Insect Protein: A Sustainable and Healthy Alternative to Animal Protein?

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Global population growth, increased lifespan, and improved economic stability are predicted to dramatically increase the amount of food required to support future generations. Coupled with the uncertainties associated with the impact of climate change on food production, there is an increasing consensus that novel sources of high-quality protein may be required (1). In general, protein of animal origin (meat, dairy, eggs, fish, and other aquatic animals) is regarded as the highest quality protein, both in terms of indispensable amino acid (IAA) content and digestibility. To date, improved national economic stability has led to increases in animal product consumption, which is seen clearly in China where consumption of meat has risen dramatically over the last two decades (2). In populations where protein-energy malnutrition and micronutrient deficiencies are common, increased consumption of animal products can considerably improve health. Meat and milk not only provide energy and high-quality protein, but also a range of readily available micronutrients including iron, zinc, calcium, B-vitamins, and essential fatty acids (3, 4). However, excessive consumption of red meat, particularly processed meat, has been associated with a range of chronic diseases including colorectal cancer, cardiovascular disease, and type 2 diabetes (5). Furthermore, diets rich in animal products tend to be energy dense, which may lead to obesity and associated metabolic disorders.

Animal production is often viewed as an uneconomical use of natural resources. Monogastric animals (largely chickens and pigs) are normally grown on human-edible crops and the increased land required for the production of such crops is frequently generated through loss of forestry and other valuable habitats (6). Aquaculture remains dependent on wild-caught fish as a source of protein and lipid for incorporation into feed. Although ruminant animals can be produced on nonhuman edible plants, in many countries this is supplemented with cereal crops to improve performance. Animal production also represents a major consumer of global fresh water reserves (for both direct consumption and crop production) and a source of pollution (7). On the basis of lifecycle analysis, farm animals have been estimated to contribute 18% of greenhouse gas production, with the majority associated with beef and dairy farming (8). It seems clear that to meet future demands, alternative protein sources for both direct human consumption and as farm animal feed are going to be required.

Insects not only represent a major source of food to support wildlife but are also widely consumed as human food in many parts of the world (9). Historically, this has largely been restricted to harvesting them from the wild environment; however, there is increasing interest in insect farming as a way of producing ingredients for food and feed. When reared in appropriate environmental conditions, they have a lower carbon footprint than animals and require less land and water, and many species can be fed on relatively low-quality feed (10). Commercial insect production is increasingly common, though in the West at least, this still represents a relatively ‘niche’ market where they are frequently fed high-quality feeds and sold at a premium. If insects are to become a significant component of the human diet, or indeed of animal feed, further research is still required to optimize production systems in order to achieve the environmental benefits ascribed to them. If they are to enter directly into the human food chain then a number of safety concerns also need to be addressed, including allergenicity and their ability to accumulate toxins or to host biopathogens (11). However, alongside other novel protein sources, including algae, fungi, and bacteria, insects may find an increasingly important role in the human food chain.

In this issue of the Journal, an intriguing potential further benefit of consuming insects has been described. Gessner et al. (12) show that replacing casein with protein-rich insect meal improves the metabolic health of hyperlipidemic rats. The insects in question are mealworms (*Tenebrio molitor*) which are already widely consumed in parts of Asia. The effects of replacing 50% or 100% of the casein with insect meal, with diets being both isoenergetic and isonitrogenous, was explored. However, it is of note that some differences were seen in the fiber content of the diets and the authors report that 12.8% of the dry weight of the insect meal was composed of chitin.

Although all diets were supplemented with the same vitamin and mineral mix, it is unclear whether the insect meal further enhanced the micronutrient content of the diets, which were carefully manipulated to ensure the fatty acid composition was identical. Significant differences were seen in amino acid composition with generally lower concentrations of IAA in the insect meal than the casein. All but two of the IAAas were present in the 100% insect protein diet at a concentration of ≥70% of the casein value, with lysine (64%) and methionine (38%) being the lowest.
The metabolic improvements associated with the consumption of insect meal included reductions in plasma and liver cholesterol and triacylglycerol. The study undertook an impressive array of transcriptomics, lipidomics, and enzyme activity measurements to try to elucidate the mechanisms underlying the effects. The data indicated that the effects on triacylglycerol metabolism may be a result of downregulation of the expression of some of the enzymes involved in fatty acid synthesis as opposed to upregulation of fatty acid oxidation. Similarly, they show downregulation of mRNA for a range of enzymes associated with the cholesterol biosynthesis pathway [which was also confirmed by parallel changes in nuclear Sterol regulatory element-binding protein 2 (SREBP2) protein concentrations].

At the present time, it is not possible to ascertain whether the effect of the insect meal is due to the amino acid composition of the protein or to other components of the insect meal. The authors compare their results to the extensive literature that has documented differential effects of casein and soy protein on lipid metabolism as, in many animal studies, soy protein has been shown to have a similar hyperlipidemic effect (13). Some of the effects of soy protein have been attributed to the amino acid sequence, leading to the production of short peptide sequences in the intestine which are resistant to digestion and exert specific effects upon absorption (14). However, there is currently no evidence that such peptides are produced from insect protein. The authors also speculate that the effects may be related to the low methionine content of the insect protein. Methionine can be converted to homocysteine which has known hyperlipidemic effects (15). However, although rats fed 100% insect meal exhibited reduced plasma homocysteine concentrations, no significant effect was seen in animals fed 50%. The authors suggest this casts doubts on reduced homocysteine production being responsible for the observed hypolipidemic effects. Finally, it is possible that the active lipid-lowering component is something other than protein. One potential component is chitin which makes up ∼13% of the dry weight of the insect meal. Chitin and/or its partially deacetylated derivative, chitosan, have been ascribed significant lipid (particularly cholesterol)-lowering activity (16). In animal studies, chitosan has been shown to increase cholesterol and bile acid secretion, perhaps through inhibiting their uptake in the intestine (17). Whether chitin is responsible for the effects on cholesterol, fatty acid, and/or triacylglycerol metabolism also remains to be established.

Replacing animal products with novel sources of protein in the human diet is a topic of increasing interest for the environmental reasons described earlier. However, it is important to note that the quality of such protein, both in terms of amino acid composition and digestibility, is taken into account. Insect protein is richer in many IAA than many alternative plant proteins though, at the present time, the digestibility of insect protein and the potential impact of any antinutritional factors that may be associated with it remain to be fully established. However, the paper by Gessner et al. (12) reveals an unexpected potential benefit of consuming insect protein that is worthy of further research.

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References