The emerging Insect industry

Invertebrates as production animals

COUNCIL ON ANIMAL AFFAIRS

RDA - The Netherlands

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Summary

More and more parties, from investors to consumers, are becoming involved in the large-scale production of insects, which raises a number of social questions regarding this new livestock industry. Often, however, there proves to be too little practical or scientific information available to provide any conclusive answers. It is for this reason that the Dutch Council on Animal Affairs (*Raad voor Dierenaangelegenheden,* RDA) has investigated the issues most important to society and presented the results in this advisory report. Our aim is to create an overview of the implications for humans, animals and the environment within this fast-growing sector, and thus reveal any gaps in policy, legislation or research that require attention. To do so, the sixteen social values were applied from "One Health: A Policy Assessment Framework" (RDA, 2015).

Since the turn of the century, there has been a clear rise in interest in the cultivation of insects and other invertebrates for various purposes. The feed and food industries are showing particular interest, due in part to the rising need for the high-quality animal proteins needed to feed a growing and increasingly prosperous world population. The production of insect protein is a potentially promising addition to protein from meat, dairy and eggs, and to livestock feeds such as soy and fishmeal. The environmental impact of insect production seems to be relatively low compared to alternative protein sources such as legumes, algae or laboratory meat, and presents a particularly environmentally-friendly option if insects can be fed using low-quality waste streams from the agriculture and food sector. The main factors affecting the viability of insect production in the circular economy are a competitive cost price and potential public health risks.

Large volumes and a consistent quality of insect meal will be necessary for application in the livestock and fish farming industry. The lack of practical experience with large-scale insect cultivation means research on new technologies is necessary to ensure the cost-efficient production of these volumes. The Netherlands is a leader in these types of innovations, due to its advanced agricultural technologies and the associated knowledge infrastructure.

Large-scale insect cultivation should therefore be viewed as a new agricultural sector. At this stage of growth in particular, it is important to monitor the risks of new production processes in order to provide prompt guidance (as necessary) in the form of supplementary policy. The RDA believes that the sector has a leading role to play in this respect, for example by creating and maintaining transparency of production. Ultimately, the social significance of this sector will depend to a large extent on the sixteen factors from the previous One Health policy framework (RDA, 2015), which are addressed below.

Intrinsic Value and Welfare: the Dutch Animals Act (*Wet dieren*) acknowledges the intrinsic value of animals, with due consideration of their capacity for sentient experience. Some ambiguity can arise regarding the intrinsic value of invertebrates, which have not conclusively been shown to be sentient beings capable of experiencing well-being and pain. Other societal issues, too, have revealed that the moral value we assign to invertebrates is ambiguous and sometimes inconsistent. The large-scale use of insects requires further reflection on the concept of intrinsic value and the moral status of invertebrates. There are already sufficient arguments, however, to ask the relevant parties to attach moral value to invertebrates and act accordingly. In the Council's view, this means due observance of welfare considerations in the treatment of these animals. Although there is no scientific evidence to date that invertebrates are capable of suffering, there is no evidence to the contrary either. There are indications, however, that certain invertebrate families (such as octopuses and bees) can experience states resembling emotions. It is for this reason that the RDA recommends treating invertebrates as sentient beings. The possibility of future research showing that some species are indeed sentient must also be taken into consideration. Such may lead to exceptions for these species, as is already the case for octopuses under animal testing legislation. Investments in the welfare of invertebrates would also seem to be in the producers' own interests, as adapting farms to suit the needs and developmental stages of certain species as much as possible not only increases production, but is also important for the social acceptance of the insect industry. More research on species-specific behaviour and well-being is therefore necessary, to serve as a basis for husbandry requirements or welfare protocols. Public exchange of best practices is important in this respect.

Instrumental and Economic value: the increasing investments in the development of large-scale insect production are a sign of economic confidence in the sector. Whereas production originally focused on insect meal intended for people and animals, by-products such as oil, fats and chitin have also emerged as promising nutritional and pharmaceutical possibilities. There is also commercial interest in potential applications for sustainable and circular agriculture, such as the bioconversion of waste streams and even manure, and in biological pest management and pollination. Economic significance is expected to increase in the short term, due to insects recently being approved for use in the EU as feed for farmed fish and their potential future use as feed for chickens and pigs. The above may also provide an incentive to use invertebrates for other applications. Whether insect production develops into a fully-fledged agricultural sector of its own will depend strongly on factors such as successful upscaling, international food market trends, the development of other alternative sources of protein and the options for incorporating insects into the circular economy.

Public Health and the Health of the Animal Population: one of the key issues concerning the increasing use of invertebrate species concerns the potential health risks for both humans and animals. Much is still unknown regarding the health risks for various types of farms, substrates and processes. Currently, as far as we know, the microbiological risks do not differ significantly from (and are sometimes even smaller than) the risks associated with foods of common production animals. In principle, this means that insect production should be subject to similar safety protocols. However, risks such as the accumulation of heavy metals in insects require special attention. The rapid developments and wide-ranging production and processing methods per species mean that much is still unknown, so monitoring remains necessary. There is also an urgent need for additional research, particularly in the field of chemical risks, human and animal allergies and the possible applications of insect manure. Sustainable methods for preventing health problems within and between farmed invertebrate populations and stopping transmission to other animal species also require investigation. Vigilance regarding health issues is not only the government's responsibility – it is also in the sector's own interests.

Contamination and Biodiversity: compared to traditional livestock farming and other alternative sources of protein, the insect sector would seem to perform relatively well in terms of the environment and biodiversity. Here, too, it is important to investigate the environmental impact of all species and production methods. Much is dependent on the substrate type used to farm the animals. Research is also required into the circular-agriculture opportunities offered by insect farming. The search is aimed at finding the best possible low-grade waste streams that are available in sufficient quantities, that pose the fewest health risks (which excludes manure and kitchen waste for the present) and produce the best insect growth. There is also room to include new agricultural crops and crop applications. One critical point to consider in insect farming is the impact that escaped animals may have on native biodiversity. Although such effects are accounted for in the admissions procedure for all production species, continued monitoring is still recommended.

Landscape architecture: insect farming offers new opportunities in agricultural areas where the space for traditional livestock farming is becoming scarce. It is for this reason that Dutch regions such as East Brabant and North Limburg are encouraging the development of a local insect sector, often as a collaboration among farmers, local government authorities, chain suppliers/purchasers, knowledge institutions and investors. The farms form the linchpin of this chain, and themselves consist of a department that produces fertilised eggs and a rearing unit that produces fully-grown larvae. There are advanced plans for a model that outsources the rearing to participating regional businesses, or perhaps even internationally in future. Depending on how successfully the insect-farming business can be scaled up, the entire chain (from substrate production to the transport of end products and waste) will impact landscape architecture. Farms may be situated in areas zoned for agriculture, but also in industrial parks. In such cases, it is advisable to ensure adequate spacing in order to limit environmental or disease-related risks as much as possible. Since insect farms sometimes fall outside the definitions in regional legislation, local farming policy will vary. We therefore recommend greater attention to invertebrate farming in local legislation, and to making regional regulations as uniform as possible.

Legal Framework: laws and legislation at European and national level have both proven to cater poorly for the use of invertebrates as production animals. Existing legislation is not always conducive to insect farming conditions, and may therefore require adjustment. Nor is legislation always consistent. This is the case for the production of insects for various purposes, and for local bylaws potentially applicable to setting up an invertebrate farm. There is a pressing need for increased collaboration between the sector and national, provincial and municipal authorities, in order to create an overview of the diverse range of relevant regulations present in various laws. This will help the sector to develop in an efficient and transparent manner, and aid governments in adapting legislation to suit changing circumstances.

Cultural Value, Inherent Dignity, Autonomy, Relational Value, Public Opinion and Social Impact: traditionally, western culture has viewed insects predominantly as unclean, disease-spreading pests, rather than as useful, valuable organisms. Hence, many people will need to overcome their aversion before using and consuming insects. In addition to this "yuck factor", certain personal convictions, such as religion and vegetarianism, will influence the social acceptance of using and producing invertebrates. Due to the promising opportunities on offer, many are cautiously optimistic about large-scale insect production. Consumers are expected to adopt a pragmatic stance: food products containing insect ingredients are likely to be accepted, provided they taste good and are not too expensive. There also seems to be some interest in niche-market products with clear benefits, such as health (special proteins for athletes) or flavour (delicacies). Everybody – either as consumer, citizen or professional – may be impacted by insect farming, necessitating choices in areas such as consumption, economics, ethics and health. However, any negative incidents (in areas such as animal welfare, the environment or health) could easily undo positive public opinion on insect production due to the ever-dormant "yuck factor". Because of the wide array of public interests, it is important for the government to monitor developments in the insect sector, to continue to promote relevant research and to ensure early and transparent knowledge exchange. The primary responsibility lies with the sector itself, which acknowledges the importance of a positive image for public acceptance, and ultimately the success of the sector.

1. Introduction and background

Since the turn of the century, worldwide interest in the use of insects as a source of food for humans and production animals has shown a clear upward trend. Several companies in the Netherlands are expecting to significantly expand their insect-production activities in the years ahead. Social attention to this new agricultural industry will consequentially continue to rise, raising questions on the usefulness, risks and importance of the sector. This advisory report aims to address the most relevant social and ethical questions surrounding the large-scale production of insects and other terrestrial invertebrates.

The key motivator driving the new social significance of insects is the fact that a number of species offer a promising alternative source of high-quality protein. The Food and Agriculture Organization (FAO) of the United Nations has forecast that, by 2050, as a result of the growing world population, the need for animal proteins will be 75% higher than in 2005/2007 (Alexandratos & Bruinsma, 2012). Currently, however, livestock farming is already using 78% of available agriculture land (Steinfeld, 2006). According to estimates, six kilograms of plant-based protein is needed to produce one kilogram of high-quality animal protein (Pimentel & Pimentel, 2003). Alternative sources are therefore being investigated, to satisfy the growing need for high-quality animal proteins, and insects would seem to provide an excellent alternative for several reasons. However, while insects constitute a normal part of the diet in many (often tropical) countries, "entomophagy" – the consumption of insects – is viewed as primitive in the western world. Despite this fact, the general view is that insects will nonetheless gain in importance in the Western food industry. This includes not only the large-scale use of insect proteins in the form of meal or fats to feed humans, but also indirectly as feed for pets and production animals, such as pigs, chickens and farmed fish.

In addition to animal proteins, there are three other high-quality sources of protein potentially suitable for large-scale production. These are legumes, the group of "microalgae, seaweed and fungi" and potentially laboratory meat, in the long term. Due to their expected importance in the future, more and more research is being conducted on the nutritional value, risks and sustainable/other production options of these protein sources. Laboratory meat-growing technology is not yet sufficiently advanced to represent a realistic, large-scale alternative in the short term (Hosselet, 2017). Microalgae, seaweed and fungi already enjoy limited consumption worldwide, just like insects. The key question regarding these protein sources is whether technology can scale up production sufficiently to create a viable food source for humans and animals. Currently, legumes represent the most realistic alternative to animal proteins. They are a traditional staple worldwide, and soy in particular is used as a major source of livestock feed. The demand for soy as animal feed is so great that concerns have arisen surrounding the import and production thereof. The same applies to the large volumes of fish being caught for the same purpose, and for use in fish farming in particular.

Large-scale insect production offers an alternative to soy as a source of quality livestock feed and could serve to supplement imports. The role of insects in the "circular economy" is also attracting interest, as various insect species are able to convert agricultural, industrial and household waste into high-quality resources. This type of "bioconversion" could help reduce the volumes of resources and nutrients consumed elsewhere, thereby supplementing existing waste-prevention measures. When it is save and legally allowed to use these insects also as food and feed, insect farms could play an important role in the conversion of waste products into valuable foodstuffs.

The most frequently cited reason for the interest in insects as a source of animal protein is the fact that insect farming in general is more environmentally friendly than traditional livestock farming. Because insects are cold-blooded and reproduce faster than mammals, they require less food per kilogram produced. Current data suggests that insects also require less surface area (Oonincx & de Boer, 2012) and water (Miglietta et al., 2015) per kilogram produced. All of the above means that insects produce fewer environmental emissions than farm animals. Depending on the species being compared, greenhouse-gas emissions (measured in CO_2 equivalents) can reach levels up to 100 times lower than for farm animals, and nitrogen emissions up to ten times lower (Van Huis et al., 2013).

The promising opportunities of insect farming are also attracting commercial interest, first and foremost in protein production. Various reports have now confirmed that insects can supply valuable amino acids (the building blocks of protein) that are beneficial to humans and animals alike. The livestock feed industry is researching the specific applications of these substances (e.g. as feed for young animals). However, the human food industry is also looking into possibilities beyond the mere addition of protein-rich insect meal to foodstuffs: investigation is underway into potential applications in the health and lifestyle industry, e.g. the healing effects of insect oils. The insect sector itself is eager to promote promising applications in food, feed and pharma. The pharmaceutical applications of insect-derived materials are currently not very concrete, but various studies suggest there is potential in this area, especially with regard to antibiotics (Ratcliffe et al., 2011).

Although insects traditionally form part of the human diet in tropical countries, the Netherlands is playing a leading role in the development of technologies aimed at the large-scale production of insects. Two of the largest insect production facilities in the world are located in the Netherlands, making the Netherlands one of the world leaders in the industry.

This is no coincidence, given the country's knowledge in the field of agricultural production and technology. Many ex-farmers and investors are also attracted by the promising opportunities that insect farming would seem to offer (Hilkens & De Klerk, 2016).

Despite the interest in large-scale insect farming, there is still relatively little practical and scientific information available about this new sector. Most basic information comes from the traditional insect farmers and their experience with producing bait for fishing and feed for exotic animals (including pets). However, this knowledge is not sufficient to scale up to the production quantities required to produce insects for bulk feed purposes at competitive prices – particularly when it comes to the volumes required for fish and livestock farming. For the present, it is unclear whether the growth of insect farming will remain limited to an interesting niche market (particularly in terms of human consumption) or whether it will emerge into a major sector with its own identity within the agricultural industry. Another potential insect application is large-scale bioconversion of waste streams from the agriculture and food industries. Insects are also being used increasingly in other sectors, for purposes including biological pest control, pollination in agriculture and as laboratory animals. The use of insects in our society would therefore seem to be on the rise, so it is important to realise that scaling up for protein-production purposes both in the Netherlands and abroad is in full swing, and that large-scale insect farming should be viewed as a new agricultural sector.

As relatively little is known about this topic, large-scale insect farming raises many questions: how safe is the consumption of insects? What emissions (greenhouse gases and ammonia) will insect farming produce? How dangerous are escaped insects? Is insect welfare a consideration? Many of these questions are based on moral or ethical principles, and some answers can be found in public research or policy reports. The number of scientific articles appearing on edible insects is growing exponentially. In 2017 alone, more scientific articles were published on the subject than in the decade from 2005-2014, signifying the need for information not only among farmers, but also among partners throughout the supply chain, investors, policymakers, advocacy organisations and – last but not least – citizens and consumers. The rapid development of large-scale insect production affects the interests of the various parties involved, often raising new questions relevant to society. However, despite the burgeoning research, there is still too little practical and scientific information available on many aspects to provide conclusive answers to these questions.

This has prompted the Dutch Council on Animal Affairs (RDA) to write an advisory report encompassing the various interests and ethical aspects involved in the large-scale use of invertebrates in our society. The core question is: what social questions are relevant in light of the emerging large-scale production of invertebrates? Our aim with this report is to create an overview of the interests of humans, animals and the environment within this fast-developing sector, thus revealing any gaps in policy, legislation or research that require more attention.

2. Approach and scope

This advisory report from the Council on Animal Affairs (*Raad voor Dierenaangelegenheden,* RDA) was prepared by a working group of Council members comprising Prof. A. van Huis (chair), Prof. J.J.M. van Alphen, Dr G.B.C. Backus, A.L. ten Have-Mellema, Ms M. de Jong-Timmerman and Dr F.L.B. Meijboom. The working group held six meetings between July 2016 and October 2017 in preparation for writing this report, and received assistance in conducting its activities from Secretary M.H.W. Schakenraad and deputy secretary B.B. Houx.

Based on the working group discussions, the deputy secretary interviewed 14 experts (see Appendix 3), often in conjunction with on-site visits. The experts had backgrounds in insect farming, as industry suppliers/customers, in research and in policy. The deputy secretary also spoke to others involved in the insect sector and attended three events on the subject for this purpose. Extensive use was made of scientific literature, policy reports, brochures and online sources, a brief summary of which is given in the reference list.

The bulk of this report is dedicated to developments in insect production as a source of food for humans and animals. Because humans also farm other invertebrate species (such as mites, earthworms and nematodes; see Box 1) to which similar questions may apply, some attention is also devoted to these species. This report therefore covers all terrestrial invertebrate species that are (or could be) produced in the Netherlands, with a focus on potential large-scale farming activities to produce food and feed for humans and animals (with the exception of the semi-wild honey bee). Aquatic invertebrates (such as mussels and freshwater worms) therefore fall outside the scope of this report, although a number of such species could play a role in the biological conversion of waste substances in water.

This report focuses on the social questions raised by the rapid upscaling of insect production. In order to pinpoint these questions and the ethical and other issues involved, an assessment framework was used that was described by the RDA in its report titled "One Health: A Policy Assessment Framework" (2015).

Box 1: Biological classification of invertebrates and insects

The term "invertebrates" encompasses extremely diverse groups of animal species, including jellyfish, worms and insects, all of which lack a spinal column. The term is not part of official biological taxonomy, but is still often used to distinguish these animals from the "vertebrate" branch of organisms, in which the spinal column is a characteristic part of both anatomy and neurobiology. The "invertebrate" taxonomy branches therefore include sponges, molluscs, annelids (segmented worms), roundworms and arthropods, which include insects. Modern estimates put the total proportion of animals being invertebrate species at 97%. Despite this fact, the vast majority of the animals farmed in our society – fish, pigs, chickens – are vertebrates. The most familiar example of a cultivated invertebrate species is the honey bee, although non-insect invertebrates are also commercially farmed in the Netherlands. These include aquatic species, such as mussels and sandworms, but also terrestrial species, such as earthworms and predatory mites. In total, 70 invertebrate species have been approved for cultivation in the Netherlands (see Appendix II to Article 2.1 of the Dutch Animal Husbandry Decree (*Besluit houders van dieren*).

Insects form by far the largest sub-group of invertebrates, with an estimated 5.5 million species (Stork, 2018), approximately 1 million of which have been documented. Defining characteristics include a segmented body in three parts (head, thorax and abdomen) with an exoskeleton made primarily of chitin, three pairs of segmented legs, two antennae and compound eyes. These features separate insects from other classes and sub-classes of arthropods, such as the arachnids (spiders, with four pairs of legs), *crustacea* (or shellfish, with five head-appendages) and the *myriapods* (which possess more than four pairs of legs). Due to their enormous variety, insect species can differ significantly in appearance, physiology and behaviour. Entomology is the branch of biology dealing with the study of insects. Around 2100 insect species worldwide are either consumed by humans or used for some other purpose (such as honey production). In the Netherlands, 26 insect species and three insect families have been approved for farming (see Appendix 1). A temporary exemption has been issued for three species (including the black soldier fly). In the Netherlands, the main species farmed on a large scale for consumption by humans and animals are: black soldier flies (*Hermetia illucens*); yellow mealworms (*Tenebrio molitor*); king worms, superworms or morio worms (*Zophobas morio*); lesser mealworms (*Alphitobius diaperinus*); house crickets (*Acheta domesticus*) and migratory locusts (*Locusta migratoria*).

3. Insect production in the Netherlands

Assessing the importance of the social issues related to large-scale insect production requires an overview of both the sector and the farming process. The background and international development are described in detail in the FAO report titled "Edible insects, future prospects for food and feed security" (Van Huis et al., 2013). This section provides a general overview of the history of insect farming in the Netherlands for the purposes of feed and food.

3.1 The scope of insect production in the Netherlands

The scope of the current insect farming industry in the Netherlands has proven difficult to determine, mostly due to the young and dynamic character of this fast-growing sector. The Dutch Association of Insect Producers (VENIK) estimates the number of professional businesses at 25, the top 10 of which are members of VENIK. There are also many insect production companies in the start-up phase, where it is unclear whether these companies can become professional and profitable. As production figures fluctuate regularly and are not made publicly available by some companies, the current scope of Dutch insect production can only be estimated. A 2016 report puts annual Dutch insect production at around 500 tonnes, representing an estimated turnover of between 3 and 7 million Euros (Hilkens & De Klerk, 2016). It should be noted, however, that the greatest limitation to production is currently regulation, and that the largest companies have sufficient infrastructure to scale up the production process very quickly to dozens of tonnes per day.

3.2 Background and growth of the insect sector

There are roughly three different types of insect farms in the "food and feed" category. For around 50 years, insects have been farmed commercially as animal feed (predominantly for birds, reptiles, fish, e.g. in zoos). These businesses mainly supply pet stores and retailers of fish supplies, or deliver directly to hobbyists who order online. For around ten years, a number of these businesses have become active in other markets in an attempt to break into the feed and food sector. The latter is the second business type: large companies that, through innovation, have taken the first step towards a production capacity of several tonnes per week. The third type (start-ups) are still in the initial stages.

The start-ups are run by entrepreneurs: often ex-farmers, starting up insect farms in former warehouses or business premises. Simply by using tips from other farmers and Internet sites, taking the initial steps in insect farming is relatively simple. A small-scale start-up does not require much specialist equipment, and many people raise insects at home as a hobby or to feed their fish or terrarium animals. The move into more commercial operations is often taken with the assistance of small investors or even advance clients, who are attracted by promising financial or environmental data. In many cases, this step towards becoming a sustainable independent business with sufficient income proves impossible. People often underestimate the technology, automation and biological expertise required to realise the expansion, which is why a relatively large percentage give up within a few years. However, there are examples of entrepreneurs who, without any previous noteworthy experience with insects, have grown into independent farms within five years. Several have even succeeded in scaling up their weekly production from several kilos to one tonne within three years.

The 25 companies in the Netherlands all specialise in cultivating one species (or several at most) intended for animal or human consumption. Successful large-scale farming requires considerable specialist knowledge and a wide array of production facilities, due to insects' various developmental stages (usually egg, larva, pupa, nymph, adult; see Box 2) and because the form and needs of various species can differ so greatly. The next, challenging step currently faced by all of these companies is the scaling up of operations to several tonnes per day, in order to supply the bulk insect feed market at a consistent quality and a competitive price.

Box 2: The insect life cycle

Insects can undergo drastic metamorphoses over the course of their lifetime. Although the exact cycle varies between species, most pass through the following stages: egg – larva – pupa – imago (adult).

While all insects lay eggs, there are some that hatch inside the mother. After hatching, the larval stage begins. This stage is aimed at rapid growth, often in an environment with plentiful food sources. Because they grow so fast, most species moult several times to replace the rigid exoskeleton (which does not grow along with the insect). In most insects, the larval stage culminates in pupation, a stage characterised by immobility and fasting. During pupation, the insect transforms into its final adult form (complete metamorphosis). However, not all insects undergo this type of drastic transformation via pupation. In some insects (such as crickets) the process is more gradual, as the animal resembles the final adult form more and more after each pupation (this process is called "incomplete" or "partial" metamorphosis). In these species, the larval equivalent is called a "nymph". Insects reach sexual maturity in the imago stage, during which their behaviour is primarily aimed at reproduction and laying eggs in a suitable location. Some species (such as the black soldier fly) no longer eat during this stage, while others rear their offspring in this stage. Social insects in particular (such as honey bees) remain active for a relatively long time to care for their young in the colony. Because of these activities, adult insects have adapted to allow travel over larger distances than the larvae. Many insects therefore have wings as adults, which they did not possess as larvae.

3.3 The production process

Successful farming relies on a sound knowledge of the specific behaviours and needs of the species being farmed, in order to provide environments and food sources that cater as optimally and efficiently as possible to each specific stage in the insect's life cycle (see Box 2). Insect housing must cater to species-specific movement needs, such as means of locomotion (crawling, walking, jumping, flying); social interaction (including cannibalism); reproduction; and concealment opportunities. Insects sometimes have specific pupation and egg-laying requirements, and food must not only have the right form and nutritional/other composition, but hygiene is also important. Since the food is also the substrate forming the insects' temporary home, it can form a breeding ground for fungi and other infections. The climate (especially the temperature, moisture and humidity) is an important factor here. At the same time, these climate factors (along with light) play an important part in regulating insect behaviour. The challenge faced by insect farmers is to use the above factors to raise quality and quantity as high as possible, while also keeping cost price as low and competitive as possible.

Insect farms generally consist of two units. The reproduction unit aims to keep adult insects in prime condition, in order to produce as many fertilised eggs as possible. The eggs are then taken to the production unit, where they are further cultivated into fully-grown larvae, pre-pupae or pupae. To this end, the eggs are placed on a substrate in containers or trays that accommodate the larvae's behaviour. Black soldier flies (*Hermetia illucens*) can be harvested after only three weeks, while mealworms take eight to ten weeks to mature. In the final stage, the substrate is separated from the larvae/pupae and processed into fertiliser, while the insects themselves are processed into insect meal (protein) and oil. Chitin, the insect's exoskeleton, is sometimes also separated from the rest as an end product.

3.4 Upscaling

After a tenuous start, market parties are now expressing serious interest in insect meal, oils and fats. However, with the exception of some small trials, the livestock feed industry in particular is only interested in bulk volumes of a consistent and guaranteed quality and quantity. Insect farmers must therefore scale up quickly in order to meet market demand, and prices must also be able to compete in the long term with those of other protein sources. Due to the global lack of experience with large-scale insect production, the farmers must develop efficient (and often automated) production methods themselves – an expensive and, as it turns out, risky process requiring large investments.

Thanks to relatively small subsidies and investments, and sometimes even crowdfunding, a number of businesses have been able to take the initial steps towards increasing production. The publication of a market survey (Hilkens & De Klerk, 2016) raised interest among investors, and 2017 saw the first joint investment in the amount of tens of millions in one of the companies. Investments and partnership agreements such as these have enabled three Dutch businesses to grow so rapidly in such a short time that they can be viewed as global operators in the industry.

And yet, there is still some trepidation, even among the major investors. Three reasons have been cited for this. The first is the restrictive legislation preventing the free inclusion of insects in foods for human or animal consumption (Section 4). One key issue here is the extent to which waste may be used to feed the insects, which would make them a very sustainable alternative source of protein. Secondly, there is a lack of information and information exchange (Section 5). Although much research is currently underway on the production process and nutritional effects, more data are still needed. Furthermore, the information that is available is often in the hands of businesses and organisations that are hesitant to share it for reasons of competitiveness. Thirdly, there are doubts as to whether insect farmers as a group will succeed in producing enough to meet the massive demands of the food and feed market, one important aspect of which is delivering a consistent supply at a competitive market price. The trends in price depend not only on efficiency within the insect industry itself, but also on developments among other (traditional or alternative) protein producers. Despite these insecurities, however, it is clear that there is mounting interest and a genuine market. Upscaling will therefore continue in the short term, and will at the very least be able to serve a niche market. There are many factors at play in forecasting whether the insect industry can grow into a fully-fledged part of Dutch agribusiness.

4. Legislation and regulations

Insects farmed for food fall under the same European legislation as other farm animals (Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation); see Appendix 2 for a concise summary of relevant European legislation governing the production of insects used as animal feed). When this animal husbandry and food safety legislation was created, no consideration was given to the advent of large-scale insect farming. The rapidly growing demand for insects as food also urges modification of legislation. The speed of these developments means that legislation is lagging behind both in the EU and in the Netherlands, and various parties involved see the situation as undesirable and even prohibitive. This section aims to provide an overview of the current legislation governing the use of insects in the Netherlands and the EU. Section 7.15 further addresses the social issues surrounding the legislation.

4.1 Insects as production animals and a source of food

Invertebrates kept or farmed in the Netherlands fall under the Animals Act (*Wet dieren*), which safeguards the general health, welfare and integrity of all animals in captivity. Additional stipulations apply to invertebrates if they are farmed as production animals. "Production animals" are animals raised for the commercial production of animal products, such as meat and wool. All production animal species listed under the Animals Act (Appendix II to the Animal Husbandry Decree) may be kept for this purpose. On request, a temporary exemption may be granted for the production of a new species by the Netherlands Enterprise Agency (RVO). Exceptions are only issued if an independent committee rules that keeping the species will not lead to any unacceptable problems with the health and welfare of the species, or pose any unacceptable risks to humans, animals, plants or the environment. These regulations also apply to insects on the list that are farmed for production purposes. Although additional accommodation and care standards can apply to production animals (see Section 2 of the Animal Husbandry Decree), this is not the case for invertebrates (Section 2.2).

Invertebrates farmed as laboratory animals, pest control agents or pollinators (such as bumblebees) do not qualify as production animals, and are often subject to separate legislation. Animals used for testing fall under the Experiments on Animals Act (*Wet op de dierproeven*). However, Section 1b.5 of this Act states that it does not apply to most invertebrate species. The Nature Conservation Act (*Wet natuurbescherming*) aims to protect exotic and native animal species, but also to prevent the unintentional spread of potentially harmful species in nature. Because this applies to invertebrates as well, a possession permit is required in order to keep these animals. The Nature Conservation Act also applies to exempted insects that can be released as a means of combating diseases, pests and weeds (Section 3.28). The Act includes a list of species permitted for this purpose (Appendix 11 to the Act) and a list of animals (mostly also invertebrates) that may be combated in this manner (Appendix 12 to the Act). These lists were based on recommendations by the Netherlands Food and Consumer Product Safety Authority (NVWA), which evaluated whether releasing certain animals would pose any threat to the environment. An exemption is required to release animals that are not on the list, which (just like the possession permit) can be requested from the RVO.

The list of invertebrates approved for production purposes (see Appendix 1a) currently contains 26 insect species. Three insect families are also listed. However, because differences between species mean that approval is granted per species, these family names will most likely be replaced. One key insect in animal feed and bioconversion – the black soldier fly – is currently not on the list, but an exemption has been granted to two businesses; this is also the case for the band cricket (*Gryllodes sigillatus*) (see Appendix 1b). Insects intended for human and animal consumption also fall under Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety (General Food Law Regulation), which forms the basis for all food legislation. It sets safety requirements spanning the entire human and animal food production chain, from farmer to consumer. Just like farmers of other livestock, insect farmers are producers, which means they have primary responsibility for the safety of their products and for their traceability within the supply chain both before and after (i.e. supplies and sales).

Moreover, just like all other producers of animal products, insect farmers must meet a wide range of hygiene and safety criteria in order to keep any public health risks to a minimum (see Appendix 2 for a concise summary). For example, they must be registered according to the hygiene regulations for food (Regulation (EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption) and animal feed (Regulation (EC) No 183/2005 of the European Parliament and of the Council of 12 January 2005 laying down requirements for feed hygiene) and undergo regular inspections according to HACCP (Hazard Analysis and Critical Control Points) protocols. Products intended as animal feed must be monitored (under Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed) for the presence of undesirable substances, such as heavy metals. The Netherlands Food and Consumer Product Safety Authority (NVWA) ensures compliance and general food safety and also carries out inspections among insect farmers. While the consequences of the regulations mentioned thus far do not differ significantly from those applicable to other livestock farmers, there are some regulations that serve to limit insect farming.

4.2 Animal feed and substrate laws and regulations

To prevent the spread of possible health risks, the Animal By-products Regulation (Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002) stipulates that animals intended for human consumption may not be fed unprocessed animal products. Animals may only be fed products that have been manufactured into Processed Animal Proteins (PAP) in accordance with the regulation. As the principal product of insect farming is protein (often in the form of insect meal), this should pose no problem. During the BSE (bovine spongiform encephalopathy) crisis in 2000, however, it became apparent that "mad cow disease" was spread principally via contaminated animal protein in the animals' feed. This is why Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies (the TSE Regulation; Transmissible Spongiform Encephalopathy, the general variant of BSE) prohibits products that may contain animal proteins from being fed to other animals in the food chain. This has two profound negative effects on the insect farming industry: the processed insects may not be fed to other animals (with the exception of pets and farmed fish) and animal waste products may not be used in insect substrate. There is no legislation prohibiting live insects from being fed to other animals, however.

Because there are indications that TSE is not transmitted in the same way among all species, efforts are currently underway to relax the legislation. In June 2013, it became permissible to feed farmed and other fish using PAP. There remained a significant hurdle in the case of insect meal, however, as the Animal By-product Regulation stipulates that animals may only be processed into PAP in a facility approved for this purpose (i.e. an abattoir). The stipulations are so specific that the approved facilities cannot be used for insects. Joint efforts by the sector and government authorities have succeeded in modifying these stipulations for insects in Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein, the principal outcome of which is that, as of July 2017, insects may be processed for use in aquaculture. Insect farmers expect to be able to take a second major step if the chicken and pig-feed market is opened up, which could be the case within several years. Due to the susceptibility of cattle and other even-toed ungulate farm animals to BSE, approval to feed insects to these species in the future is unlikely.

Exactly which animals are allowed to eat insects will also depend on the substrate used to feed the insects, and the final product. Unprocessed insects may be fed to exotic and other pets, for example. In principle, insect oils and fats may be included in livestock feed, provided the insects are only fed plant-based waste or other plant-based materials. Less and less is permissible as the risk of spreading infection increases (see Table 1). Kitchen waste, offal and dung are not approved as feed for insects intended for animal consumption.

Table 1: A general overview of the livestock feed market in which various end products containing insect parts are allowed, depending on the substrate with which the insects have come into contact (see also Appendix 2).

insect substrate	end product	pets	aquaculture	chickens	pigs	ruminants
Plant based	unprocessed	+	+[1)]	+[1)]	+[1)]	
	PAP[3)]	+	>July 2017	>2019[2)]	>2020?	-
	Oils and fats	+	+	+	+	+
pre-consumer[4)]		+	>July 2017	>2019[2)]	>2020?	-
post-consumer[5)]		+	-	-	-	-
dung		-	-	-	-	-

1) only if the Animal By-products Regulation is not applicable; 2) 2019 is given as a target date. 3) PAP = Processed Animal Proteins; 4) pre-consumer = unsold food products; 5) post-consumer= kitchen waste; + = allowed; - = prohibited; > = starting from.

4.3 Human consumption laws and regulations: The Novel Food Regulation

Production of foodstuffs for human consumption is subject to its own laws and regulations. Products of animal origin (which therefore includes insects) must meet the criteria for food hygiene (Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs and Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin) and food information (Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004). However, in the human food market, there are again regulations that stand in the way of insect farmers. The most significant of these is Regulation (EC) No 258/97 of the European Parliament and of the Council of 27 January 1997 concerning novel foods and novel food ingredients, stipulating that foods and ingredients that were not sold within the European Union prior to 15 May 1997 must be approved before being sold for human consumption on the European market. Under this regulation, each species of insect must be evaluated as a Novel Food. Approval is granted at EU level, on the recommendation of the European Food Safety Authority (EFSA). Since 2005, approval may also be issued by the competent authority of the relevant member state. In the Netherlands, this is the Medicines Evaluation Board (*College ter beoordeling van Geneesmiddelen, CBG*).

This Novel Food Regulation did leave the opportunity open to incorporate insects into human food, which is why insects for human consumption have been tolerated on a trial basis in the Netherlands since 2009, under the General Food Law regulation. In conjunction with the NVWA, the Dutch Association of Insect Producers (VENIK) has drawn up a quality protocol that meets the standards of the legal frameworks. Three species have been deemed safe for human consumption: the mealworm, the lesser mealworm (or buffalo worm) and the grasshopper. Products with these insects as ingredients can even regularly be found in major supermarkets.

A revised European Novel Foods directive (Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001) means that the grace period is coming to an end, and as of 2020, farmers will only be able to include insects in human food that are approved as Novel Foods by the EU. To gain approval, an application for the admissions procedure must be submitted before 2018, which must include a dossier of specialist research on certain risks, such as allergens and pathogens. A procedure such as this is estimated to take two years and cost over €200,000 – quite a large investment for an individual farmer. The fact that approval is valid for the entire European Union encourages farmers to work together. Any sensitive information (e.g. for reasons of competition) may remain confidential. There is also a protective procedure that grants approval to the applicant only for a period of five years, with no data being made public. For new foods that are very similar to existing foods or approved Novel Foods, an accelerated application procedure (notification) is possible through the competent authority of an EU member state. At European level, the International Platform of Insects for Food and Feed (IPIFF) is the main body leading efforts to initiate collaboration. At the same time, there are signs that many farmers (with few exceptions) are biding their time in the hope of being able to benefit from approval requested by others.

5. Research and Education in the Netherlands

The future development of the new insect sector is dependent on knowledge. In part, such knowledge is gained in practice by the farmers themselves, in their search for profitable farming systems. Wageningen University and Research (WUR) plays an important part in this process. In addition to the expertise available in the field of agricultural technology and innovation, the Laboratory of Entomology is also an important entity in the collection and dissemination of knowledge on insect farming. The laboratory is involved in considerable applied research and takes advantage of the noticeable rise in interest by offering courses and symposiums and facilitating other forms of knowledge exchange. Although most other universities (the University of Groningen in particular) have at least some entomological expertise, this usually focuses on fundamental knowledge of insects. There are also other university disciplines involved in research on the production and use of insects. In 2017, two relevant dissertations were published in areas other than entomology, one on the allergy risks of insect proteins in food (Broekman, 2017, UMC Utrecht) and one on consumer acceptance of insect-based products (Tan, 2017, WUR). The Entomology chair group also organises an annual "Insects as food and feed" course, which is attended by over 100 students and regularly included as part of symposiums.

In addition to WUR, the "green" universities of applied sciences are likewise focusing increasingly on applied research and education in the field of insect farming. To this end, HAS University of Applied Sciences in 's-Hertogenbosch has its own trial facility (Insectlab) and lecturers who are becoming more and more specialised in the field. In addition to teaching their own students, HAS offers training and information for interested parties. The education and research programmes at Aeres UAS and Van Hall Larenstein UAS also examine the potential applications of insects, and actively search for industry partners and sponsors. In addition, other disciplines at these universities of applied sciences are looking at the production of insects too, such as the New Proteins, Insects and Fish lectorate (INVIS) launched by HAS in 2017.

Businesses are showing increasing interest in the commercial opportunities offered by insect products, and as a result are often involved in research on their nutritional and pharmaceutical effects on humans and animals. The collaboration between education institutions and industry is bringing about new research institutes, some of which conduct research on the production and use of insects (such as New Generation Nutrition and the Feed Design Lab). Established research institutes such as the Netherlands Organisation for Applied Scientific Research (TNO) and the Louis Bolk institute are occasionally involved in research of this type as well.

Furthermore, commercial and social interests give rise to partnerships between research centres, local/other government authorities and industry, aimed at the advancement of large-scale insect production. The hope is that the combination of innovative research, education and industry will give a boost to the sector at the regional level. One example is the Insect Protein Innovation Platform (IPIP) in North Limburg, which even seeks cross-border collaboration. InsectCentre portrays the structure visually by putting the manufacturers and purchasers in the centre, the suppliers of equipment, knowledge and expertise in a circle around that and the supporting parties, such as government authorities, NGOs, sponsors and interested consumers, in a third outer circle.

The central government encourages research on insect-farming applications primarily through subsidies, such as a joint research project run by WUR and VENIK on the sustainable production of insect proteins for human consumption (Supro2, 2010-2013). Various research projects receive a lot of their financial support via the government's "Top Sectors" policy and from the Netherlands Organisation for Scientific Research (NWO)/Technology Foundation STW. In addition to research on insects as food and feed, the focus on the circular economy is also growing. As an example, two of the seven projects approved in 2017 under the NWO programme titled "Closed Circles – Transitioning to a Circular Economy" were insect-farming projects.

6. International aspects

In many Asian, African and South American countries, insects have traditionally been eaten and farmed on a small scale for personal use or sale on the local market. New insights into nutritional value and the relatively simple and sustainable production methods have generated renewed interest in local insect production in developing countries.

Until recently, commercial production of insects and other invertebrates was aimed primarily at specific products such as silk, honey and the colouring agent E120 (carminic acid or cochineal), which are also imported by the Netherlands. Recent developments surrounding the demand for insect protein clearly show the emergence of a major international market for mass-produced insects for use in feed and food.

In addition to the Netherlands, several other countries (South Africa, France, the United States, Canada) are also scaling up in order to meet the forecast demand. With investments in the order of the tens of millions, these companies are focusing partly on the production of the same species as the Netherlands. Besides feed and food, there is also international interest in the mass production of insects as a means of bioconversion.

As not only the opportunities are the same internationally, but also the challenges, some companies are seeking international collaboration. The Netherlands is quite active in both the dissemination of knowledge and entering into partnerships. At the same time, various companies are attempting to establish a multinational profile. Establishing strategic alliances with partners in other countries (such as China) boosts opportunities.

7. Relevant Social values

As a means of identifying potential social issues and problem areas, the upscaling of insect farming is examined below in light of the sixteen values presented in the RDA advisory report titled "One Health: A Policy Assessment Framework" (2015). These values are important when making animal husbandry decisions in accordance with the One Health principle, which aims for an optimal health balance (including well-being) for humans, animals and the environment. The assessment framework therefore covers the most relevant social values. Not all of these are of equal importance to the insect sector, so some are discussed here in greater detail than others.

7.1 Intrinsic Value

To most people, invertebrates hold a different level of value than vertebrates. This is evident in legislation such as the Experiments on Animals Act (*Wet op de dierproeven*), which provides protection to vertebrates, but not to representative invertebrate species (with the exception of cephalopods, such as squids and octopuses). The difference in value is not only connected to the supposed lower cognitive and emotional capacity of invertebrates, but also their negative image due to the fact that insects in particular are often viewed as pests and a vector for disease. Other reasons for the lack of social interest in the protection of invertebrates include the preponderance of species and individuals; a lack of familiarity with their behaviour; the supposed simplicity of their life patterns; and the often limited lifespan combined with a high capacity for reproduction. Despite this, not only the scientific community, but also society at large is showing increased interest in the value of insects. Recent reports on a potentially drastic drop in insect numbers in nature reserves (e.g. Hallmann et al., 2017) have prompted general concern. Additionally, the desire to farm invertebrates for mass production is the primary reason for discussion on the moral value of these creatures, and on our potential obligations in the treatment of invertebrates. In concrete terms, this has raised the question of whether these animals have intrinsic value, and if so, what consequences this entails.

According to the RDA definition (Conceptual Framework, *Denkkader*, 2018), intrinsic value refers to an integrity that is independent of the animal’s utility or use to humans. The Council believes that two consequences arise from the acknowledgement of intrinsic value. The first is that all instances of keeping and using animals must be justified in a manner that takes the animals’ interests into account. The second consequence is that we should show respect to animals, expressed in various ways, including appropriate care. There is no single, unequivocal basis or definition of intrinsic value, however. The Animals Act acknowledges the intrinsic value of farmed animals (Sections 1.2.1 and 1.3.1) and gives specific details (see

Box 3). An interesting fact is that Section 1.3.2 – in accordance with the Treaty of Lisbon (EU, 2007), which forms the basis for all European animal welfare regulations – explicitly refers to animals as sentient beings as though this were a prerequisite. From a philosophical perspective, however, the acknowledgement of intrinsic value is not necessary dependent on the capacity to experience pleasure or pain.

Box 3. Animals Act, Section 1.3.2 (translation)

"Recognition of intrinsic value as referred to in Subsection 1 is understood to mean recognition of the value that animals possess in their own right as sentient beings. In drawing up rules under or pursuant to this Act, and in taking decisions on the basis of these rules, due consideration shall be given to the impact of these rules or decisions on the intrinsic value of the animal, notwithstanding other legitimate interests. In all cases, any violation of the integrity or well-being of animals, beyond what is reasonably necessary, shall be avoided and the care reasonably required by the animals guaranteed."

This can even lead to confusion in the case of invertebrates, since they fall under this legislation as soon as they are "kept" (Section 1.2.1 of the Animals Act), while the science is still unclear on the extent to which invertebrates are "sentient beings" capable of suffering due to pain or a lack of welfare (see Section 7.2). The general assumption that invertebrates are not sentient beings is even one of the reasons why they do not fall under the Experiments on Animals Act (Section 1.b.5.a), with few exceptions; cephalopods (squids and octopuses) are one example, as they have been shown to possess greater cognitive capacity (Section 1.b.5.b). Invertebrate species also fall outside the European directive on the protection of animals kept for farming purposes (Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes, Article 1.2.d). The fact that invertebrates fall under the Animals Act as soon as they are farmed for production purposes means that the government formally acknowledges their intrinsic value, thereby imposing clear welfare requirements as specified under Sections 1.3.2 and 1.3.3, such as the five freedoms (see Box 4). This has the potential to create inequality between the protection of invertebrates kept for production purposes and those used for testing purposes.

The formal acknowledgement of the intrinsic value of invertebrates farmed for production can also lead to inconsistencies in other areas. For example, it raises questions regarding the methods and scale with which insects that are perceived as harmful (such as malarial mosquitoes, oak processionary caterpillars -*Thaumetopoea processionea*- and desert locusts -*Schistocerca gregaria*-) are combated. The most glaring contradiction might be seen in insects that are mass-produced as a form of biological pest control. These include predators that consume their prey, as well as parasitoids, which lay their eggs inside the host that is subsequently consumed by the larvae. The increasing use of insects inevitably raises ethical questions regarding the intrinsic value and welfare of insects.

Box 4. Animals Act, Section 1.3.3 (translation)

"For the purpose of Subsection 2, the care reasonably required by animals shall in any event include safeguarding the animals against:

a. thirst, hunger and malnutrition;
b. physical and physiological discomfort;
c. pain, injury and diseases;
d. fear, distress and chronic stress;
e. limitation of their natural behaviour;

insofar as can be reasonably required."

Given the anticipated increase in the production and use of invertebrates, it is therefore important to clarify the degree to which invertebrates subject to treatment by humans are deserving of protection. Three lines of argument can be applied here. The first takes current legislation as its starting point, which makes intrinsic value (and therefore concern for animal welfare) contingent on the capacity to experience pleasure and pain (i.e. sentience). This implies that the moral right to protection depends entirely on the scientific answer to the question of whether (and if so, which) invertebrates are "sentient beings". Given the current situation, this means that more research into cognitive capacity is necessary on moral grounds.

A second and similar line of argument also ties intrinsic value to sentience, but adds, as a precautionary measure, that given a lack of scientific certainty or knowledge regarding sentience, we should err on the side of caution and treat some or all invertebrates as sentient beings, and therefore as beings to which we ascribe intrinsic value. Essentially, we would give invertebrates the benefit of the doubt. More research is also required on the capacities of invertebrates from this perspective, along with a consideration of the concrete operationalisation of the acknowledgement of intrinsic value in those cases where animal welfare is provided to invertebrates as a precautionary measure.

A third line of argument disregards sentience as a necessary prerequisite for the acknowledgement of intrinsic value. From this viewpoint, creatures with their own interests and/or that develop independently deserve our respect and the attribution of their own individual value. An acknowledgement of the fact that invertebrates have interests is therefore a moral reason to include those interests in ethical considerations. A different type of research is required here, which does not merely aim to answer the question of whether and to what extent invertebrates can experience suffering. The question here is how the above relates to current legislative frameworks and the means used to satisfy the requirement to acknowledge intrinsic value.

The opinion of the RDA is linked to the second line of argument, under which – despite the lack of scientific evidence, but based on the current state of research (see Section 7.2 on Welfare) in combination with the precautionary principle – the Council believes it would seem justified to treat some or all invertebrates as sentient beings. This also means that the concept of intrinsic value may be applicable to invertebrates, subject to certain conditions.

One potential social consequence of respecting the intrinsic value of invertebrates farmed for production could be a reconsideration of how we treat invertebrates that are either perceived as harmful or used for testing purposes. Some stakeholders have expressed concerns regarding the possibility that intrinsic value may also be ascribed to these groups of invertebrates, resulting in these animals falling under more stringent welfare policy without any further evidence of the capacity for well-being of the species in question. In animal testing especially (particularly regarding the many experiments involving fruit flies and roundworms, *Caenorhabditis elegans*), this would have far-reaching consequences.

In view of the new insights into the cognitive and emotional capacity of invertebrate species (see Section 7.2 on Welfare), an ethical debate would seem unavoidable. A clear distinction between the acknowledgement of intrinsic value and of sentience may offer some clarity in this regard. In a review of the ethical aspects of insects as production animals, Gjerris et al. (2016) conclude that welfare legislation is mainly applicable to sentient beings, and that it is therefore important to determine which species are included and which are not. Because exemptions will not always be as clear-cut as in the case of cephalopods, as mentioned previously, the classification of sentient species will require much research, discussion and time. Almost all research published to date on the welfare perception of invertebrates concludes that too little is currently known and calls for a decision to give invertebrates in captivity the benefit of the doubt. Formal acknowledgement of intrinsic value could offer an effective basis in this regard.

Acknowledgement of intrinsic value puts additional pressure on producers, and insect farmers in particular. It therefore makes sense to clarify the formal acknowledgement of intrinsic value now, while the sector is still in its infancy, in order to strike a balance between mutual ethical interests as early as possible. This is mainly because – just as for other production animals – an ethical discussion will arise regarding the extent to which it is acceptable to modify invertebrates for production purposes (e.g. via genetic or hormonal techniques). The RDA has observed such techniques already coming into play among some insect farmers. Public knowledge of such techniques in insect farming could spark social objections. This is also partly why producers should adopt an ethical stance as early as possible, in the interests of their image.

Questions on Intrinsic Value

1) What are the consequences of acknowledging invertebrate animal species as sentient beings?
2) Should sentient beings be given the same status under both the Animals Act and the Experiments on Animals Act?
3) To what extent does the moral status of invertebrates differ from that of vertebrates, and what are the consequences of this for the acceptability of human treatment of invertebrate species?

7.2 The Welfare of Invertebrate Production Animals

Not many people will concern themselves with the welfare of invertebrates. However, as a value, welfare is extremely relevant to the farming of invertebrates and of insects in particular. Farmed invertebrates are covered by legislation such as the Animals Act, for example, which stipulates that they must be kept in a manner that caters for their well-being. But how can insect welfare be ensured and monitored? The large-scale farming of invertebrates also raises a number of fundamental welfare-related questions, such as whether invertebrates experience suffering and well-being. How can this be determined in these species? Because it is generally assumed that invertebrates do not experience pain (or at least that their suffering is less or different to that of vertebrates), these species often fall outside protective legislation, such as the Experiments on Animals Act. This is also often the reason why some see the mass production of insects as a welfare-friendly alternative to traditional livestock farming (see Van Huis et al., 2013; Van Huis, 2017). The question is whether this assumption is correct. Recent scientific findings provide more and more evidence of a sense of well-being in at least some invertebrate species, suggesting that they should perhaps be counted among the sentient beings.

The scientific arguments for whether certain animals experience a sense of well-being or not are often derived from a combination of behavioural observations, cognitive capacity and neurobiological processes that are either analogous to or homologous with those of humans. Research on the experience of pain and well-being among invertebrates has also revealed an additional complication; not only does their biology differ significantly from that of vertebrates, but there are also major differences between species and even between developmental stages. It should be noted here that even modern scientific methods cannot determine animals' subjective states with certainty, meaning that debate continues as to whether (and to what extent) certain species are capable of experiencing pain or well-being. Despite this, the sheer volume of indications of emotional states in animals in certain cases has given rise to social concerns and modification of legislation, such as the recognition of animal sentience in the Treaty of Lisbon (EU 2007) or the exemption of cephalopods under the Experiments on Animals Act.

Observations of invertebrates not only responding abruptly to unpleasant or painful stimuli, but subsequently learning to avoid them, would seem to lend credence to the idea that these animals experience pain (Elwood, 2011). However, scientific research also shows that many such responses are automatic reflexes, sidestepping the need for conscious perception. Experiments on humans and animals have even shown that conditioned avoidance behaviour can be learned subconsciously (Mason, 2011). This is why such observations are not sufficient to conclude that invertebrates consciously experience pain. There are even observations that seem to suggest that invertebrates experience no pain, such as the much-cited example of a grasshopper that continues to eat while itself being consumed from behind (Eisemann et al., 1984). Hence the general assumption that, while invertebrates are capable of nociception (the experience of painful stimuli), they do not do so consciously (with few exceptions), meaning they do not suffer pain. A number of invertebrate species (including the fruit fly) even serve as an experimental model for the neurobiological functioning of nociception and pain suppression.

Multiple levels of cognitive processing are necessary in order to experience pain and suffering, allowing the perception of pain to be mediated by hormonal states in particular (such as endorphins). In vertebrates, this explains how pain can be suppressed via intense stress, and augmented by fear. The function of a complicated cognitive pain perception system such as this is – just as with other emotional states – the varied influence of motivational behaviour systems (Le Neindre, 2016). The consequence is that, rather than the automatic suppression of all other behaviour in favour of a single response for an extended period, the response to and processing of a pain stimulus varies according to circumstances and experience. Due to the advanced cognitive functioning, the neurobiological complexity and the energy required for these processes, many scientists consider the presence of such a system in small, primitive invertebrates unlikely. This applies in any case to the species and larval stages of animals that have limited behavioural means to withdraw from pain stimuli.

However, a large number of publications report that the adult stages of at least some species possess more advanced capacities than was thought until recently, especially in the areas of pain perception, cognitive ability, stress responses and personality differences (for a review: Horvath et al., 2013). Barron and Klein (2016) conclude that the structure of the insect brain has the capacity to support subjective experiences. Recent studies have shown that species from the bee family (*Apoidea*) may indeed perceive their internal state and base behavioural decisions on it. This "cognitive bias" is regarded as a fundamental emotional state that is necessary for various functions, including the perception of pain (Mendl & Paul, 2016). The extent to which these bee species constitute a possible exception with regard to other insect species (such as cephalopods, which possess advanced cognitive abilities) is still unclear, since this has never been investigated among most invertebrates. In any case, it does indicate the probability that insect species may exist that are capable of experiencing states similar to emotions. This would classify these species as sentient beings, thus influencing their moral status.

Just as suffering cannot be incontrovertibly demonstrated among most invertebrate species, nor can it be conclusively disproved. This is why, based on the existing evidence, the most recent scientific reviews and reports give invertebrates the benefit of the doubt when it comes to pain and well-being, and call for application of the precautionary principle, that we should care for the well-being of farmed invertebrates and limit their suffering as much as possible. Section 1.3.3 of the Animals Act specifies that care for production animals must in any case provide for the "five freedoms" (see Box 4). As the list of animals approved for farming also includes invertebrates (see the production animals list, Appendix 1), these fundamental welfare regulations should in principle also apply to those listed species. The last line of Section 1.3.3 ("to the extent that such can be reasonably required") may give rise to uncertainty and debate. The Animal Husbandry Decree (*Besluit houders van dieren*) avoids this issue by excluding invertebrates from housing, care and slaughtering standards in Sections 1.11 and 2.2. Recent scientific insights support the claim that invertebrates should be treated as sentient beings by taking their potential suffering into consideration in the production process (e.g. when choosing a slaughtering method, see Hakman et al., 2013).

Aside from statutory obligations and possible sentience among invertebrates, many insect farmers claim that the well-being of their animals is important to them, as their growth improves the more the environment is adapted to the specific needs of the species. For this reason, many farmers conduct intense research to determine the optimum housing conditions, such as climate, light, feed, substrate and population densities. It is also important to the image of the emerging sector that there be no negative welfare reports, which could otherwise increase the aversion to the consumption of insects in particular. The welfare of mass-produced animals is therefore not only ethically important, but economically as well. The Dutch Association of Insect Producers (VENIK) also sees insect welfare as a key issue.

Biological markers such as reproduction, growth and health have traditionally always been useful in determining and monitoring animal welfare, and can also easily be applied to invertebrates. However, recognising the signs of well-being listed in the last three freedoms (such as pain, fear and stress) is much more difficult among invertebrates. Disregarding the question of whether and to what extent emotional states even occur in invertebrates, the main problem is that much is still unknown regarding the last freedom – that of natural behaviour – which can differ significantly between species and even between developmental stages. At a very basic level, active avoidance or approach behaviour can be an indication that the stimuli eliciting such behaviour are important to a certain species, but no conclusions can be drawn regarding internal perceptions or a state of well-being in invertebrates based on such behaviour. For the present, the basic biological and behavioural markers concerning the five freedoms are therefore the best way to determine the well-being of invertebrates. As the body of knowledge on the production of invertebrates increases, so too does knowledge on the measurement and perception of well-being per species. Given the major differences between species, this type of species-specific knowledge is important not only to well-being and the monitoring thereof, but also to production. To this end, welfare criteria for each species and developmental stage could be set out in farming requirements or welfare protocols.

The presupposition that farming invertebrates as an alternative to livestock could reduce welfare problems has sparked much debate, as it carries the implicit assumption that invertebrates have no sense of pain or well-being. The possibility that some invertebrates do have some emotional perception leads to philosophical questions, such as the extent to which the well-being of, say, a cow can be compared to that of a quantity of insects equal to a cow's carcass weight. Many animal protectionists therefore avoid the debate by dismissing the idea that insects constitute a valid alternative to meat. In particular, the additional step of farming insects as feed for animals intended for human consumption has met with some objection.

On the other hand, using whole insects as feed is seen as potentially good for the well-being of animals such as chickens and pigs. Because these omnivores eat insects naturally, feeding them insects may provide not only dietary benefits, but also general improvements to well-being, due to more intensive foraging behaviour, or a drop in excessive feather pecking or cannibalism among untreated egg-production hens, for example. Using live insects as feed can provide particular behavioural enrichment that is appropriate to the natural behavioural needs of these species. Knowledge on how invertebrates experience well-being is also important in this discussion on considering the welfare of various animal species.

Questions on Welfare of invertebrate production animals

1) To what extent can invertebrate species experience pain and other emotional states?
2) What are the consequences if, as is generally accepted, bees and potentially other insect species genuinely do experience emotion-like states, and can therefore be classified as sentient beings?
3) To what extent is current animal-protection legislation adequate and applicable to farmed invertebrate species? What are the consequences of applying or not applying this legislation?
4) Companies are making major investments in optimum insect-rearing conditions. To what extent is it ethically acceptable for such welfare-related information to be kept secret for reasons of competitiveness?
5) Is there a need for a body that monitors the well-being of invertebrates during various stages of the production process? How can the needs and signs of well-being be identified and monitored per species and developmental stage?
6) Is feeding live insects to animals farmed for human consumption ethically acceptable from an animal welfare standpoint?
7) Are the health and welfare of insects effectively safeguarded against smaller profit margins due to competition?

7.3 Instrumental Value

The instrumental value of invertebrates is the utility they represent for human purposes. Wild insects, for example, are of great value to agriculture and horticulture as pollinators and biological pest control agents. The economic value of biological pest control in the US alone has been estimated at $4.5 billion (Losey & Vaughan, 2006). The role played by wild insects in breaking down organic waste (bioconversion) and keeping the soil in good condition is of inestimable worth. The instrumental value of insects is recognised to such an extent that they are now farmed for all three of the above purposes. New insights continue to increase our understanding of insects' usefulness in a diverse range of human applications, further boosting the need to farm them (Van Huis et al., 2013).

Although insects for human consumption are relatively new in the Netherlands, many invertebrates have been traditionally farmed as food, including shellfish, crustaceans and even Roman snails (escargot). Insects are farmed in the Netherlands as food for exotic or other pets and fish, as bait for fishing, and for the production of specific animal products such as honey, wax and silk. The red colouring agent carminic acid (E120, or cochineal) and shellac are products of lice that are imported on a large scale (the latter far less than used to be the case, however). A relatively new phenomenon is the interest in invertebrates due to their potential value in the production of pharmaceuticals (Ratcliffe et al., 2011). This interest pertains primarily to insects with possible applications in combating infections, fungi and cancer. Chitin in particular offers possibilities in this regard (Roos & Van Huis, 2017). There are also new potential applications, such as the production of biodiesel using insects that are also effective in the bioconversion of waste products and residue. Insects as an option simply for processing waste or manure remains somewhat neglected in the Netherlands, due to the focus on their use as "feed and food". Nevertheless, this potential application, which China is currently looking into, warrants further investigation here as well.

Services are another area for which invertebrates are being farmed on an increasing scale. They are of inestimable value as laboratory animals; medical and biological advancements would be nigh impossible without the pivotal role played by fruit flies, or the nematode *Caenorhabditis elegans*. Many other species are also farmed for applied and fundamental research in various fields. Clinical medical applications constitute one such field, where applications include the use of fly larvae to clean wounds (maggot therapy). One relatively new application is the training of insects (bees in particular) to detect illnesses, explosives and drugs. The next step is the use of insects as "biosensors", connecting the sensory input of live or dead insects to electronic equipment to detect chemical substances in minute quantities. Conversely, it is a relatively simple matter to use electronics to control insects remotely, as biobots or cyborg insects. Although it is even possible to steer flying insects using a mobile phone, the technology currently has very few applications. Biobots of this type are expected to have applications in (possibly large-scale) investigation and intelligence operations where access is problematic. In any case, the technological developments show that invertebrates could represent instrumental value in many more areas in the near future, forming a potential driver for the farming of relevant species.

Questions on Instrumental Value

1) What types of products and services will require invertebrates?
2) What are the relevant interests both in and of the Netherlands?
3) Is current legislation adequately equipped to handle these developments?
4) To what extent is it feasible to actually use insects for the large-scale bioconversion of organic wastes and residues?
5) In each of the fields listed above, how does the instrumental value of insects weigh up against their intrinsic value?

7.4 Economic Value

There is currently no comprehensive overview of the economic value represented by the large-scale production of invertebrates. The European and worldwide market for invertebrate species as biological control agents is currently in a growth spurt due to the increasing demand for environmentally friendly pest control in agriculture and horticulture (Van Lenteren et al., 2017). In 2016, five times as many beneficial insects were imported into the EU than five years previously. Koppert – a Dutch company – is the market leader in biological pest control, with a 2016 turnover of €183 million, 15% of which went to the Dutch market. The market for insects as exotic pet food is relatively stable (Hilkens & De Klerk, 2016). Due to the interest in insects as an alternative source of high-quality protein, the sector expects the insect industry to grow to represent significant economic value. Because the sector is still developing, actual figures are still scarce. A market survey report from 2016 gave an estimate of the market potential in the Netherlands, based on the latest data and trends (Hilkens & De Klerk, 2016). It put the number of active Dutch insect farmers in that year at 25, with a combined production of 500 tonnes, representing an estimated turnover of between 3 and 7 million Euros. However, 70,000 tonnes would be required for insects to replace even one per cent of the total volume of broiler poultry feed used in the Netherlands (2020). Evidence for the market potential is clear from the observed 10-25% annual growth in the sector, plus the fact that over half of the total volume is produced by only three large companies. It is therefore reasonable to assume that production will increase rapidly once the problematic legislation is eliminated and insect proteins can be freely applied. Economic confidence is also evident from the rising investments in the sector, which now occasionally mount to tens of millions of Euros both in the Netherlands and abroad.

Overall, the greatest economic value for insect production is expected to be in the animal feed industry, where experiments with insect meal are currently in full swing, as a high-quality replacement for fishmeal and soy to feed farmed fish, chickens and pigs. The higher production costs during the start-up phase will be more readily accepted especially if the health or flavour of production animals is improved by the use of food containing insect ingredients. The promising characteristics of insect-based products, such as oil and chitin, also have potential applications in human lifestyle products and pharmaceuticals. Several current active contracts with the food industry show that the incorporation of insect proteins into food for human consumption also offers real market opportunities. However, one prerequisite for both the animal feed and the human food market is that the sector provide a consistent quantity and quality to meet the demand, at a cost that is competitive with that of other sources of protein.

Based on several conservative sample calculations, one market survey from 2016 claims that a potential turnover of several hundred million is attainable for insect protein production within several years (Hilkens & De Klerk, 2016). Streamlined production through improved substrates, economies of scale and automation to generate higher production rates and lower prices will enable the larger companies in particular to take advantage of the market opportunities. The production companies may eventually be able to outsource the production of larvae to farmers in a cooperative model. In China, there is a company that sells black soldier fly eggs to a variety of businesses, most of which use them to process waste. Due to the desire to reduce labour costs, however, the greatest economic social value lies not in employment at the farms themselves, but rather in the knowledge economy surrounding the production process. Employment opportunities also exist in the peripheral supply chain, such as the supply of substrate and technical aids and the disposal and processing of both final and waste products.

The sector does not expect production to ultimately disappear to another country where labour is cheaper, for the simple reason that successful mass production will depend to a large extent on process automation. It is precisely the knowledge and technology required for these processes, combined with the desire to mass-produce a consistently high-quality end product, that characterise the traditional Dutch agricultural sector. Several Dutch companies are actively seeking collaboration with companies in other countries to secure a firm international position, as are many major insect farmers abroad. Despite the competition, the sector expects parties to be able to help each other (at least in the short term) by jointly guaranteeing sufficient production to meet the high demand, from the animal feed industry in particular. An added bonus of insect farming is the potential role of the sector in the local and circular economy. Because of the potential risks and associated legislative restrictions, the extent to which insects can actually contribute to the circular economy through the bioconversion of waste is still uncertain. In 2017, two research grants were issued to investigate precisely this possibility, and research projects on insects as waste processors are also ongoing in Belgium. In light of so many possibilities, the insect industry is expected to occupy its own niche within the Netherlands.

There is a general expectation that the insect industry in the Netherlands is capable of rapid growth in the short term. The longer-term development will depend primarily on four factors: 1) the extent to which the production process can be made more cost-effective; 2) the extent to which the market will actually make use of insect proteins; 3) the development of other alternative protein sources; and 4) the potential role of insects in the circular economy. In the wake of these developments, there is another potential application of insects that could gain in economic importance: bioconversion (see also Section 7.3 on Instrumental Value).

Although the economic importance of the sector will increase, it will probably remain relatively small in comparison with other livestock farming sectors. As insect farming will remain principally supplementary, no negative effects are expected in the Netherlands (e.g. due to competition with other forms of livestock farming). The current lack of experience means that little data are available on the economic costs resulting from environmental impact or the prevention of escaping insects or disease.

Questions on Economic Value

1) What is/will be the economic significance of the insect industry in the Netherlands and worldwide? Can a realistic estimate be given of the future added value to the agricultural sector?
2) Is additional policy required in order to bolster the international position of the Dutch insect sector?
3) How does the economic significance of the insect sector compare to that of other alternative protein sources?
4) Is it both possible and useful to keep central records of the growth, turnover and exports of the insect sector and/or to investigate the entire chain surrounding the insect industry to get an idea of its economic importance?
5) Is the Dutch insect sector capable of producing adequate volumes to meet a substantial market demand?
6) What are the consequences of upscaling and cost-reduction on the economic vulnerability of the sector, and on the other values?

7.5 Public Health

Because the mass-production of insects is still an emerging industry, little is known about the potential public health risks. Precisely these health risks are a source of social concern, as insects are often associated with the transmission of diseases, through bites and stings (venomous defence mechanisms). There are also recorded cases of farmers exhibiting allergic reactions in their businesses. It is therefore important to thoroughly investigate the potential health risks of large-scale insect farming. Some countries, including the Netherlands, use an admissions procedure to assess the risks associated with the production of each species. Several scientific publications are now also available. In 2015, the EFSA published an overview of the information available at that time on the health risks related to the production and consumption of insects. Since then, two Dutch dissertations on health risks have been published (Van Broekhoven, 2015; Broekman, 2017).

Assessing health risks is a complex matter. The chemical composition of insects depends not only on their species, but also on the developmental stage they are consumed in; the substrate they grow on; the production process (environmental factors such as temperature, moisture and exposure to light); means of processing (e.g. milling, heating, freeze-drying); and storage methods. Health risks can also be subdivided into four categories: biological or microbiological (bacteria, viruses, parasites, fungi and prions); chemical (toxins, heavy metals, hormones and medications); allergenic; and environmental impact.

Based on the data available, the EFSA concludes that the microbiological risks are no greater (and possibly even smaller) than those associated with the production and consumption of other animals. The immense taxonomical difference between insects/other invertebrates and vertebrates mean it is unlikely that transmissible microbiological risks specific to insects will constitute a risk to production animals or humans (Eilenberg et al., 2015; Van Broekhoven, 2015). Although prions seem unable to reproduce inside insects, there is a danger that prions from contaminated substrate (of ruminant origin) could still be transmitted via insects to humans and animals. The greatest biological and microbiological risks of insect farming are contaminants present in the substrate, which can re-enter the food chain via the insects. By using a clean substrate and implementing standard hygiene procedures, most risks can be reduced to an acceptable level. Many companies work with HACCP, GMP+ or TrustFeed certification. The VENIK also has its own protocol, not only to standardise the available and often specific knowledge as much as possible, but also to help prevent incidents that could impact negatively on the image of the sector. Since prion contamination is more difficult to combat using standard hygiene practices, the existing preventive ban on substrate derived from ruminants or human excreta will need to remain in force for the present.

Chemical substances also represent a genuine health risk in the consumption of insects. Not all insect species can be used, as some store plant toxins or create them as a defence against natural predators. Chemical substances such as heavy metals and pesticides (or their residues) can also accumulate in some insects (for examples, see Van der Fels-Klerx et al., 2016). Additionally, fungi present in the farming environment can produce poisonous substances (mycotoxins) that can enter the food chain via insects, although recent studies on the black soldier fly (Purschke et al., 2017) and the mealworm (Van Broekhoven et al., 2017) seem to show no signs of this occurring. The EFSA notes that insufficient toxicological research has been conducted in order to provide a comprehensive overview of the chemical public health risks in insect farming. As most chemical contamination occurs via the substrate, substrate monitoring will be an important part of the farming process. Antiseptics, antibiotics, hormones and veterinary medicines that are occasionally used to combat disease and infection in insect production form another source of chemical contamination. As in other animal industries, the use of these substances could be made subject to regulation.

Like any other food, the consumption of insects or parts thereof can occasionally produce allergic reactions, varying from a mild rash to anaphylactic shock (De Gier & Verhoeckx, 2018). Cross-sensitivity would seem to exist between insects and other arthropods, such as shrimp and dust mites (Van Broekhoven, 2015). Packaging should therefore contain a warning. Inhalation of or contact with some parts of insects can also cause an allergic reaction. Some farmers have even developed allergies in this fashion, and can no longer enter their production zones. The recent interest in the health effects of livestock farming on surrounding residents (Maassen et al., 2016) may give cause to further investigate farm emissions and waste products for allergens.

Alongside the risks listed above, insects can also have beneficial effects on public health (Roos & Van Huis, 2017). A relatively large body of research shows that insects can be a source of well-balanced, high-quality and essential nutrients that even have positive health effects on people and animals in some cases. Chitin, for example, strengthens the immune system, and lauric acid (a saturated fatty acid in black soldier flies) has an antimicrobial effect and combats diarrhoea in pigs (Gasco et al., 2018). When drawing such general conclusions, it is important to keep in mind the enormous variation between insect species and even production systems. Research on the applications in pharmacology and food technology is still in its infancy, but is often viewed as promising (Ratcliffe, 2011).

Taking all of the above into consideration, the EFSA expects the microbiological risks of standard processed insect protein production (PAP) to be comparable to or even lower than those in other forms of animal protein production. Due to the absence of sufficient data, the EFSA was unable to draw conclusions regarding the chemical risks. Too little is still known about the specific risks of using manure and animal waste products as substrate. What is clear is that substrate quality and processing have a major influence on health risks. Interactions with the farming climate and the species and developmental stages in contact with the substrate mean that the risks in each case can vary. This is why the risks should in fact be assessed separately for each farming procedure.

Questions on Public Health

1) What are the specific risks per farming type?
2) What are the effects of regular consumption of insects by humans and animals?
3) What are the health effects of the various substrate types, especially those using manure and animal waste products?

4) What are the biological and chemical risks of consuming unprocessed insects?
5) How will we process the farming waste and manure, and what are the associated health risks?
6) How will the emission of allergens affect the area surrounding the farms?
7) What are the anticipated effects of using antibiotics?

7.6 Health of the Animal Population

In the case of invertebrates, the "health of the animal population" refers not only to the animals being farmed, but also to the health of related and unrelated native animal species in and around the farm and, of course, the animals to which the invertebrates are being fed. Escaped or infectious members of the farm population can constitute a health risk to these groups. Conversely, animals from the surrounding environment that get into the farm accidentally (e.g. flies or mice) can also present an infection risk to the farm population. Even as food, invertebrates can pose a health risk to the animals to which they are fed; on the other hand, there are also indications that certain insects or their constituents can have positive effects on health and well-being.

Due to health considerations, a production permit for new farm types is only issued by the Netherlands Food and Consumer Product Safety Authority (NVWA) if the species in question is not a "Q-organism" (a potentially dangerous organism that is not yet found in the Netherlands). The greatest health risk lies in the intensive farming system, where cost reduction and efficiency mean that animals are kept in dense populations, thus increasing the risk of disease outbreaks. The consequences can sometimes be extreme; there are recorded cases of infections having spread throughout entire insect farming populations. In such cases, the entire population must often be destroyed and a new colony obtained to start production up again. Most cases involve more mild disease outbreaks, however, which can often be combated using standard methods. Still, there is little research available on the nature of these diseases, or on control methods using standard protocols. Due to the major business risks, many farmers are fearful of the risk of infection. Most take sanitary measures to prevent contamination via food, objects and new farm insects, as well as via the free movement of external insects, people and air through the farm. These last two in particular are viewed as significant causes of infection. Stakeholders have also cited cases in which farmers have used antibiotics and pesticides to rein in disease, and it is precisely the use of such methods that poses new health risks to humans and animals. Given the developments in large-scale insect farming, outbreaks of new diseases will be inevitable (Eilenberg et al., 2015), and guidelines and protocols will be necessary in order to combat such cases and control any damage.

The extent to which diseases from farmed populations will have an effect on related or other species in the nearby natural or domesticated surroundings is unclear. There are recorded examples of cricket farms having suffered greatly from the outbreak of a virus (the densovirus) that occurs naturally in Europe. On the other hand, it is clear that some viruses are transmissible to unrelated arthropod species, such as crickets, crabs and shrimp (Eilenberg et al., 2015). Although there are indications in wild populations that invertebrate and vertebrate species are often not susceptible to the same microbiological infections, invertebrates can sometimes act as a vector. Research is therefore necessary on the possibility of the reciprocal transmissibility between populations in production facilities and those in the nearby surroundings.

Another risk to the animal population is genetic selection. The genetic variation in the first generation breeding populations is often necessarily lower than that of wild populations, and then undergoes further adaptation to production conditions via artificial and incidental selection processes. Although this presents opportunities to make farmed populations more resistant to threats such as disease (Jensen et al., 2017), one disadvantage is that it often further limits the genetic variation, making specific populations more vulnerable. Their short reproduction cycle means this process can be more rapid in insects than in vertebrates, which is why it is important to continue to work on genetic variation within and between populations (Eilenberg et al., 2015). Theoretically, there is also the possibility of genetic exchange between farmed and natural populations (see also Section 7.8, Biodiversity).

In principle, animals being fed insects are exposed to the same risks to Public Health (7.5) that affect humans, although there is less research on the effects in animals. One example is the extent to which animals can be allergic to insects with which they are fed. Although hypoallergenic cat and dog food containing insect proteins is available on the market, there is evidence that even these animals can be allergic to insects. Because insects feature naturally in the diets of pigs, chickens and some fish species, the risks in these species are considered lower. Certain insect constituents even seem to have positive health effects, on young animals in particular. Experiments have also shown that feeding entire (and even live) insects can be beneficial to the well-being of piglets and chickens. A large number of veterinary aspects are relevant to the production of insects and their use as food for other animals, which is why it will be important for the veterinary sector to be involved in the growth of this new livestock industry.

Questions on Health of the Animal Population

1) Are any playbooks, protocols and open exchanges available in the case of farm outbreaks? Is policy needed for this?

2) What are the disease transmission risks between farm populations and related species and/or animals in the immediate vicinity?
3) Are there veterinary and planning considerations?
4) Is legislation necessary to ensure the health of local animal populations?
5) To what extent can animals be allergic to eating insects?
6) Are antibiotics necessary, and is advance legislation required?

7.7 Contamination/Emissions

Based on a number of studies, insect farming is considered to be more environmentally friendly than traditional livestock farming. It produces significantly fewer carbon dioxide equivalent emissions and requires less water and land than cattle and pig farming, and slightly less than chicken farming, which is possibly marginally more energy-efficient. Even when compared to other protein alternatives, insect farming performs relatively well in terms of environmental impact (Smetana et al., 2015). In a comparative life-cycle analysis, the production of insect and soy-based proteins showed less environmental impact than the production of chicken, milk and grain proteins, while the production of laboratory meat and fungal proteins (mycoprotein) had the greatest impact.

Life-cycle analyses can differ in terms of their objective, scope, method and fundamental assumptions (Halloran et al., 2016). This often makes comparing studies difficult, especially those on insect farming, which often use different species and substrate values as well. Another confounding factor is the potential increase in the efficiency of new alternative protein production systems, which are expected to improve environmental performance even more. Insect farming could have an even more positive effect on the environment due to the reduction of organic waste streams. Due to the qualitative variation in these streams, the possible health risks and the legal restrictions, only a fraction of the potential offered by insect farming will be used for bioconversion. Because insect farming can potentially make such a large contribution to the circular economy and have a positive effect on the environment, policy could focus on supporting research and the application of safe and efficient use of waste streams as substrate. One important question in this regard is the extent to which insects can be safely mass-produced using waste streams other than the relatively high-grade waste products used to feed chickens and pigs.

Despite its relatively favourable environmental performance, insect farming does produce emissions, and a number of species can create significant odour pollution. The potential emission of allergens has already been discussed under Public Health (7.5), along with the possibility of limiting this type of air contamination using filters. The most important and direct source of pollution is therefore substrate waste. It is unclear to both the EFSA and many stakeholders what kind of waste the insect farms produce. Although the waste differs per farm type, the waste products generally consist of a combination of substrate residue, insect dung and insect remains (exoskeletons in particular). The specific characteristics of this mixture (including the antibacterial effects of residual chitin) make it attractive as a soil enhancer. The other potential effects are not always evident in practice, however, nor what the possible environmental and other health risks are. The EFSA concludes that undesirable substances could enter agricultural land and surface water via insect-farming waste products. Although the same applies to all animal production systems, the EFSA advises monitoring of insect production system waste management.

Questions on Contamination/Emissions

1) What are the life-cycle analyses (LCAs) of each insect production system?
2) What types of LCA should be applied when (see also Van Zanten et al., 2018)?
3) What emissions/other negative impact will farms have on their immediate surroundings?
4) What are the waste streams and associated environmental risks, particularly of insect waste/dung?
5) Can the use of waste streams be improved, and does this require monitoring? Can policy help in this regard?
6) To what extent can insects actually benefit the circular economy?

7.8 Biodiversity

In theory, mass production of insects as an alternative to traditional meat production could serve to be beneficial with regard to biodiversity. This is primarily due to the volumes of land required for the production of livestock feed (e.g. soy, grass and corn). The modern, efficient techniques currently in use often lead to monocultures that negatively impact biodiversity. The same applies to the increasing quantities of fish being caught to produce the fishmeal used as aquaculture feed. Insect farming could make more efficient use of waste streams and even represent more efficient feed conversion. Compared to traditional animal protein production, insect farming is therefore likely to impact less on biodiversity. The question remains, however, as to how insect farming compares to other alternative protein sources, about which there are currently no data available.

Insects that escape from a farm can potentially also influence the local biodiversity. Firstly, escaped insects can attract predators, as was pointed out by one stakeholder whose farm specifically attracted insect-eating birds. Secondly, escaped farm insects can potentially also interact with related native populations or even develop their own population, affecting the local biodiversity. Various stakeholders believe that the likelihood of this occurring is very small, as the Ministry considers this aspect when issuing permits and most of the farmed species cannot survive in the Dutch climate. There is a lack of good data, however, on both this aspect and on the likelihood of farmed insects (and their modified genetic variants) potentially being able to survive in the changing Dutch climate regardless. Examples of other escaped invertebrate species that were originally introduced by humans for production purposes (such as the Pacific oyster) illustrate the importance of creating a realistic overview at an early stage of the effects of potential escaped individuals on ecology and biodiversity.

Questions on Biodiversity

1) Will escaped insects be able to survive (considering the potential effects of climate change)?
2) To what extent can farmed insects (genetically modified or not) present a real threat to local or other biodiversity?

7.9 Landscape Architecture

Most large farms are currently located in agricultural areas. This is not only because many local zoning plans see insect farms as agricultural businesses (or even intensive livestock farms) – the land required for the large production sheds is often cheapest in rural areas, where substrate can also often be obtained locally. Processing insects in or near agricultural areas can also be an advantage, especially if insect products are used for livestock feed. Interest in creating large-scale production is greatest in Brabant and Limburg (including North Limburg), but in other rural Dutch regions too, former livestock farmers in particular are expressing interest in using their production equipment (sheds) for insect farming, under a franchise or other system.

There are also examples of large farms that have successfully set up premises in business parks. Depending on the species, insect farms can cause problems through the emission of odours or allergens. Closed systems using modern filters prove to effectively limit these problems, ensuring compliance with local and national legislation. The parent companies that manage egg production can certainly set up in industrial parks, while rearing units (which sometimes fall under separate legislation) can operate in surrounding rural areas.

The necessary substrate will also affect the landscape. The quality of insect production is largely dependent on the substrate used, even if this is derived from waste streams. Insect farming, possibly in combination with other sectors, may create a demand for certain crops (such as rapeseed or root crops), affecting future land use and possibly also the landscape architecture.

A regional clustering tendency is developing within the insect industry, due to a combination of active support from several regional authorities and the dependency on feed supplies and delivery opportunities to processing industries. There is currently little awareness of the risks of this type of clustering among the parties involved. Now, however – while considering the spatial planning of the sector – is a good opportunity to incorporate the lessons learned from intensive livestock farming regarding pests and disease, in aspects such as farm spacing and diversity of species.

Questions on Landscape Architecture

1) Is there a need for a uniform status as agricultural businesses (or even intensive livestock productions) under zoning plans?
2) Which social groups will be affected by these changes?
3) What effect will large-scale insect production have on the landscape architecture (farm types, locations, feed production, supply/delivery)?
4) How much planning control is desirable in the developing sector, particularly in view of the lessons learned from intensive livestock farming?

7.10 Cultural Value

Although our society owes a great deal to insects and other invertebrates, we do not attach much cultural value to them. Insects in particular are often viewed as harmful, dangerous or unclean, which is why our historical response has been to combat rather than protect them. Whereas quality and quantity of meat is still associated with prosperity, insect consumption is viewed as primitive or a sign of poverty. Religious cultures (such as Islam and Judaism) prohibit the consumption of most insects, with few exceptions (such as halal grasshoppers and certain specific species of kosher grasshoppers). Other lifestyles, such as veganism and vegetarianism, also object to the consumption of invertebrates.

When it comes to the consumption of insects, most westerners will not only need to overcome the "yuck factor", but must also see past insects' negative image. Following some initial hesitation, however, most consumers have proven willing to try products containing insect constituents out of curiosity and rational (environmental, health) considerations, especially if the insects are not recognisable as such. Furthermore, recent research has shown that more pragmatic considerations such as taste, price and availability quickly factor into determining whether insects become part of a regular diet (House, 2016). If they taste good, certain insects may even become recognised as delicacies, such as shrimp.

Practical considerations are also clearly evident in those contemplating starting their own farms, and in livestock/fish farmers thinking of feeding their animals with insects. There is a generally positive attitude towards the production and use of farmed insects, which is strongly motivated by environmental impact, dietary value and economic considerations (Verbeke et al., 2015). The health and welfare of natural insect-eaters such as pigs, chickens and certain fish also figure in the equation. Because insects are of low cultural and moral value, the interests of the insects themselves are often secondary.

Rapid developments in insect production have already brought about noticeable changes to cultural values. Media attention, marketing and products including insect ingredients have all increased. Advancements in knowledge and new applications will also cause social importance to change, and cultural value with it. The question, however, is whether there will be a shift in the appreciation of insects and how we treat them.

Questions on Cultural Value

1) Is the cultural value of insects changing, and does it need to be monitored?
2) Will the insect industry affect people's attitudes toward insects, and will this in turn influence the moral status allocated to insects by humans?

7.11 Human autonomy

The RDA One Health advisory report defines autonomy as people's ability to "have their own possessions and take decisions independently". In principle, all people have the right to keep invertebrates as they see fit, within the confines of the law. However, scaling up the production of insects and other invertebrates will affect not only the producers and their personnel, but also the parties up and down the supply chain and the investors. These include the livestock and fish farmers who feed the insects and other invertebrates to their animals, consumers who are increasingly confronted with products containing insect ingredients, residents surrounding the farm and citizens in general who are affected by the intensification of insect production in some way or other.

Individuals can be affected by insect farming in various ways, and will need to take economic, ethical, religious or health-based decisions in this capacity. Transparency and early dissemination of knowledge are important aids in making these choices. It is important for consumers to know whether products include farmed insects or other invertebrates, so that they can make informed choices based on religious or health reasons. Transparency is important not only for consumers, but also for the sector and even the animals, as it contributes to well-considered social decisions concerning their use.

Questions on Human Autonomy

1) Is there enough transparent information available on the use and processing of insects to allow producers, citizens and consumers to make well-founded choices? Who ensures the availability of this information?

7.12 Inherent Dignity

Inherent dignity as mentioned in the One Health advisory report refers to the fundamental principle of human dignity and worth as set out in the Universal Declaration of Human Rights. There is currently no reason whatsoever to assume that the production, use or consumption of farmed insects or other invertebrates will affect these rights in any way. Political decision-making and European, national or regional legislation allow for advocacy of most interests and rights, although the emerging insect sector does not always fit within the existing frameworks. This is why modifications are underway at various levels, which must also do justice to the various interests (see also Section 7.11 on Human Autonomy). Transparency and early dissemination of knowledge are important here too, not only because they can be viewed as important rights in themselves, but also because they clarify the various social interests. Information on the interests of the animals themselves is also important, so that they can be incorporated into the decision-making process.

Questions on Inherent Dignity

1) Does national and international society have the right to information on the new insect sector, and if so, what are the roles of the various parties involved?

7.13 Relational Value

Relational value concerns the level of emotional connection that an individual has with other people, animals or the ecosystem. Given the enormous biological differences, most people will not feel a strong emotional connection with invertebrates. The emotional connection at insect farms relates more to the business than the animals. Relational value would therefore seem irrelevant to the production of invertebrates, although the broader social significance could potentially lead to a greater general appreciation of invertebrates (e.g. due to their role in the circular economy). Recent reports on the rapid drops in certain insect populations show that many people show a genuine concern for insects beyond their mere ecological and instrumental value.

7.14 Public Opinion

Many of the values listed here influence public opinion. Some are regularly mentioned in the media, including risks, environmental benefits, health and cultural background. Rational arguments are often insufficient by themselves to answer complex questions such as these. Many studies have been conducted on how the "yuck factor" can be overcome, in order to increase the acceptance of insect-based products among western consumers. Information provision, processing (flavour and recognition of the end product) and marketing all play an important part in this. In modern society, trends play an important but often unpredictable role. Some stakeholders, for example, have noticed that the interest from the food and lifestyle sector is now greater and more serious than was thought possible five years ago. It is clear that there is still much scope for development, not only in the bulk market of oils and fats, but regarding niche products as well. It is also evident that overall public opinion, although still somewhat uncertain, is cautiously positive regarding the production of insects as an alternative source of protein. At the same time, most stakeholders are aware that a negative incident in the insect sector (e.g. a welfare, environmental or health problem) could cause a rapid turnaround in public opinion due to the ever-dormant "yuck factor".

Because knowledge in many relevant fields is still in its infancy, it is hard for the public to get an objective idea of the current status of invertebrate mass-production. Even for the initiated, it is often difficult to compare aspects such as the nutritional value or environmental effects of various alternative protein sources. Now that the market, investments and upscaling are starting to take shape, the interests are also growing, and with them public approval. For this reason, some stakeholders see knowledge sharing and image building as important. At the same time, it is important to keep a close eye on the various sector interests and their effects on public opinion.

Questions on Public Opinion

1) What is the public opinion regarding the effect of insect production on the environment, public health and well-being and the associated risks, and how will it be affected by upscaling?
2) How will public opinion affect the upscaling of the insect sector?
3) Which parties have interests in social information provision, and in what type? How can the various movements enhance each other and balance each other out?

7.15 Legal Framework

The legal framework was discussed rather extensively in Section 4 above, as the various European directives are instrumental in determining the current status of the insect sector (see Appendix 2). These directives sometimes fail to consider the specific circumstances of the emerging insect farming industry. The farmers must navigate a multitude of laws and regulations concerning the protection of individual animals' health and well-being, food safety, animal feed, the environment and potential impact on the surroundings. Many efforts in the sector and by the Ministries of Economic Affairs and Agriculture in particular aim to identify and modify, where necessary, the regulations that affect insect farming. This must often take place at EU level, and many EU countries are still very hesitant to modify the existing legal frameworks to benefit the insect industry. Procedures thus become very complicated and time-consuming, requiring cooperation at both national and international level. The success of these efforts is evident in regulations such as Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein, which stipulates a number of legislative amendments specific to insect production. Due to these changes, it became permissible to feed insect proteins to fish in July 2017. Any further developments at EU level will depend in part on the member states where insect farming is not yet an emerging industry. National vigilance is also advisable regarding early and specific regulations on the new sector and the increasing usage of invertebrates, via the Animal Husbandry Decree (*Besluit houders van dieren*) and other instruments.

Most environmental and anti-nuisance legislation affecting farmers exists at provincial and municipal level, such as zoning plans. Here, too, there is sometimes evidence of little attention to the rise of this specific sector. Depending on the region and the type of farm, there can be differences in the categorisation and accompanying regulation of insect farms. The biggest difference concerns their designation as agricultural business, livestock farm or breeder, and the addition or omission of the "intensive" label. The above categorisation is also important to the applicability of elements such as the Nitrogen Action Programme (*Programmatische Aanpak Stikstof*), the Ammonia and Livestock Farming Regulations (*Regeling Ammoniak Veehouderij*) and the Fertilizers Act (*Meststoffen wet*). Given the major differences observed in evaluating the other values, separate regulations may also be required for each farm type. On the other hand, uniformity of regulation is important to creating an equal playing field.

Questions on Legal Framework

1) Where are there gaps in legislation that serve only to inhibit insect farming and have no further relevance to the sector?
2) Is any specific regulation necessary for the new sector and the increasing use of invertebrates, including any steps necessary to prevent problems that have arisen in traditional livestock farming?

3) How relevant is the TSE decision to insects?
4) Do insect farms, potentially in combination with other forms of animal farming, require a separate status under regional decision-making?

7.16 Social Impact

The mass-production of insects attracts regular attention in the media and politics. Several questions have been posed in the House of Representatives regarding insect production, and some political parties have adopted clear stances on the issue. In part, these positions overlap with those of civic organisations. The Party for the Animals (*Partij voor de Dieren*) and several animal protection and vegetarian organisations, for example, are against increasing the production of animals for feed when plant-based alternatives are available. Other parties, regional parties in particular, such as the Brabant Development Agency (*Brabantse Ontwikkelings Maatschappij*), are investing in the optimisation of business opportunities for insect farmers. A third movement is attempting to promote the consumption of insects for environmental reasons, focusing less on mass production and more on insects as one of the many potential alternative protein sources.

A striking number of people remain unaware of the growing insect industry, however. The values listed above show that society will quickly become increasingly aware of large-scale insect production. The evaluations under Human Autonomy (7.12) and Public Opinion (7.14) showed that, after some initial aversion, many people are actually prepared to consider eating insects for various reasons, especially if the insects are not recognisable as such. Public opinion also turns out to be difficult to predict, however, and it is hard to say what role the insect industry will ultimately play in agriculture.

The insect industry is currently still in its infancy, so the social impact remains minor and the direction it will take is difficult to forecast. It is clear, however, that the removal of legislative barriers and the associated growth of the sector will create a dynamic that will influence social impact. Monitoring this process can help identify problem areas or conflicts of interest early on, which will benefit both the sector itself and the various social interests.

Questions on Social Impact

1) What is the best way to monitor the social interests surrounding the insect industry and the associated developments?

8. Conclusions

The farming of invertebrates as feed and food seems to be on the rise. At present, there appear to be no indications of any insurmountable social disadvantages. The most common objection to insect production is ethical, and concerns the increased production of animals (as feed for other production animals, no less). At the same time, the benefits to the environment and the production of relatively high-quality foodstuffs represent the main draw cards of insect farming. There are more and more indications that the production of insects not only creates less environmental impact than the production of meat, but also less than the production of most other high-quality alternative protein sources. Especially if insects can be used for the bioconversion of poor-quality waste streams, insect farming could play an important part in the circular economy. At the same time, developments are progressing fast and much is still unknown regarding a number of essential aspects of the new sector. The RDA therefore has no objection to the production of insects, on the proviso that the parties involved see to their social responsibilities in a transparent fashion and – particularly at the current stage of development – maintain vigilance to prevent avoidable risks to society.

The scaling up of insect farming will definitely gain momentum over the next few years, as the EU prohibition on including insects in livestock feed is expected to be gradually removed, creating genuine access to a large market. Production for human consumption is also increasing, revealing profitable opportunities for the inclusion of insect components in pharmacological and skin-care products. The market opportunities are so tangible that both national and international insect-farming investments have seen an increase, and a new agricultural sector is taking shape in which farmers are seeking contact with parties up and down the supply chain, local and other government authorities and knowledge institutes. The sector is still young and relatively small, however, making it unclear what insect farming will ultimately mean to agriculture and food production. The long-term development will depend primarily on four factors: 1) the extent to which the production process can be made more cost-effective; 2) the extent to which the market will actually make use of insect proteins; 3) the development of other alternative protein sources; and 4) the potential role of insects in the circular economy.

In addition to the question of the economic development of the insect sector, numerous other questions that are relevant to society can often not be conclusively answered due to the lack of practical and scientific information available on many aspects. This report took stock of these questions through an analysis of the 16 social values presented in the RDA advisory report titled "One Health: A Policy Assessment Framework" (2015). The main conclusions are summarised below.

1) The insect industry is in great need of knowledge development and exchange in a wide variety of policy fields, such as the environment, public health and regional/other legislation. Many chain partners have proposed the option of a centralised consultation body made up of themselves and various government authorities, to encourage the sector in close consultation with the relevant government parties. There is also a need for centralised record-keeping of the economic developments in the sector, especially since it is becoming increasingly international.

2) The biggest barrier the chain partners are facing is the national and European legislation, which was not drawn up with the mass production of invertebrates in mind. Although the government and the sector are working on addressing needlessly prohibitive regulations, and have so far been quite successful in this regard, this aspect still requires attention. The greatest benefits are to be gained through clarification of the various applicable laws at regional, national and EU level; consistent treatment of invertebrates under this legislation; and improved consultation between the various ministries involved, at both national and international level. At the same time, there is a need for greater uniformity of regional regulations governing opportunities for the large-scale farming of invertebrates.

3) The potential role of insects in circular agriculture (in the food chain or otherwise) merits attention. Relevant questions in this regard include: which waste streams of sufficient and consistent quality and quantity can actually be used in large-scale insect production? What are the associated risks, and how can they be mitigated? To what extent can mass insect production utilise waste streams that are less suitable for other purposes, such as chicken and pig feed? What are the bioconversion opportunities outside the food chain?

4) The potential status of invertebrate species as sentient beings and the ensuing consequences for welfare standards deserves greater attention, as evidence suggests that some invertebrate species may qualify as sentient beings. There is scope for improved coordination in the legislation governing the use of invertebrates as production animals, laboratory animals and biological pest control agents, including opportunities for exempting certain species. More research is also needed on the behaviour and well-being of farmed species, and on the extent to which invertebrates can perceive pain and well-being. Based on this research, instruments need to be developed for monitoring well-being in practice.

5) There is a pressing need for more data in the field of public health and the environment. Although general impressions seem to indicate that the risks of insect farming are not

serious, the impact of the different farming types may differ significantly. The differences in substrate alone can have major impact, which is why continuous monitoring of the developments seems necessary. A key objective in this regard is the prevention of problems that have occurred, and continue to occur, in traditional livestock farming and aquaculture.

6) Prompt and transparent sharing of information could help citizens and consumers to make decisions regarding products containing insects. The attitude of the general public would seem to be cautiously positive, and the expectation is that some consumers will choose products containing insects as long as they are reasonably priced and taste good. Public opinion is a key factor in the development and acceptance of the insect industry.

9. Recommendations

9.1 General

1. Despite the rapid growth of the insect industry and the associated expansion of knowledge, the RDA has observed that this burgeoning agricultural sector is still lacking knowledge and experience in many of the areas discussed in this report. Most of the social questions regarding the following essential aspects therefore remain unanswered:
   a) health risks for humans and animals;
   b) environmental impact compared to other alternative and traditional agricultural sectors;
   c) welfare issues;
   d) potential effects on ecology and biodiversity;
   e) public opinion.

   In addressing these issues, the insect industry has primary responsibility. However, the fast-growing complexity means the impact of the industry is superseding the farms' immediate interests and sphere of influence, resulting in mounting social consequences at regional, national and even international level. The RDA therefore advises the relevant authorities (EU, Dutch National Government, provincial authorities and municipal authorities) to arrive at a shared vision and policy for the development of the sector and, in collaboration with the sector, to closely monitor the points listed above (see also Recommendation 7).

2. The RDA recommends supporting research on the points listed under Recommendation 1 and making the results publicly available, regardless of the potential commercial applications, while paying due respect to the intrinsic value of the animals, of course. The following concrete aspects merit special attention in this regard:
   a) the practicability of using invertebrate species for the bioconversion of organic waste streams, thereby contributing to the circular economy. One question requiring particular attention concerns how the use of waste streams as substrate can be reconciled with the need for the large-scale and efficient production of high-quality and safe foodstuffs at a constant and guaranteed quality and quantity;
   b) the specific consequences of using antibiotics, control agents and genetic technologies in invertebrate farms, concentrating particularly on the prompt identification of any adverse side effects;
   c) the specific risks of the various invertebrate farm types to the health of humans and animals. Supplementary to the EFSA recommendations (2015), the RDA argues for more research based on the One Health approach, as many human and

animal health risks are interrelated. The impact of emissions and waste products on the surrounding environment also merits extra attention;

d) In line with both animal welfare considerations and production efficiency, more research on the behaviour, needs and signs of well-being per species and developmental stage, as well as into the development of instruments for monitoring the well-being of insects in production environments. In general, health and welfare improve if animals and their environments are better adapted to one another. Much research that focuses on optimising conditions for the farming of a particular species will therefore also have welfare implications, which is why it is important from a welfare perspective for such information to be shared. Another relevant question concerns the extent to which the various species and their different developmental stages are capable of suffering and can be viewed as sentient beings, displaying states similar to emotions.

3. The production of insects is frequently viewed as an alternative to meat, and is hence often compared to traditional livestock farming. The RDA recommends placing the evaluations within a broader perspective and including other high-quality protein alternatives (even the issue of the need for additional animal protein powder) as standard in the evaluations of environmental, nutritional or health aspects, both nationally and internationally.

4. The RDA advises examining factors such as animal welfare, health risks and environmental impact not for the sector as a whole, but per farm. The major differences between species, substrates and production systems can result in significant differentiation between farms, allowing the inclusion of new techniques (and even new species that until now have not been farmed on a large scale) due to their relative benefits.

5. The RDA advises the government to ensure that the sector informs the public in a transparent, objective and prompt fashion on the advantages and disadvantages of the production and use of invertebrates. It is precisely during the initial growth phase that it can become important for the government to promote clear communication on the ethical aspects of animal welfare, public health, environmental impact and biodiversity. These aspects of mass insect production raise the most questions among the general public. Accessibility of information is not only important for public opinion and creating a support base for a new sector; it also enables the public to make well-informed choices as citizens and consumers.

6. Because some parts of existing laws and legislation governing the farming, processing and use of animals do not provide for the large-scale production of invertebrates, the RDA recommends a critical examination (and, where possible, modification) of local, national and international regulations in light of the new role to be played by these species. A clear, centrally accessible overview of the various relevant laws and regulations at regional, national and EU level may help the sector to find its bearings in the complex, potentially changeable legislative landscape. In addition to the initiatives already underway to modify legislation that inhibits production unnecessarily, additional attention should be devoted to a uniform approach to the intrinsic value of invertebrates and their status as sentient beings. The desirability of a uniform approach to invertebrate farms in local legislation also merits further attention. Some aspects to keep in mind when modifying food farming policy are the consequences for other sectors that also involve invertebrates, such as their use in laboratory testing, pollination and biological pest control.

7. The RDA advises the government to support a "platform for the production of invertebrates" (an invertebrate platform) in which various government bodies, interest groups, knowledge institutes and commercial parties participate. Its aims will include the collection, exchange and publication of knowledge; the identification of problem areas in society; promotion of the sector; sharing potential solutions; and facilitating social debate. Several of the recommendations given in this report can serve as more detailed, concrete input. The platform could also help to keep central and objective records of relevant economic data, in order to establish and monitor the social and international significance of the emerging sector.

9.2 Animal-specific

8. The RDA advises all parties involved to explicitly respect and promote the intrinsic value of insects and other invertebrates. The immediate consequence is that, just like with vertebrates, any and all use of these species must be justified; decisions on their use must be taken with due observance of all interests and moral principles (e.g. the RDA's One Health framework); and the farmers must ensure the animals' well-being, taking the behaviour and needs of specific species as their reference point. The above applies not only to the invertebrate species farmed for the food industry, but also to new sectors or applications where insects represent instrumental or economic value (e.g. as biobots).

9. Acknowledging the intrinsic value of invertebrates also creates responsibilities to safeguard well-being. In this context, it is important to determine whether and to what extent invertebrates are sentient beings. As long as no reasonable scientific case can be made for a species' sentience or non-sentience, the RDA advises treating invertebrates in production systems as sentient beings as much as possible, and – just like in the Experiments on Animals Act – for such to be made explicit (e.g. in the Animal Husbandry Decree). This means that measures must be taken throughout the production process to optimise animal welfare according to the current state of research to prevent suffering as much as possible, and that the Netherlands Food and Consumer Product Safety Authority (NVWA) should act as supervisory body in this regard. Although ensuring the welfare of farmed invertebrates can entail additional costs, it is ultimately not only the animals, but also the farmers and the sector as a whole that benefit. As a means of incentive, both the government and the industry could actively investigate and promote win-win scenarios.

10. The RDA considers it likely that scientific advances in the near future will spark social debate in favour of acknowledging certain insect species as sentient beings, i.e. as creatures capable of suffering. Although it has proven difficult to scientifically and definitively demonstrate a capacity for emotional awareness, accumulated evidence can give cause to amend legislation, as in the case of cephalopods (squids and octopuses) under the Experiments on Animals Act. The RDA therefore recommends supporting research on the perception of well-being and suffering among farmed invertebrates, not only to justify the need for any additional protection of specific invertebrate species, but also as the basis for welfare and husbandry stipulations.

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Appendices

Appendix 1: Invertebrates approved for production purposes

1a. Invertebrates listed in Appendix II to the Animal Husbandry Decree (*Besluit houders van dieren*) of 5 June 2014, setting out the regulations governing keepers of animals:

"Appendix II as referred to in Section 2.1 of the Animal Husbandry Decree: Species and categories of animals that may be farmed in the Netherlands for the purpose of making products of animal origin."

Crustacea	
litopenaeus vannamei	Shrimp
Homarus gammarus	European lobster
Homarus americanus	American lobster
Astacus leptodactylus	Danube crayfish
Orconectes limosus	Spinycheek crayfish
Procambarus clarkii	Louisiana or Red swamp crayfish
Palinurus spec.	Spiny lobster
Eriocheir sinensis	Chinese mitten crab
Cancer pagurus	Brown crab
Cladocera	Water flea
Copepoda	Copepod
Balanus spec.	Acorn barnacle
Artemia salina	Brine shrimp
Artemia franciscana	North-American brine shrimp
Artemia gracilis	Woodentub brine shrimp
Daphnia pulex	Water flea
Moina macropoda	Japanese water flea

***Bivalvia* (bivalves)**	
Mytilus edulis	Blue mussel
Ostrea edulis	European flat oyster
Crassostrea gigas	Pacific oyster
Crassostrea angulata	Portuguese oyster
Crassostrea virginica	Eastern oyster
Cerastoderma edule	Common cockle
Pecten maximus	Great scallop
Veneridae	Venerids, Prairie clam, Venus clam
Glycimeris glycimeris	Sea almond clam

Donax trunculus	Wedge clam
Donax vittatus	Banded wedge shell
Spisula subtrunculata	Surf clam

***Gastropoda* (snails)**

Helix pomatia	Roman snail
Littorina littorea	Common periwinkle
Cornu aspersum	Garden snail
Lissachatina fulica	Giant African snail

***Insecta* (insects)**

Blaberus craniifer	Death's head cockroach
Blaptica dubia	Dubia roach
Periplaneta americana	American cockroach
Acheta domesticus	House cricket
Gryllus bimaculatus	Two-spotted cricket
Locusta migratoria	Migratory locust
Schistocerca gregaria	Desert locust
Carausius morosus	Common stick insect
Baculum extradentatum	Annam walking stick
Pachnoda butana	Sun beetle
Pachnoda aemole	Sun beetle
Pachnoda marginata	Sun beetle
Alphitobius diaperinus	Lesser mealworm
Zophobas morio	King worm, superworm, morio
Sitophilus ganarius	Wheat weevil
Sitophilus oryzae	Rice weevil
Drosophila hydei	Fruit fly
Drosophila melanogaster	Fruit fly
Musca dom. var.	Housefly
Galleria mellonella	Greater wax moth
Achroia grisella	Lesser wax moth
Sitotroga cerealella	Angoumois grain moth
Plodia interpunctella	Indianmeal moth
Pyralis farinalis	Meal moth
Apis mellifica	Honey bee
Tenebrio molitor	Yellow mealworm
Calliphoridae	Blow flies *
Chironomidae	Lake flies *
Vespidae	Wasps *

* These are families, not individual species. Because approval is granted per species, the three insect families will eventually be removed from the list.

Lower animals

Lumbricus rubellus	Red earthworm
Lumbricus terrestris	Common earthworm
Eisenia foetida	Brandling worm
Arenicola marina	Lugworm
Dendrobaena veneta	European nightcrawler
Polychaetae	Bristle worm
Brachionus spec.	Rotifer
Arenicolides ecaudata	

1b. Temporary exemption under the use of insects as production animals, September 2017:

Species	Decision date	Reference	Valid for
Black soldier fly (*Hermetia Illucens*)	26-02-2015	RVO/2015/73	Protix Biosystems
Banded cricket (*Gryllodes sigillatus*)	25-04-2016	WDP/10/2015/002	Kreca Ento Feed BV
Black soldier fly (*Hermetia Illucens*)	14-03-2017	WDP/10/2017/001	Bestico B.V. (Koppert)

Source: https://www.rvo.nl/onderwerpen/agrarisch-ondernemen/dieren-houden/huisdieren-houden-en-fokken/productiedierenlijst

Appendix 2: Brief overview of EU laws and regulations

This list provides a non-exhaustive overview of EU legislation pertinent to the production of insects as animal feed.

1 Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies – **TSE regulation**: to prevent the spread of Transmissible Spongiform Encephalopathy, a general variant of BSE (mad cow disease) that is transmitted via prions (even following heat treatment). Because prions are misfolded proteins, this regulation prohibits processed animal protein (PAP) from being fed to production animals, which includes insects, with the exception of fishmeal and blood meal being fed to non-ruminants. The regulation dictates the procedure in case insects are made into PAP and lays down standards for particle size, heat treatment, time and pressure.

2 Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety – **General Food Law Legislation**: food safety and the safeguarding thereof by the European Food Safety Authority (EFSA).

3 Regulation (EC) No 183/2005 of the European Parliament and of the Council of 12 January 2005 laying down requirements for feed hygiene – **animal hygiene provisions**: like EC 178/2002, this regulation pertains to food safety, traceability and production requirements.

4 Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC – **trade in/use of animal feed**: stipulates that insects as farm animals may only be fed with safe foodstuffs, which excludes faecal or waste matter from the digestive tract (Appendix III). Later supplemented by EU 68/2013.

5 Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 – **Animal By-products Regulation**: specifically targets the risks of animal products and by-products that are not intended for human consumption. This regulation also dictates that insects farmed as food must also be designated as "farm animals", making them further subject to additional legislation such as Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health. N.B.: this regulation supersedes EC 1774/2002.

6 Commission Regulation (EU) No 142/2011 of 25 February 2011 **implementing Regulation (EC) No 1069/2009** of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive – the implementation of EC 1069/2009 on animal by-products (see Item 3 above) stipulates that insects may not be farmed on unprocessed foodstuffs that have not been approved for human consumption, while EC 1069/2009 itself stipulates that insects may not be farmed on manure or kitchen waste. This limits the opportunities for the deployment of insects in the circular economy.

7 Commission Regulation (EU) No 68/2013 of 16 January 2013 on the Catalogue of feed materials – **catalogue of foodstuffs**: dictates the approved substrates and the conditions under which they may be used as animal feed. It covers the substrates on which insects may be farmed. However, as "terrestrial invertebrates", insects are themselves also a source of food (provided they are not pathogens). Further supplemented by Commission Regulation (EU) 2017/1017 of 15 June 2017 amending Regulation (EU) No 68/2013 on the Catalogue of feed materials.

8 Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health – **transmissible disease regulation**: regulates the biosafety and animal health of animal farms, and therefore applies to insect farms as well (Article 10 in particular).

9 Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein – **amendments to the provisions applicable to processed animal protein (PAP)**. This regulation sets out a number of specific amendments to the processing and use of insects. This modification to sections of EU 142/2011 and EC 999/2001 (see Items 7 and 8 above) allows insects to be used in aquaculture and specifies which species, substrates and processing methods are approved for the manufacture of PAP. Among other things, it stipulates that insects must be processed in facilities specially approved for the purpose, and also sets out import regulations.

10 Commission Regulation (EU) 2017/1017 of 15 June 2017 amending Regulation (EU) No 68/2013 on the Catalogue of feed materials – **amendments to the foodstuffs catalogue** (EU 68/2013): provides an updated list of substrates, refers to processed insect proteins (in 9.4.1) and fats (in 9.2.1) as food and specifies the labelling of foodstuffs, among other things.

Appendix 3: Stakeholders interviewed

The following external experts were consulted in the creation of this advisory report:

- Mr T. Arsiwalla, co-owner of Protix;
- Mrs J.M.A. Bakkenes, senior policy officer, Ministry of Economic Affairs;
- Mrs H.M.J.W. De Bruin, CEO of Protifarm;
- Mr B.J. Carrière, UEVP vice-president, FVE delegate, insects task force;
- Mrs Y.M.H. Kleintjes, Farm Animal Welfare cluster coordinator, Ministry of Economic Affairs;
- Mr F.B. Leijendekkers, senior policy officer, Plant Agro-food Supply Chains and Food Quality Department, Ministry of Economic Affairs;
- Mrs S.N. Lems, Farm Animal Welfare senior policy officer, Ministry of Economic Affairs;
- Mrs G.J.F.M. Van Megen-Boekestijn, managing director of Feed Design Lab;
- Mr E. Michels, chair of VENIK;
- Mrs M. Peters, CEO of NGN;
- Mr W.A. Ruiterkamp, former senior policy officer, Plant Agro-food Supply Chains and Food Quality Department, Ministry of Economic Affairs;
- Mr G.T.J.M. Theunissen, senior policy officer, Plant Agro-food Supply Chains and Food Quality Department, Ministry of Economic Affairs;
- Mr H. De Vor, general manager, Coppens Diervoeding;
- Mr M.J.B.M. Weijtens, acting manager, Plant Agro-food Supply Chains and Food Quality Department, Ministry of Economic Affairs.

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