	Evaluation of full-fat and defatted maggot meals in the feeding of clariid catfish Clarias gariepinus fingerlings	Maggots	Animal (fish)	Prolonged	Malabsorption risk Growth alteration risk	n y	-	Fish performed better when fed diets containing defatted maggot meals than full-fat maggot meal, and compared favourably with fish fed

										the fish meal-based diet.
23	S. A. Adedutan	2005	Nutritonal and antinutritional characteristics of some insects foragaing in Akure forest reserve Ondo State, Nigeria	Ant, termite, cricket, meal bug, grassoppher, anaphe venata, tree hopper, winget termite	Non specific	Prolonged	Chemical contamination risk Malabsorption ris	y	-	More work is needed to ascertain the impact of processing on the levels of nutrient and antinutritional factors (tannin and phytate)

							k			
24	Y.A. Adebowale et al.	2005	Evaluation of nutritive properties of the large African cricket (Gryllidae sp)	African cricket	Non specific	Non specific	Malabsorption risk	n	-	Results of the in vitro protein multienzyme digestibility indicated high digestibility.
25	R. F. Ogunleye	2006	Biochemical implications of the consumption of Zonocerus	*Zonocerus variegatus,* and *Cirina forda Westw*	Human	Prolonged	Growth alteration ris	n	-	No significant alteration in growth, cholesterol and glucose

			variegatu s, (Orthoptera: Notodontidae) and Cirina forda Westwood (Lepidoptera: Saturnidae)	*ood*			k Hematic and qualitative meat alteration risk			levels were observed.
26	O.T. Omotoso	200	Nutritional quality, functiona	*Larvae of Cirina*	Non specific	Non specific	Malabsorption risk	n	-	The results of anti-

		6	l properties and anti-nutrient compositions of the larva of Cirina forda (Westwood) (Lepidoptera: Saturniidae)	*forda*						nutritional analysis revealed that oxalate and phytic acid fell within nutritionally accepted values. Tannin was not detected
27	J. Zhou et al.	2006	Safety evaluation of protein of silkworm	Silkworm pupae	Non specific	prolonged	Growth altera	n	-	No statistically significant

			(Antheraea pernyi) pupae				tion risk Malabsorption risk Hematic and qualitative meat			differences had been found in body weights, food consumption and food efficiency of rats in each test group ($P > 0.05$)

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28	O.T. Omotoso et al.	2007	Nutritional evaluation, functional properties and anti-nutritional factors of Macrobrachium rosenbergii, an	*Macrobrachium rosenbergii*	Non specific	Non specific	Malabsorption risk	y	-	Three anti-nutrients were determined: phytic acid was 4.00 ±0.01 mg/100 g, oxalate 1.05 ±0.00 mg/100 g while

			underutilized animal							tannin was not detected.
29	A.O. Sogbesan et al.	2008	Nutritional evaluation of termite (Macrotermes subhyalinus) meal as animal protein supplements in the diets of Heterobranchus longifilis (Valencie	Termite	Animal (fish)	Non specific	Malabsorption risk Growth alteration risk	n	-	50% inclusion levels of termite meal will yield the best result in a practical diet for H. longifilis fingerlings for a profitable and sustainable

			nnes, 1840) fingerlings								aquaculture venture.
30	J. Hwangbo et al.	2009	Utilization of house fly-maggots, a feed supplement in the production of broiler chickens	House fly-maggots	Animal (poultry)	Prolonged	Growth alteration risk Malabsorption risk He	n	-		Feeding diets containing 10 to 15% maggots in chicken dropping after biodegradation can improve the carcass quality and

							matic and qualitative meat alteration risk			growth performance of broiler chickens.
31	S. O. Yeboah et al.	2009	Further lipid profiling of the oil from the	*Imbrasia belina*	Non specific	Non specific	Hematic and qualitative meat alteration	y	-	Adverse effect of the high cholesterol content

			mophane caterpillar, Imbrasia belina				risk			given by *Imbrasia belina* could be mitigated by the presence of the substantial amounts of β-sitosterol and campesterol
32	W. Braide et al.	2010	Microbiological and nutritional status of an edible	*Rhynchophorus phoenicis*	Human	Non specific	Microbiological	y	-	Poor sanitation and inadequate storage and

			caterpillar (Rhynchophorus phoenicis)				contamination risk Chemical contamination risk			marketing conditions may contribute to the contamination and re-contamination of the products
33	J. N. Kinyuru et	201	Effect of processing	*Macrotermes subhyl*	Human	Non specific	Malabsorption risk	y	-	The processing

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	al.	0	methods on the in vitro protein digestibility and vitamin content of edible winged termite (Macrotermes subhylanus) and grasshopper (Ruspolia differens)	*anus* and *Ruspolia differens*						methods of the insects affected their nutrient potential as evidenced by the changes in protein digestibility and vitamins content
34	K. E. Ekpo	20	Nutritional and	*Oryctes*	Non specifi	Prolonged	Ma lab	n	-	Studied insects

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		11	biochemical evaluation of the protein quality of four popular insects consumed in Southern Nigeria	*rhinoceros, Gonimbrasia belina, Macrotermes belicosus and Rhynchophorus phoenicis*	c		sorption risk Growth alteration risk			are good sources of essential nutrients, which could go a long way in helping to solve most nutritional problems in many developing countries.
35	K. E. Ekpo	201	Effect of processing on the	*Oryctes rhinoc*	Non specific c	Non specific	Hematic	n	-	Insects are good sources of

		1	protein quality of four popular insects consumed in Southern Nigeria	*eros, Gonimbrasia belina, Macrotermes belicosus and Rhynchophorus phoenicis*			and qualitative meat alteration risk Growth alteration ris			essential nutrients

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36	T. Longvah et al	2011	Nutrient composition and protein quality evaluation of eri silkworm (Samia ricinii) prepupae and pupae	Eri silkworm	Non specific	Non specific	Malabsorption risk	n		Protein digestibility corrected amino acid score (PDCAAS) was 86
37	F. I. Aigbodion et al.	2012	A preliminary study on the entomophagous response	*Blattaria: Blattidae*	Ainimal (poultry)	Prolonged	Growth alteration	n	-	Insect-enhanced meals could be used as an alternative feed

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			of Gallus gallus domesticus (Galliformes: Phasianidae) to adult Periplaneta americana (Blattaria: Blattidae)				risk			within the formative stage of development of G. domesticus
38	W. O. Alegbeleye et	2012	Preliminary evaluation of the nutritive	*Zonocerus variegatus*	Animal (fish)	Prolonged	Malabsorption	n	-	The results indicate that apparent

	al.		value of the variegated grasshopper (Zonocerus variegatus L.) for African catfish Clarias gariepinus (Burchell. 1822) fingerlings				risk Growth alteration risk			protein and lipid digestibility were high at all levels, although there were decreases with an increase in the inclusion levels
39	S.H. Hyun	20	Evaluation of	*Oxya chinen*	Human	Non specif	Ma lab	n	-	It would be

	et al.	12	nutritional status of an edible grasshopper, Oxya chinensis formosana	*sis formosana*		ic	sorption risk Chemical contamination risk			recommended to use the grasshopper (OCF) as substitute to the traditional sources of protein.
40	H. C. Klunder et al.	2012	Microbiological aspects of processing and	Farmed mealworm larvae	Non specific	Non specific	Microbiologica	n	-	Simple preservation methods such as

			storage of edible insects	and house crickets			l contamination risk			drying/acidifying without use of a refrigerator or were demonstrated effective in safeguarding shelf-life and safety by the control of - Enterobacteria -and bacterial --spores.

41	J. Lee et al	2012	Response of dietary substitution of fishmeal with various protein sources on growth, body composition and blood chemistry of olive flounder (Paralichthys olivaceus,	Silkworm pupae	Animal (fish)	Prolonged	Malabsorption risk Growth alteration risk	n	-	Dietary substitution of fishmeal Silkwarm papae based feed could be made.

			Temminck & Schlegel, 1846							
42	T. Longvah et al.	2012	Eri silkworm: a source of edible oil with a high content of alpha-linolenic acid and of significant nutritional value	Eri silkworm	Non specific	Prolonged	Malabsorption risk Growth alteration risk He	n	-	The study showed that eri silkworm pupae oil is safe and nutritionally equivalent to commonly used vegetable oils.

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43	T. Shant ibala et al.	2012	Nutrition al and antinutriti onal compositi	*Lethoc erus indicus* ,, *Laccot*	Human	Non specif ic	Ch em ica l co	n	*C. tripunct atus* possesse d strong	Edible insects are rich in protein, fat,

			on of the five species of aquatic edible insects consumed in Manipur, India	*rephes maculatus, Hydrophilus olivaceous, Cybister tripunctatus* and *Crocothemis servilia*			ntamination risk		antioxidant activity	carbohydrates, minerals, and other activated elements that promote human health.
44	T. Sun et al.	2012	Aspects of lipid oxidation of meat from free-	Grasshoppers	Animal (poultry)	Prolonged	Malabsorption ris	n	-	Meat in free-range broilers feeding on grasshopp

			range broilers consumin g a diet containin g grasshop pers on alpine steppe of the Tibetan Plateau				k He ma tic an d qu alit ati ve me at alt era tio n ris k			ers has more antioxidat ive potential and longer storage life.
4 5	A. Tama le et	2 0 1	Use of mayflies as total	May flies	Anima l (fish)	Prolo nged	Gr ow th	n	-	The analysis of the

	al.	2	replacement of Rastrineobola argentea in diets for catfish, Clarias gariepinus in Lake Victoria basin				alteration risk			conversion ratio, suggest that May flies are a perfect replacement for the fishmeal in the fish diets.
46	N.S. Azad Thakur et al.	2012	Ochrophora montana (Distant): a precious dietary suppleme	*Ochrophora montana*	Human	Non specific	-	-	Medicinal value and nutrient composition of different Thangna	-

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			nt during famine in northeastern Himalaya						ng-based traditional products should be studied to determine its benefits as a food source	
47	Z. Xia et al.	2012	Nutritional evaluation of protein from	*Clanis bilineata*	Non specific	Prolonged	Malabsorption oris	n	-	CBP may be a suitable alternative dietary protein

			Clanis bilineata (Lepidoptera), an edible insect				k Hematic and qualitative meat alteration risk				source for humans
48	E. Memis et	201	In vitro biomonitoring of	*Zonocerus varieg*	Human	Non specific	Chemical contamination risk	y	-		Studied insects can be

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	al.	3	the genotoxic and oxidative potentials of two commonly eaten insects in southwestern Nigeria	*atus* and *Oryctes boas*						consumed safely, but it is necessary to consider the cellular damages that are likely to appear depending on the oxidative stress.
49	M. Z. Mujahid et al	2013	A combination of bitter gourd	*Momordica charantia L.* and	Human	Non specific	-	-	The result indicated that the	-

			ethanolic extract with ant lion larvae aqueous extract for a blood glucose-lowering agent	*Myrmeleon sp.*					combination of bitter gourd and ant lion larvae is potential to be developed as a blood glucose-lowering agent for diabetic patients	
50	Z. Xia et al.	201	Hypolipidemic activity	*Clanis bilineata*	Human	Non specific	-	-	The results suggest	-

		3	of the chitooligosaccharides from Clanis bilineata (Lepidoptera), an edible insect						that LCBL I may be a suitable alterative hypolipidemic source for humans.	
51	A. Adámková et al.	2014	Calcium in edible insects and its use in human nutrition	*Lethocerus indicus*, *Laccotrephes maculatus*, *Hydro*	Non specific	Non specific	-	-	Selected species of edible insect could serve as an alternative	-

				philus olivaceous, Cybister tripunctatus and *Crocothemis servilia*					source of calcium for people with lactose intolerance and allergies to soy	
52	A. Barre et al.	2014	Entomophagy and the risk of allergy	Non specific	Non specific	Singular	Risk of allergy	y	-	Because of the existence of cross-reactive allergens in insects, it seems wise to advise

										individuals known to be allergic to shellfish or mollusks to avoid eating edible insects.
53	H. Enghoff et al.	2014	Millipedes as food for humans: their nutritional and possible antimalarial value -	*Diplopoda*	Human	Non specific	Malabsorption risk	n	The millipedes' defensive secretions, hydrogen cyanide	Contents of unsaturated fatty acids, calcium, and iron in millipedes are

			a first report						and benzoquinones, may act as insect-repellents.	particularly high
54	C. U. Igwe et al.	2014	Biochemical and haematologic effects of intake of macrotermes nigeriensis fortified functional diet	Macrotermes	Non specific	Prolonged	Hematic and qualitative meat altera	-		Fortified diets do not have detrimental hepatic, renal or haematologic effects but rather may be recommended for

							tio n ris k Gr ow th alt era tio n ris k			fortificati on of human and animal.
55	J. B. Jadalla et al.	2014	Effects of inclusion of different levels of watermel on bug meal in	Water melon bug	Anima l (poultr y)	Prolo nged	Ma lab sor pti on ris k Gr	n	-	Watermel on bug meal could replace sorghum grains as source of

			broiler rations on feed intake, body weight changes and feed conversion ratio in North Kordofan, Sudan				owth alteration risk			energy in broiler rations
56	K. Koc et al	2014	Biomonitoring of the genotoxic effects and oxidative potentials	*Onitis sp.*, *Caelifera sp.*, and *Gryllotalpa sp.*	Human	Non specific	Chemical contamination risk	y	-	Studied insects can be consumed safely, but it is necessary to

			of commercial edible dung beetles (Onitis sp.), grasshopper (Caelifera sp.) and mole crickets (Gryllotalpa sp.) in vitro							consider the cellular damages which are likely to appear depending on oxidative stress at higher concentrations.
57	R. Musundire et al.	2014	Nutrient and anti-nutrient composition of	*Henicus whellani*	Non specific	Non specific	Chemical co	y	-	The relatively high ash content compared

			Henicus whellani (Orthoptera: Stenopelmatidae), an edible ground cricket, in south-eastern Zimbabwe				ntamination risk Malabsorption risk			with that from other edible insects indicates a rich source of minerals such as calcium, iron, magnesium, phosphorus and potassium. However, the presence of

										saponins, oxalates and tannins could be a limitation .
58	H. Turkez et al.	2014	The cytogenetic effects of the aqueous extracts of migratory locust (Locusta migratoria L.) in vitro	*Locusta migratoria*	Non specific	Non specific	Chemical contamination risk	n	-	Extracts of *Locusta migratoria* did not exhibit genotoxicity at tested concentrations
5	K. C.	2	House	Yellow	Human	Singu	Risk of	y	-	Based on

9	M. Verhoeckx et al.	014	dust mite (Der p 10) and crustacean allergic patients may react to food containing Yellow mealworm proteins	mealworm		lar	allergy			these cross-reactivity studies, there is a realistic possibility that HDM- and crustacean allergic patients may react to food containing Yellow mealworm proteins.
6	B.	2	Oryctes	*Orycte*	Non	Non	Malabsorp	n	-	The larva

0	Assie lou et al.	015	owariensis larvae as good alternative protein source: nutritional and functional properties	*s owariensis*	specific	specific	tion risk			flour shows good functional characteristics for use in many food industries.
61	H. Barennes et al.	2015	Insect Consumption to Address Undernutrition, a National Survey on the Prevalenc	Eggs of weaver ants, short-tailed crickets, crickets,	Human	Singular	Risk of allergy	y	-	Entomophagy is general in Laos, and well accepted despite a decreasing trend in consumpt

			e of Insect Consumption among Adults and Vendors in Laos	grasshoppers, and cicadas						ion
62	M. Bauserman et al.	2015	A cluster-randomized trial determining the efficacy of caterpillar cereal as a locally available	Caterpillars	Human	Prolonged	Malabsorption risk Growth altera	n	-	Infants who consumed caterpillar cereal had higher Hb concentration and fewer were anaemic, suggestin

			and sustainabl e complem entary food to prevent stunting and anaemia				tio n ris k He ma tic an d qu alit ati ve me at alt era tio n ris k			g that caterpillar cereal might have some beneficial effect.

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63	F. Bovera et al.	2015	Yellow mealworm larvae (Tenebrio molitor, L.) as a possible alternative to soybean meal in broiler diets	*Tenebrio molitor larvae*	Animal (poultry)	Prolonged	Malabsorption risk Growth alteration risk Hematic and qu	n ny	-	TML did not affect feed intake and growth rate of broilers. The lowest albumin-to-globulin ratio in broilers fed on TML suggests a higher immune response, probably

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							alitative meat alteration risk			due to the prebiotic effects of chitin.
64	H. Broekman et al.	2015	Effect of thermal processing on mealworm allergenicity	Mealworm	Human	Singular	Risk of allergy	y	-	Thermal processing did not lower allergenicity but clearly changed solubility of

										mealworm allergens.
65	X. Chesseto et al.	2015	Potential of the desert locust Schistocerca gregaria (Orthoptera: Acrididae) as an unconventional source of dietary and therapeutic sterols	*Orthoptera: Acrididae*	Human	Non specific	-		Desert locust ingests phytosterols from a vegetative diet and, amplifies and metabolizes them into derivatives with potential salutary	-

									benefits	
66	L. Hernandez-Flores et al.	2015	Bacteria Present in Comadia redtenbacheri Larvae (Lepidoptera: Cossidae)	*larvae of Comadia redtenbacheri Hammerschmidt*	Non specific	Non specific	Microbiological contamination risk	y	-	This indicates that bacterial flora can vary in accordance with how the larvae are handled during extraction, collection, and transport.
67	H. Ji et al.	201	Effect of replacement of	Silkworm pupae	Animal (fish)	Prolonged	Growth	n y	-	The study demonstrates that it

		5	dietary fish meal with silkworm pupae meal on growth performance, body composition, intestinal protease activity and health status in juvenile Jian carp (Cyprinus carpio					alteration risk Hematic and qualitative meat alteration ris			is practical to replace 50% of the Jian carp dietary FM protein with SP, higher SP levels are not recommended and that oxidation status of the SP should be carefully

			var. Jian)				k			assessed.
68	O.T. Omotoso	2015	Nutrient composition, mineral analysis and anti-nutrient factors of Oryctes rhinoceros L. (Scarabaeidae: Coleoptera) and winged termites, Marcrotermes nigeriensi	*Scarabaeidae: Coleoptera Termitidae: Isoptera*	Non specific	Non specific	Chemical contamination risk Malabsorption risk	n		The levels at which antinutrient/secondary metabolites occur is not a threat to animals that feed on these two insects.

			s Sjostedt. (Termitidae: Isoptera)							
69	C. Srinroch et al.	2015	Identification of novel allergen in edible insect, Gryllus bimaculatus and its cross-reactivity with Macrobrachium spp. allergens	Gryllus bimaculatus	Human	Singular	Risk of allergy	y	-	The allergens in Macrobrachium lanchesteri were identified as AK and HC. In addition, hexamerin1B (HEX1B) was

										identified as a novel and specific allergen in G. bimaculatus.
70	J. J. Tang et al	2015	Constituents from the edible Chinese black ants (Polyrhachis dives) showing protective effect on rat mesangia	*Polyrhachis dives*	Non specific	Non specific	-	-	The results of biological studies show that the Chinese black ants contain compou	-

			l cells and anti-inflammatory activity						nds that display anti-inflammatory, immunosuppressie, and renoprotective activities.	

*Main risk analyzed:

Risk of allergy: reported allergic reaction or laboratory confirmation of known allergens.

Microbiological risk: reported microbiological contamination in any fase of production (collection, storage, transportation) or specific insect microbiological contamination.

Chemical risk: reported presence of insect contamination with any known risky chemical substance or with anti-nutrient factors

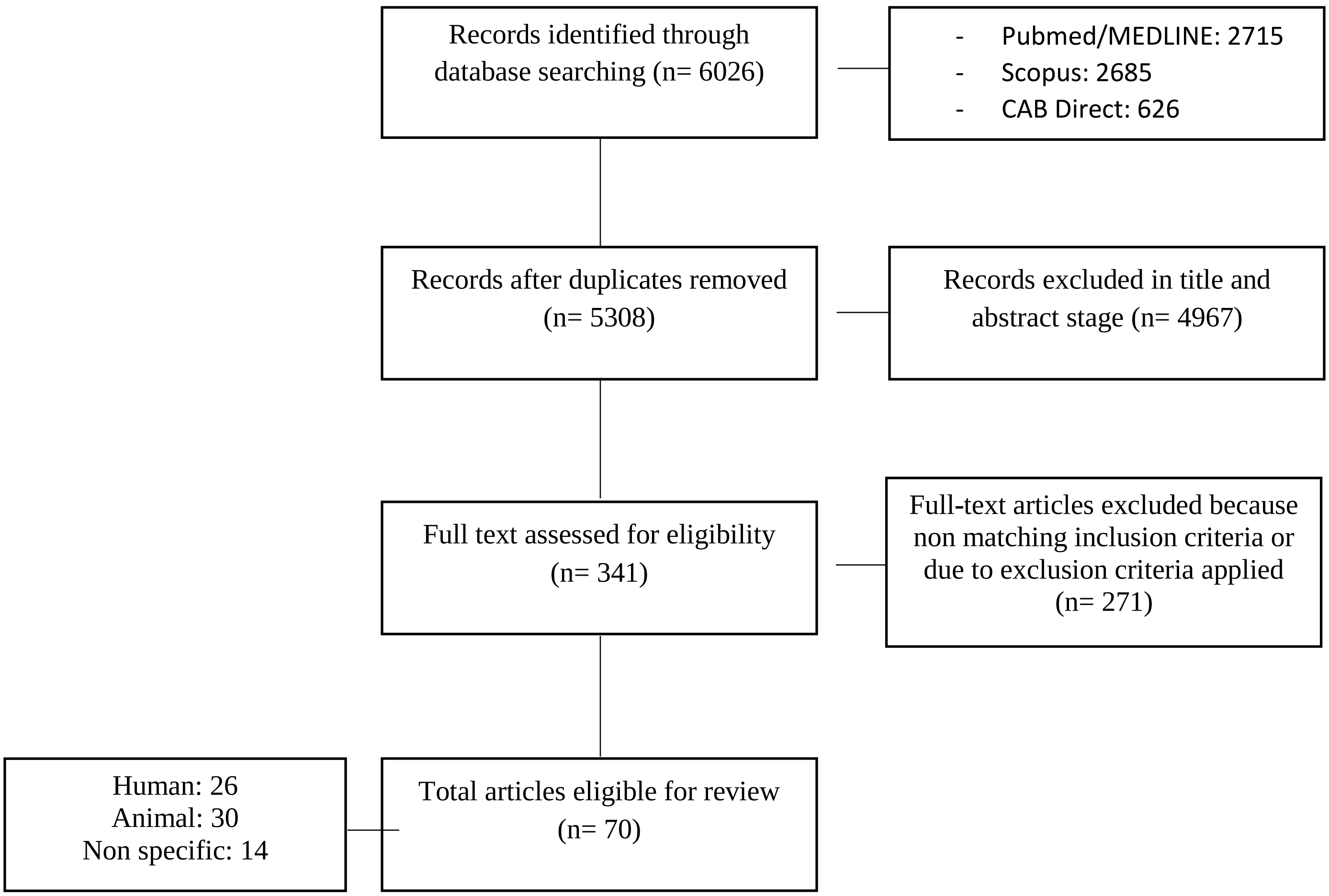
Malabsorption risk: reported risk of pathological nutrient malabsorption associated with the consumption of edible insects

Growth alteration risk: reported risk of pathological growth alteration associated with the consumption of edible insects.

Hematic and qualitative meat alteration risk: reported risk of pathological hematic and qualitative meat alteration associated with the consumption of edible insects.

Pharmacological effects: any reported pharmacological effects associated with the consumption of edible insects.

Flow-chart


Records identified through database searching (n= 6026)
- Pubmed/MEDLINE: 2715
- Scopus: 2685
- CAB Direct: 626
Records after duplicates removed (n= 5308)
Records excluded in title and abstract stage (n= 4967)
Full text assessed for eligibility (n= 341)
Full-text articles excluded because non matching inclusion criteria or due to exclusion criteria applied (n= 271)
Human: 26
Animal: 30
Non specific: 14
Total articles eligible for review (n= 70)

