spreading. A lot of this negativity is due to the belief that insects are an unsafe source of food because they harbor diseases. These beliefs are reflected in current legislation, and in many places, insects are deemed to be food contaminants. However, in terms of suitability as human food, insects are no different from other animals: some are inedible, some are toxic and some people are allergic to insects. Otherwise the main safety issue is proper storage and cooking.

Why should insects be used as food? Insects are an abundant and easily obtained food source. There are about 2,000 species of insects that are eaten globally and they are a valuable source of subsistence food that can be important for nutrition. The nutritional value of some insects is equivalent to some conventional meats. The resources required to produce a kilogram of insect protein compared to a kilogram of beef protein are significantly lower so insect production has a much smaller environmental footprint. Furthermore, except for termites, insects produce less greenhouse gas than conventional stock animals.

Currently a lot of conventional animal foods are provided with wild-harvested fish meal as part of their diet, to the detriment of global fish supplies. Insects could play a more important indirect role as food through their use as feed for animals that people use as food (especially poultry and aquaculture) or as supplements in the booming pet food industries. If insects can be used as an effective substitute for fish-meal in food, it will help conserve global fish resources.

One of the major reasons that many people eat insects is that they are generally free. The intensified interest in insect foods has resulted in increasing commercialization that has boosted demand and many people who normally utilize insects for subsistence now collect them to sell. Increasing demand, in conjunction with other adverse environmental problems, has put pressures on the wild populations of several species of edible insects, and insect farming is seen as a way of meeting increased demands. Food production, distribution and the way it is used in industrialized societies results in a lot of waste. Organic farm wastes, unused food, and even waste food, can be used as food substrates to produce insect protein that can be used as food or feed. The consumption of insects need not involve ingesting whole insects but rather the inclusion of powdered insects as protein supplements in more traditional foods such as bread or noodles.

The media hype has led to several facts being overlooked. First, insects were eaten by most cultures during some time in their histories. In fact, the use of insects as food still continues in Africa, Asia and in Latin America, with an estimated two billion people including insects as part of their normal diet. Secondly, insects are often a food of choice and not associated with famine (although insect-derived protein could in future play an important role in famine situations). The use of insects as food is actually increasing with rising living standards in these countries, and some insects can be more expensive than the meat of conventional food animals.

Insects were an important food item for many groups of Australian Aborigines. They provided nutrients in a harsh environment and many were important in their cultural life (2). More effort is required in identifying the insect foods of Australian Aborigines and their nutritional and health benefits.

Insects should be viewed as another type of food that has enormous potential as an additional food source to help alleviate hunger, and the potential to be a gourmet food item in their own right. There are several key questions to be answered about insects as food. Can they provide some nutritional or health benefits that cannot be obtained from other food sources, or are they a better supplier of these? Can they provide the same nutritional elements as conventional meat animals or plants? Can we collect or harvest insects in numbers that will meet future demand? Can we convince people to accept insects as food?

Funding source(s): N/A.

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EFFECTIVE STRATEGIES FOR FEEDING AQUACULTURE SPECIES

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Global aquaculture currently equals wild fishery production, aquaculture production will continue to increase and a gap will progressively widen as it dominates supply. Aquaculture has an important role in global food security, it must be developed in a sustainable way and navigate multiple challenges including developing shared societal values, negotiating access to limiting resources, dealing with environmental variability and climate change effects. Effective strategies for feeding aquaculture species will contribute to ensuring the sustainability of aquaculture. Strategies will be outlined in relation to trends in global aquaculture systems and Atlantic salmon will be discussed in detail as one of the most important intensive aquaculture species. Strategies include: determining the most effective use of finite marine protein and lipid sources; ingredient development including plant proteins and biotechnological innovation; closer alignment between fish nutrition and fish health needs including gut health; feeding for new aquaculture systems including species new to aquaculture, integrated multi-trophic aquaculture, offshore and recirculation technology; selective breeding that considers traits related to both fish and human nutrition; managing product quality for human health.

Aquaculture is as diverse as terrestrial agriculture: vertebrates, invertebrates and plants are farmed using many different systems and aquaculture meets both human nutritional needs and market demand for luxury foods. A significant difference is the range of species that have been investigated, commercialisation of over 300 different species from several phyla including finfish, crustaceans (arthropods), molluscs and echinoderms has been considered at some level. This raises questions about how to approach developing strategies for feeding aquaculture and optimising research and development. Choices about which species to farm may have to be made. Some species obtain nutrition directly from the environment and don't require feeding, these not only include aquatic plants but also animals such as filter-feeding molluscs or detritus-feeding "worms". Apart from seaweeds, aquaculture production is dominated by Chinese major carps grown under semi-intensive systems that integrate polyculture in freshwater ponds with terrestrial agriculture. Carp polyculture presents an excellent approach to sustainable aquaculture, it is based on sophisticated management of at least six key fish species that occupy different trophic niches, these connections allows cycling of nutrients through food webs and recycling of by-products from terrestrial agricultural. In 2011 nearly 23 million Mt of carp were grown and accounted for 38% total aquaculture production (1). Semi-intensive aquaculture systems represented by carp polyculture are essential components underpinning increasing aquaculture production and a global strategy for food security.

Whilst Atlantic salmon and other products from intensive aquaculture are relatively expensive human foods they have high market place acceptance and great potential in human nutrition, they should be viewed as integral components national food planning. Currently intensive aquaculture, including nearly 2 million Mt of Atlantic salmon, accounts for less than 10% of global aquaculture production but has an increasing value of at least US$ 20 billion. Under a typical intensive aquaculture system all of the food is supplied in a sequence of aquafeeds formulated to meet changing nutritional needs of different life-history stages over the production cycle. Control of feed formulations provides fine-tuning to support sustainability. For example, Atlantic salmon grow from 0.1 g yolk-sac fry to 4-5 kg harvest fish in around 2 years. Understanding how and when to change the feed formulation provides several opportunities for optimising the use of limited or expensive feed ingredients. Atlantic salmon are carnivorous ectotherms and current feeds are mainly protein and lipid. In comparison to terrestrial farm animals the feeds are high in protein, it is therefore effective to develop alternative protein sources and these will be discussed in detail. Furthermore, Atlantic salmon can utilise feeds with remarkably high lipid to deposit large amounts of fatty acids.

Greater knowledge about nutrient requirements and considerable ingredient development underpins a shift from aquafeeds being based mainly on

marine products, particularly fishmeal and fish oil, to being mainly based on terrestrial products. One of the most important on-going strategies for feeding aquaculture is continually refining feeds to ensure they remain sustainable. This is especially the case for intensive aquaculture systems that rely on formulated manufactured aquafeeds. Ingredient screening and development underpin this and sit alongside other strategies to improve animal performance and increase how efficiently feeds are used.
Aquaculture has global reach and offers aquaculture systems that are appropriate in different regions depending on environmental, cultural and socio-economic factors. For Atlantic salmon, off-shore and land-based systems are being discussed. Location-specific integrated multi-trophic aquaculture provides one direction with great promise, it also reflects the 3000 year old history of aquaculture that achieved an elegant solution through integrated polyculture.
Funding source(s): N/A.

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AUSTRALIAN NATIVE SHRUBS: DELIVERING BENEFITS TO LIVESTOCK, SOIL, PLANTS AND PEOPLE

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Background: Grazing ruminants – which are capable of supplying high-quality protein for human consumption from landscapes and environments that are not always amenable to crop production – are, in essence, their own nutritionists. They are required to select forages that best meet their requirements, with the challenge of coping with temporal and spatial variability in plant species, forage abundance and chemical composition of the plants. Ruminants select their diets based on expected nutritional rewards and post-ingestive feedback that links nutrient supply to metabolic requirements. To successfully adapt to a variable nutritional environment, animals require dietary choice. Under conditions of low nutrient supply, such as during a seasonal drought, a heterogeneous environment with a variety of forage types leads to higher levels of animal productivity.
Why Australian shrubs? In grazing systems of southern Australia based on annual pasture species, there are often 'feed gaps' in autumn when feed quantity and quality limit animal production. The 'Enrich' research project has explored the potential for Australian shrub species to contribute to the diet of grazing livestock to partially fill these 'feed gaps', improve the management of natural resources, and increase farm profitability. Another potential benefit, which is less recognised, is a possible improvement in the nutritional quality of the meat produced from animals that consume a more diverse range of plants.
On-farm benefits, including nutrition and health of livestock: From over 100 Australian shrub species tested, we identified those that: (i) produced adequate levels of edible biomass and re-grew after moderate-heavy grazing; (ii) provided green feed in autumn when annual plants were senesced (dead); (iii) possessed a nutritional composition that complemented other pasture species, principally by providing adequate to high levels of crude protein and minerals, and moderate levels of digestible energy (1); (iv) grew well with companion pasture species; (v) were selected by livestock as part of a mixed diet, particularly when grazing management allowed animals to learn about the attributes of the novel forages (1); (vi) had desirable characteristics when fermented by rumen microbes *in vitro*, including high levels of volatile fatty acids and/or reduced methane production (2); and (vii) reduced development of gut parasites *in vitro* (3). At the farm-system level, we found that grazing shrubs in autumn allowed farmers to defer the grazing of other pastures on the farm, thereby increasing whole-farm productivity and better managing vegetation cover. We also found an improvement in the microclimate of shrub-based paddocks, which would help conserve soil moisture and provide a more suitable thermal environment for livestock, potentially reducing maintenance energy requirements.
Benefits to people: Bio-economic modelling showed that the addition of Australian forage shrubs could increase whole-farm profit or maintain whole-farm profit with reduced risk (4). We propose a further advantage to people beyond farm economics: bioactive plant compounds for health. Plants growing in challenging environments, especially those that have not been selected for use in agricultural monocultures, often use bioactive phytochemicals as part of their defence or survival mechanisms. We have shown bioactivity in some Australian shrub species in terms of effects on microbial activity and gut parasite larvae, yet a relatively unexplored area is the potential for beneficial levels of plant-derived compounds in the meat of animals that consume these plants. Meat from sheep grazing saltbush (*Atriplex spp.*) contains elevated concentrations of vitamin E_5, and we suggest there are likely to be other phytochemicals that may enhance the nutritional value of meat from animals selecting a diverse diet that includes bioactive plants. By altering the range of plants consumed by animals, a broader assessment of meat traits, including 'extra-nutritional' factors, would seem warranted.
Funding source(s): Future Farm Industries Co-operative Research Centre and Meat and Livestock Australia.

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Plenary 4: "new" plant foods

NEW CEREALS AND PSEUDOCEREALS IN AUSTRALIA – HYPE OR REAL NUTRITIONAL BENEFIT?

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Pseudocereals, such as buckwheat, amaranth and quinoa, are broadleaf plants whose seeds have a gross structural anatomy and culinary applications akin to those of the grains of (true) cereals. Indeed, they are promoted as alternatives to the more familiar cereals, especially ones containing gluten, and are being increasingly sought as ingredients in bakery items and other commercial food products. Pseudocereals are also garnering attention on websites and in the popular press where they are lauded as 'superfoods' on the basis of their nutritional credentials, especially the presence of unique antioxidant compounds, and many presumed health benefits.
But the claims are overstated and not well grounded in evidence. Individual differences aside, the nutrient profile of most pseudocereals and conventional cereals is not markedly different. Both are rich in essential minerals and B group vitamins. The germ and outer layers of grains from both groups of cereals are also abundant in dietary fibre, phenolics and other bioactives, although fibre diversity tends to be greater for cereals. Typically, processed pseudocereal and cereal grain products contain little resistant starch and have moderate to high glycaemic indices.
Whereas the evidence linking regular consumption of wholegrain cereals and cereal fibre with reduced risk of several major diseases is well documented, there is little empirical data on the health benefits of