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Insect based pet food

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Preface

My interest in insect based pet foods started a few years ago when someone asked my opinion about feeding meat to carnivore pets. Actually, I am trying to live a more sustainable lifestyle and avoid animal protein due to low sustainability. Based on that, one question arise, what can be feed to pets to avoid animal protein consumption? I started looking for alternative but adequate protein sources, and ended up realising that insect protein could be an interesting substitute. This thesis was a great opportunity to increase my knowledge about it, but specially to know the opinion of people from Belgium and the Netherlands about using insect protein as an alternative protein for their pets.

I would like to extend my sincere thanks to various people who played a crucial role in completing this thesis. Firstly I would like to express my gratitude to everyone who participated in my questionnaire. Without their responses this limited research would not have been possible. Secondly, I also wish to thank dr. Ruiz-Suárez and professor dr. Hesta for their help and feedback in the process of writing this dissertation. Last but not least, I very much appreciated the support of my boyfriend Dion. His practical suggestions and second opinions were valuable to me.

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Abbreviations:

ADF	Acid detergent fibre
BSF	Black soldier fly
BSFL	Black soldier fly larvae
DM	Dry matter
ECI	Efficiency of conversion of ingested material
FCR	Feed conversion ratio
FM	Fresh matter
NDF	Neutral detergent fibre

1. Abstract

Insect based pet food is a new option among the various types of pet food. It was developed because of its sustainability combined with good nutritional quality. Nowadays, there are still challenges like European legislation, the price of the current type of production, uncertainty about animal welfare and the perspective of consumers. Particularly, the perspective of Belgian and Dutch pet owners toward feeding insect based pet food was not known.

This dissertation is a limited research study and aims to investigate whether Belgian and Dutch pet owners are willing to feed insect based pet food. This current study investigated the possible influencing factors including gender, age, the relation to veterinary medicine, the pricing, own diet, concerns about climate change, complete insect versus processed versions, the percentage of insect protein, interest in insect based snacks for pets, knowledge and experience in entomophagy and knowledge about feeding insects to pets. Participants were also questioned about their point of view on insect based pet food and the advantages and disadvantages they could think of. This research was performed in dog and cat owners.

The results showed that around half of the Belgian and Dutch pet owners are open to feeding insect based pet food. This percentage was higher (2/3rd) when owners were asked about feeding insect based snacks. The latter group is neutral (about 1/3rd) or not (+/- 1/6 in cat owners, ¼ in dog owners) willing to feed insect based pet food. Influencing factors are the level of knowledge about entomophagy, worrying about and taking action against climate change, the price of the product and how good or bad the taste was in case of the experience of entomophagy in pet owners. Another finding is that female veterinarians are significantly more willing to feed insect based dog food.

2. Samenvatting

Insect gebaseerde diervoeding is een nieuwe optie binnen de diervoeders. Het is ontwikkeld omdat het duurzamer is en tegelijk nutritioneel een goede samenstelling heeft voor honden- en kattenvoeding. Op het moment zijn er nog steeds uitdagingen zoals de Europese wetgeving, de prijs die voort komt uit de huidige manier van produceren, onzekerheden rond dierwelzijn bij de kweek van insecten en het perspectief van consumenten. Het perspectief van Belgische en Nederlandse honden- en katten eigenaren over insect gebaseerde diervoeding is nog niet diepgaand onderzocht.

Deze masterproef is een beperkt onderzoek met als doel te onderzoeken of Belgische en Nederlandse huisdieren bezitters zich klaar voelen voor insect gebaseerde diervoeding. De mogelijke beïnvloedende factoren op dit perspectief worden ook onderzocht. Dit omvat geslacht, leeftijd, relatie tot de diergeneeskunde, de prijs, het eigen dieet, hoe bezorgd men is over klimaat verandering, complete insecten of verwerkte varianten, het percentage insecten eiwit, interesse in insect gebaseerde snacks, kennis en ervaring met het eten van insecten en kennis over het voeren van insecten aan huisdieren. Deelnemers worden ook bevraagd over hun perspectief op insect gebaseerde diervoeding en de voor- en nadelen die zij zien. Dit onderzoek is gericht op honden- en katten eigenaren, de antwoorden van beide groepen zijn apart en zullen worden vergeleken.

De resultaten van de studie laten zien dat ongeveer de helft van de Vlaamse en Nederlandse huisdieren eigenaren open staan voor het voeren van insect gebaseerde voeding. Ongeveer 2/3e staat open voor insect gebaseerde snacks. Het overige deel van de respondenten staat er neutraal in (ongeveer 1/3) of wil geen (+/- 1/6 van de katten eigenaren, ¼ van de honden eigenaren) insect gebaseerde voeding geven. Beïnvloedende factoren zijn het niveau van kennis van het eten van insecten, zorgen en het nemen van actie tegen klimaatverandering, hoe goed dan wel slecht de smaak was in geval van een ervaring met het eten van insecten als diereigenaar. Een andere significante bevinding is dat vrouwelijke dierenartsen meer open staan voor insect gebaseerde voeding.

3. Introduction

It is expected that the global population will grow to over 9 billion people in 2050 (Gerber, 2013). Combined with increasing standards of living in third world countries, this will create a higher, even double, demand for animal-derived protein (Boland et al., 2013; Baiano, 2020). Feeding the growing world population with animal protein will be problematic and unsustainable (Caparros Megido et al., 2014; Biesalski et al., 2017). The meat industry has a severe impact on the environment by influencing climate change through the consumption of natural resources and environmental pollution. (Djekic, 2015).

Companion animals also take part in this competition for protein as they consume animal-derived protein sources too. Although the volume of protein eaten by dogs and cats is very low compared to the amount consumed by humans, it cannot be ignored. Most dogs and cats' diets use meat and animal by-products that still can be partially be consumed by humans (Boland et al., 2013). To sustain the growing demand of protein, alternative protein sources for both petfood and humans should be found. (Boland et al., 2013).

Insects are an interesting protein source because of their nutritional composition, especially their amino acid content. It is promising for pet food as well. Practical aspects of producing insects for humans and petfood are still being explored. Legislation, economically feasible production, animal welfare and large-scale production are aspects that have to be investigated, designed or adjusted toward insects as a protein source. These processes are currently accelerating, and insects are already available in supermarkets and in some petfood stores in Europe.

Insects might seem promising, but there are still challenges. One of the biggest challenges is that consumers from the Western world are not used to eat or feed insects. They have associated insects with a sense of dirtiness, disgust and danger for a long time (Looy et al., 2014). Therefore, even though there are several advantages for the environment and food security, many Western consumers still have to get used to the idea. Studies in other countries showed that some pet owners are slowly getting used to the idea of feeding insects to their pets. A study that focuses specifically on this topic has not been conducted in Belgium or The Netherlands yet. Thus, it is not known what Belgian and Dutch pet owners think of feeding their pet(s) insect based pet food.

This present study aimed to gain more insight into this topic through a survey among Belgian and Dutch pet owners. An important condition to consider feeding insects as a protein source to pets, is that the nutritional value has to be adequate to be part of their diets. This will be discussed in section 4.1 of this thesis. After that, the environmental advantages of using insects as a protein source will be further elaborated in section 4.2. Next, the practical aspects of eating and feeding insects will shortly be considered in section 4.3. In section 4.4, the current data about the perspective of Western consumers on entomophagy and insect based pet food will be explained. Finally, the results of the survey among Dutch and Belgian pet owners will be shown and discussed in section 5.

Knowing the opinion of Belgian and Dutch pet owners about using insect based pet food, evaluate the factors that could possibly influence their opinion about it, is of great value, not only for the industry but for sustainability too.

4.1 Nutritional composition

4.1.1 The nutritional composition of commonly used insect species

Species that are predominantly used for pet food and animal feed in Europe are black soldier fly larvae and pupae (*Hermetia illucens)*, housefly pupae *(Musca domestica),* mealworm larvae (*Tenebrio molitor),* adult house cricket (*Gryllidae)* and silkworm (*Bombyx mori).* Black soldier fly and mealworm larvae turn out to be the most feasible in large scale production (EFSA, 2015) and will be discussed in more detail below. The focus will be on amino acids as these are the most important nutrient when using insects as a protein substitute. All nutritional data in this chapter is based on DM.

4.1.1.1 Nutritional composition of *Hermetia illucens*

Hermetia illucens, also known as the black soldier fly (BSF), is high in protein and lipids, although the exact percentages of its composition differ depending on the life cycle stage and diet (Kroeckel et al., 2012; Liu et al., 2017; Wang and Shelomi, 2017). The BSF contains an average crude protein of 40.8% with a standard deviation of ± 3.8% and 28.6% ± 8.6% of fat per dry weight of BSF larvae. These percentages are also attainable when the BSF is fed with waste or manure, which could be interesting for sustainability (Wand and Shelomi, 2017). The general nutritional values of *Hermetia illucens* can be found in table 1. These values are based on captive-bred insects, which are mostly used in pet feed as well.

4.1.1.2 Changes in nutrient composition of black soldier fly over its life cycle

Different phases of a BSF can be used for food production, see figure 1. The early prepupa and mature larvae contain the highest level of crude protein and crude fat combined, which makes them more interesting to use. The percentage of crude protein increases significantly from egg to larvae. From that point, it decreases again over the different phases until the early pupa phase, where the amount of crude protein rises again. The highest amount of crude protein can be found in post-mortem adults; 57.6% (Liu et al., 2017).

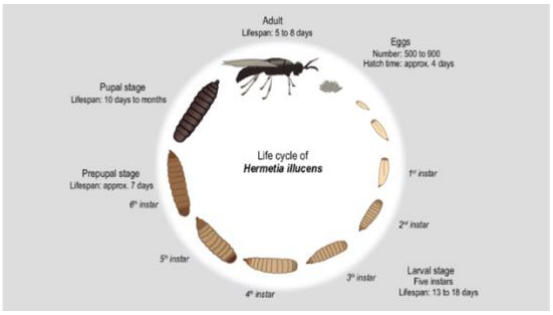


Figure 1: The life cycle of BSF. From *Chemical safety of BSF larvae (Hermetia illucens), knowledge gaps and recommendations for future research: a critical review. By Lievens et al., (2021). Journal of Insects as Food and Feed 7, 383 – 396.*

Over the larval development phases, the amount of crude fat increases rapidly. The latest (14 days) larvae show 28.4% crude fat based on DM, this is followed by a significant drop towards the late pupae phase. In adult BSF it is over 30% again, post-mortem adults contain 21.6% crude fat. BSF contains a high level of mineral elements. The prepupal phase contains a higher level compared to the larval period when there is no cuticle yet (Liu et al., 2017).

4.1.1.3 Changes in the nutrient composition of the black soldier fly based on its feed

Another influencing factor on the composition is the feed. BSF can grow on different waste streams and even manure. Protein content and quality of the BSF remain high regardless of the different types of rearing substrates they have tested. Nonetheless, differences in ash content and fat depending on the feed can occur and should be considered (Spranghers et al., 2017). Currently, it is illegal to use waste streams or manure as feed in Europe. This will be discussed in chapter 4.3.3 about legislation in Europe.

4.1.1.4 Nutritional composition of *Tenebrio molitor* and influencing factors

Tenebrio molitor larvae are also known as mealworms. Larvae form is the most commonly used of this mealworm in food and feed. Their nutritional content can be found in table 1. *Tenebrio molitors'* chemical composition varies widely depending on their diet and stage of development. For instance, the amount of protein in larvae is 46.44%; in adult mealworms, 63.34%; and still 18.51% in excreta. This means the excreta could still be recycled into an additional food supplement for animal feeding (Ravzanaadii et al., 2012).

4.1.2. The nutritional composition of insect versus animal protein

BSF and *Tenebrio molitor* will be compared to two different types of animal protein as shown in table 1. The first one is poultry, which is the most commonly eaten meat and can often be found in petfood as well. Its nutritional content depends on feed composition, production type, living conditions, age, gender and which part of the body is eaten (Probst, 2009). Bone meal is often used in pet food, therefore, it is interesting to include it in the comparison. The BSF and *Tenebrio molitor* will be compared with these conventional types of protein in terms of general nutritional composition, amino acids, fatty acids, vitamins, minerals and carotenoids. Results will be discussed in 4.1.3.1 and 4.1.3.2.

Table 1: Nutritional values of BSF, *Tenebrio molitor*, poultry and bone meal. General composition based on FM, specifics based on DM.
Yellow means deficient to cats, blue means deficient to dogs and green means deficient to both when compared to the 2021 FEDIAF guidelines. Insect data based on all edible elements. Poultry data based on 'Chicken, broiler or fryers, breast, skinless, boneless, meat only, cooked, braised or breast meat' or 'Proximate composition, amino acid profile, and oxidative stability of slow-growing indigenous chickens compared with commercial broiler chickens' or undefined. Bone meal based on bone meal with >7,5% fat. The insect data are based on the larval phase.

Adapted from: Finke, M.D., (2013). Complete Nutrient Content of Four Species of Feeder Insects. Zoo Biology 32, 27-36, Sauvant, D., Perez, J.M., Tran, G., 2004. Other animal by-products. In: Sauvant, D., Perez, J.M., Tran, G., Tables of composition and nutritional value of feed materials, 2nd edition. Wageningen Academic Publishers, Wageningen, The Netherlands and INRA, Paris, France. pp 288. And: Spitze, A.R., Wong, D.L., Rogers, Q.R., Fascetti, A.J., 2003. Taurine concentration in animal feed ingredients; cooking influences of taurine content. Journal of animal physiology and animal nutrition, 87, 251-262.and [12]. Siemianowska, E., Kosewska, A., Ajewicz, M., Skibniewska, K.A., Polak-Juszczak, L, Jarocki, A., Jedras, M., (2013). Larvae of mealworm (Tenebrio molitor L.,) as European novel food. Agricultural sciences 4, 287-291. Ravzanaadi, N.Seong-Hyun, K., Ho Choi, W., Hong, S., Jung Kim, N., (2012). Nutritional value of Mealworm, Tenebrio molitor as food source. Industrial Entomology 25, 93-98. Jones, L.D., Cooper, R.W., Harding, R.S., (1972). Composition of mealworm Tenebrio molitor larvae. Journal of zoo animal medicine 3, 34-42.Finke, M. (2015). Complete nutrient content of four species of commercially available feeder insects fed enhanced diets during growth.Zoo Biology 34, 554-564.

	Black soldier fly	***Tenebrio molitor***	**Poultry**	**Bone meal**
General g/100g (FM)				
Moisture	61.2	57,75	65.3	4,6
Dry matter	38,8	42,25	34,7	95,4
Crude protein	17,5	22,32	92,51	56,8
Crude fat	14,0	14,96	9,22	10,0
NFE	0,8	3,61	0,00	0,20
Ash	3,5	1,36	3,46	28,4
Metabolizable energy kcal/100g	199,4	213	455,33	215
Amino acids g/100g (DM)				
Alanine	3,14	1,71	3,14	4,21
Arginine	3,17	1,13	4,18	4,15
Aspartic acid	4,25	1,67	5,04	4,33

[1] *https://fdc.nal.usda.gov/fdc-app.html#/food-details/331960/nutrients On 1-11-21*

[2] *https://tailblazerspets.com/blog/2019/02/how-to-add-extra-taurine-to-your-pets-diet/ On 1-11-21*

Cysteine	0,26	0,24	0,61	0,42
Glycine	2,35	1,12	2,51	7,36
Glutamic acid	5,08	2,64	8,39	6,82
Histidine	1,52	0,71	1,76	1,05
Isoleucine	1,96	1,65	2,71	1,60
Leucine	3,12	3,43	4,38	3,53
Lysine	3,07	2,12	5,16	3,04
Methionine	0,88	0,91	1,01	0,90
Phenylalanine	1,96	1,97	2,19	1,88
Proline	2,63	3,23	2,16	4,66
Serine	1,80	5,14	2,71	2,23
Threonine	1,75	2,06	2,39	1,95
Tryptophan	0,77	0,0	x	x
Tyrosine	3,12	3,31	1,87	1,34
Valine	3,32	2,57	2,65	2,44
Taurine	<0,03	0,10	0,06 (*4)	0,04 (*4)
Fatty acids g/100g (DM)				
Capric 10:0	0,18	<0,03	0,04	x
Lauric 12:0	13,20	<0,03	0,01	0,02
Myristic 14:0	3,09	1,42	0,05	0,24
Myristoleic 14:1	0,13	x	0,01	x
Pentadecanoic 15:0	0,03	<0,03	0,01	x
Palmitic 16:0	4,15	7,76	2,15	2,38
Palmitoleic 16:1	1,28	1,24	0,45	0,32
Heptadecanoic 17:0	0,05	<0,03	0,01	x
Heptadecenoic 17:1	<0,02	<0,03	0,01	x
Stearic 18:0	0,63	1,16	0,61	1,66
Oleic 18:1	4,02	20,05	3,11	3,51
Linoleic 18:2	4,36	14,04	1,73	0,31
Linolenic 18:3	0,17	0,63	0,07	0.07
Arachidic 20:0	0,04	<0,03	0,01	0,13
Eicosenoic 20:1	<0,02	0,11	0,05	x
Eicosadeienoic 20:2	<0,03	x	0,03	x
Arachidonic 20:4	<0,02	<0,03	0,25	x
Benhenic 22:0	0,02	<0,03	0,01	x
Minerals mg/100g (DM)				
Calcium	2407,22	31,5	17,29	10.679,12
Phosphorus	917,53	700,2	694,52	5135,20
Magnesium	448,45	144,6	92,22	230,56
Sodium	228,61	81,1	135,45	765,04
Potassium	1167,53	726,6	988,47	461,12
Chloride	298,97	x	x	x
Iron	17,16	4,10	1,41	61,41
Zinc	14,48	8,2	2,77	11,53
Copper	1,04	1,19	0,13	2,10
Manganese	15,93	0,82	0,03	2,62
Iodine	0,07	<0,03	x	0,13
Selenium	0,08	<0,01	0,09*	0.045
Vitamins and others (DM)				
Vitamin A	<773,20 µg/kg	<753,77 µg/kg	x	x
Vitamin D2	<206,19 IU/kg	<40 IU/kg	x	x
Vitamin D3	257,73 IU/kg	<40 IU/kg	x	x
Vitamin E	15,98 mg/kg	24,5 mg/kg	0,95 mg/100g	1,36 mg/kg
Vitamin C	<25,77 mg/kg	99 mg/kg	x	x
Thiamine	19,85 mg/kg	1,1 mg/kg	0,28 mg/100g	x
Pantothenic acid	99,23 mg/kg	15,6 mg/kg	4,55 mg/100g	5,24 mg/kg
Niacin	182,99 mg/kg	0,41 mg/kg	27,23 mg/100g	56,60 mg/kg
Pyridoxine / B6	15,49 mg/kg	6,9 mg/kg	2,65 mg/100g	5,24 mg/kg
Folic acid	6,96 mg/kg	x	x	0,54 mg/kg
Biotin	0,90 mg/kg	0,43 mg/kg	x	0,12 mg/kg
Vitamin B12	143,81 µg/kg	1,3 µg/mg	5,8 µg/kg	128,90 µg/kg
Riboflavin / B2	x	0,68mg/kg	5,4 mg/kg	5,24 mg/kg
Folate / B11	x	x	x	x
Vitamin K	x	<50 mg/kg	x	x
Beta-carotene	<0,52 mg/kg	x	x	x
Lutein	1,52 mg/kg	x	x	x
Zeaxanthin	3,30 mg/kg	x	x	x
Chitin	54,12 g/kg	x	x	x

4.1.3 Nutritional deficiencies in insect based pet food

4.1.3.1 The nutritional guidelines for pet food

The data in table 1 were compared to the FEDIAF nutritional guidelines for dog and cat food. Many pet food brands in Europe base their pet nutrition on these guidelines. The FEDIAF tables used in this study are based on units per 100g DM (FEDIAF, 2021). We compared the nutritional requirements of an adult animal, based on a MER of 95 kcal/kg^0.75 for dogs and a MER of 75 kcal/kg^0.67 for cats. Table 1 shows which components lack in BSF larvae and *Tenebrio molitor* larvae when compared to the FEDIAF guidelines. More specifically we see that Taurine and several vitamins are a problem in both insect species, *Tenebrio molitor* is also lacking some minerals.

4.1.3.2 Black soldier fly components compared to the nutritional guidelines

When comparing the nutritional value of BSF to the FEDIAF nutritional guidelines in table 1, it is shown that some nutritional components are lacking in BSF. The only amino acid that is deficient in BSF, was taurine for cats. Taurine is essential for cats, a lack of taurine in the diet can cause serious eye problems, heart disease, reproduction problems, digestive issues, dental problems and poor fur and skin condition (Delaney and Fascetti, 2012). Taurine is not an essential amino acid for dogs (FEDIAF, 2021). The only mineral that was too low in BSF was iodine for both, dogs and cats. The right proportion of Ca/P differs related to age, species, reproduction state and breed. The Ca/P of 2.6 in BSF is relatively close to what is needed in cat and dog food, approximately 1:1 to 2:1 (Dzanis, 2012).

There is a shortage of vitamin A, D and E for dogs. Cats need more vitamin A, D2 and E than what is available in BSF. All essential B vitamins were available in BSF. When dogs need retinol, they can convert beta-carotene to retinol in case retinol was not available in the diet. Cats do not have this ability and need to get enough vitamin A from external sources. Vitamin A has several important functions and a lack of Vitamin A often leads to eye-related problems, among others. There are no reports of clinical signs of vitamin D shortage in dogs, only in puppies. (Delaney and Fascetti, 2012).

4.1.3.3 *Tenebrio molitor* components compared to the nutritional guidelines

Tenebrio molitor is another edible insect species that can be used in pet food, although it is less commonly used compared to BSF. The nutritional composition of this insect can be found in table 1. Taurine is again an amino acid that is lower than recommendations. *Tenebrio molitor* contains more taurine than BSF, but still not enough. Tryptophan is also too low for both dogs and cats in *Tenebrio molitor. Tenebrio molitor* contains all essential fatty acids for dogs and cats (FEDIAF, 2021). This insect contains too little iodine, selenium and calcium to both dogs and cats. Especially the Ca deficit is important as this also influences the Ca:P of this species. The Ca:P in *Tenebrio molitor* is too low, +/- 1:22 based on the data. Relatively too little calcium or too much phosphorus can lead to nutritional secondary hyperparathyroidism, rickets and osteomalacia. These diseases are seen more often in pets fed on non-commercial diets like homemade and raw diets. It is important to get this Ca/P balance right to produce a healthy diet for pets (Verbrugghe et al., 2011). Iron is low for cats, this can have a role developing in anemia (Delaney and Fascetti, 2012).

Tenebrio molitor is deficient in vitamin A, D2, D3, B1, B3 and B2 in both, dogs and cats. For cats, it contains too little of vitamin E as well. Cats need more vitamin E than what is in *Tenebrio molitor*. The different vitamin B types that are not enough in *Tenebrio molitor* can play important roles such as co-enzymes in processes, among others in the metabolism of nutrients (Delaney and Fascetti, 2012).

4.1.3.4. Nutritional deficiencies for dogs and cats in edible insects in general

The amount of fat and protein in insects varies substantially between edible insect species. To use insects as a protein source in pet food, it is necessary to monitor and control these variations. There is also a difference in digestibility of the insects, which is relevant to the nutritional value of the insect species. Housefly pupae and BSF are very high in crude protein and amino acid scores, but also that these are less digestible. Cockroaches also contain high crude protein and amino acids scores, and they are relatively easy to digest. But even though cockroaches contain large amounts of amino acids, these insects lack some essential amino acids (Bosch et al., 2014).

A study compared edible insect species (BSFL, cockroaches, blowfly larvae and adults, ants) to the National Research Council's minimal requirements for canine and feline pet foods in all essential amino acids and crude protein. Results showed that all insects in the study met the requirements except taurine in BSF (McCusker et al., 2014). Crickets (*Acheta domestics)* have the highest amount of taurine with 1-4mg taurine/g adult cricket and 0-8mg taurine/g cricket nymphs. The amount of essential fatty acids in edible insects showed little to no deficiencies depending on the species. Usually, they were noticeably higher than the recommended minimum amounts.

The types and amounts of essential minerals differ greatly between insect species, the often-used black soldier fly contains most of them (Oonincx and Dierenfeld, 2012). Natrium and calcium are the macro minerals that are lacking the most in the different insect species. Calcium has to be judged combined with the amount of phosphor, the Ca:P relation is crucial. Insect species often contain an inverse Ca:P ratio, meaning that there is less calcium compared to the amount of phosphor. In cat and dog food, we prefer a Ca:P of 1:1 to 2:1. The Ca:P of insects is often wrong, containing more phosphor and less calcium to get a decent ratio. Black soldier fly is close to what it should be, approximately 2,6:1, see table 1. This makes BSF even more interesting to use in pet food.The Ca:P of other insect species might become more interesting to use in pet food by using calcium powder on the insects. This practice has already been used in insects produced for insectivore feed (Boykin et al., 2020). Trace minerals in insects is highly variable. This can partly be linked to the difficulties of measuring them correctly, small sample sizes in research, dietary influences, species-specific metabolism, different analytical techniques and possible contaminations (Oonincx and Dierenfeld, 2012).

Many insect species are low in vitamins A, D and E. The retinal content which was used as a measure of vitamin A activity was low in the tested species (Oonincx and Dierenfeld, 2012). The vitamin E content was low for most edible insect species except for *M. rhombifolium* and *D. melanogaster.* Vitamin D deficiencies in insect protein could be linked to Ca and P regulation problems. Vitamin D content also depends on UV-B radiation during the insects' development (Van Huis et al., 2021). The insects' nutrient profiles can be modulated to create a better nutritional composition. This can be done with appropriate dietary supplementation with synthetical substitutes. Like in exotic animal feed, where a vitamin powder can be used to add the specific component which is lacking (Gasco et al., 2020). It might be interesting to combine different insect species as well, to create a net correct nutritional composition.

In general, insects have been stated to contain the same or even more nutritional content compared to other more conventional foods. Insects usually have an efficient conversion ratio, but because of the lower digestibility of insects, they can still have a lower efficiency of protein conversion. To reach a comparable level, it could be interesting to remove chitin from the insect. This will create a product with a comparable digestibility to conventional foods according to studies (Ravzanaadii et al., 2012). Because crude protein digestibility in edible insects is just moderate, it is recommended to use a safety margin when creating an insect based diet to prevent nutritional deficiencies in pets (Nadine Paßlack and Jürgen Zentek, 2018).

4.1.4 Insects as a hypoallergenic protein source

4.1.4.1 Insects, a new type of protein

Insect based pet foods are not completely new to the market of dog and cat foods. They have been fed to animals that have an allergy instead of more conventional proteins. Cats and dogs can have food allergies, characterized as ‘’all immune-mediated reactions following food intake’’. Non-seasonal skin problems and gastrointestinal issues can be noticed, scratching is a frequently mentioned clinical sign in these cases. There are various diagnostic tests but most of them are inaccurate. The diagnosis can only be made by feeding the animal a hypoallergenic diet or a new protein source for several weeks. It is important that the protein source used is completely new to the patient and that the patient is challenged with the original protein (Verlinden et al., 2007). Insects can be such a new protein source because insects are not a common protein in pet food yet.

A study analysed how 20 dogs with a food allergy responded to commercially available insect protein based diets. This showed that insect based pet food can be an interesting alternative to other hypoallergenic or new protein diets for dogs (Böhm et al.,2018). Cats can also eat insect based pet food if the suffer from food allergy. An aspect to keep in mind in cats specifically is the fact that they can be picky in food. In a study about insect based pet food for cats, it became clear that the insect based food was generally tolerated by most cats, but individual differences were present (Paßlack and Zentek, 2018).

4.1.4.2 Allergy to insects

Pets can also have an allergic reaction to insects. More specifically immunological responses to insect bites are well known. Dogs who are allergic to mites, can also clinically show cross-reactivity with mealworm proteins (Premrov Bajuk et al., 2021). Therefore, although it is still rare, attention should be paid when using insects as a protein source because allergic reactions to it can still occur.

4.2 Sustainability

The Western world was averse to feeding or eating insects for a long time. It is becoming more interested in it because of sustainability. Insects need less food, water and land to produce the same amount of protein when compared to conventional production animals. Insects pollute less, although some species need more energy because of their living standards. Altogether, insects can be part of the solution to the climate crisis and they can help to feed the growing world population in the future. Feeding pets with insect based food will also be more sustainable compared to most current pet foods.

4.2.1 Feed conversion ratio and efficiency

The feed conversion ratio (FCR) is the amount of kg feed needed to obtain one kg of weight gain for the production animal. Thus, a lower feed conversion ratio is positive. With a low FCR less feed is needed and all environmentally negative aspects that come along with this production is reduced. Ending up with the same amount of animal product (Oonincx et al., 2015). Although several influencing factors can change the FCR, a rough average can show interspecies differences. The following FCRs (kg feed/kg live weight) and edible portion (%) can be found for the most commonly used species:

	FCR (kg feed/kg live weight)	**Edible portion (%)**
Poultry	2.5	55
Pork	5	55
Beef	10	40
Crickets	1.7	80

Table 2: FCR and edible portion of different protein sources. *Adapted from: Oonincx, D.G.A.B., Van Broekhoven, S., Van Huis, A., Van Loon, J.J.A., 2015. Feed Conversion, Survival and Development, and Composition of Four Insect Species on Diets Composed of Food By-Products. PLoS ONE 10, DOI:10.1371/journal.pone.0144601.*

Another study shows the FCR of various insects based on different types of food by-products. Depending on the type of food by-products, the following FCRs can be found: Argentinean cockroach: 1.5 – 2.7, BSF: 1.4 – 2.6, yellow mealworm: 3.1 – 19.1, house cricket: 2.3 – 10. As this study is based on a diet of various food by-products, the FCRs could turn out better when fed on the ideal type of feed. These numbers show that insects are an interesting option in general, but one has to closely consider what species and food by-products to use for the lowest FCR possible (Oonincx et al., 2015).

Entomologists often use the efficiency of conversion of ingested food (ECI) as well as FCR. ECI is weight gained / weight of ingested food x 100% (Oonincx et al., 2015). Insects have a good ECI that can even be improved, comparable to conventional livestock. Genetic selection and diet are important factors to reach the highest feed conversion efficiency and ratio possible. But research has shown that the starting level of insect protein efficiency is already higher than that of conventional livestock, even without optimising the influencing factors (Van Huis and Oonincx, 2017).

Insects' low FCR is even more environmentally interesting because they can obtain this FCR even if they are fed on food by-products and waste. Insects can grow on organic side streams, using microbes to make the substrate more fit. Thus, organic waste can become products of value in this way. In conventional livestock, growth rates and efficiencies are determined by the energy content of the feed. But it turns out that this is different for insects as they do not need the energy to maintain a constant body temperature. Protein density and composition are more crucial in insect food (Van Huis and Oonincx, 2017).

High protein diets result in lower FCRs and higher ECIs for most insect species. Thus, as long as organic side streams contain these factors, most insects can be fed by this and still have a good FCR and ECI (Oonincx et al., 2015). By feeding insects with organic side streams, waste can be transformed into high-protein feed for livestock and pets or even food for humans. This also creates a sustainable option for the management of biowaste. Even manure can be used to successfully feed some insect species and turn them into high-protein products. BSF can especially handle this type of feed very well (Van Huis, 2013). The current legislation does not allow this yet, this will be explained in part 4.3.4.

4.2.2 Land and water usage

A rapidly growing world population has to be fed with food from a limited amount of agricultural land. It has been proven that livestock cannot feed the growing world population due to the scarce amount of available land. This also leads to deforestation and an increase in fertiliser use. Currently, 80% of the agricultural land is used for animal grazing or the production of their feed and fodder, even though meat only serves as 15% of the total energy in the global human diet. The production of beef is especially demanding and takes 50 times more land to produce 1kg of beef compared to 1 kg of vegetables. Although some land is not suitable to produce vegetables like marginal lands, which can still be of use when cattle is grazing there (Van Huis and Oonincx, 2017).

When one compares different conventional livestock species to insects as shown in figure 2, it becomes obvious that insects need far less land, feed and water to produce the same amount of live animal weight. Cattle demands over 6 times the amount of square meters of land to produce the same amount of live animal weight. Furthermore, a large amount of the insect is edible, which is only 40% in cattle (Dobermann et al., 2017).

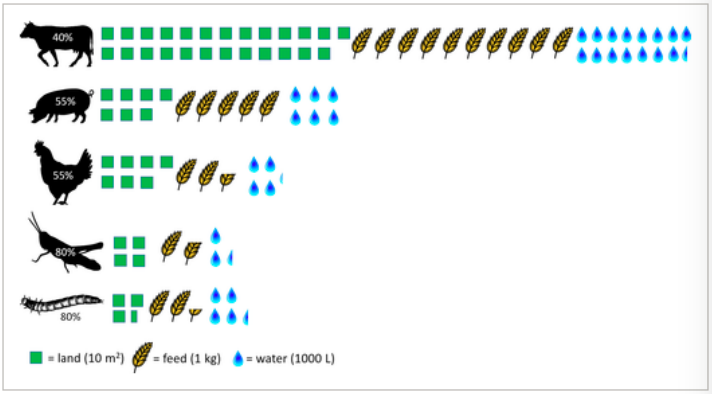


Figure 2: Insect data was estimated based on FCR and calculations about what is necessary for insect feed production. *From: Dobermann, D., Swift, J., Field, L.M., 2017. Opportunities and hurdles of edible insects for food and feed. Nutrition Bulletin 42, 293-308.*

Water will become increasingly scarce due to climate change. Freshwater is a finite resource, it is estimated that 70% of it is used by livestock and agriculture industries. Compared with livestock production, insects perform better when measured per amount of edible product. For instance, researchers found that mealworms within a commercial system have a greater water footprint per ton compared to conventional livestock like pigs and chickens. Nevertheless, taking into account that almost twice as much of an insect is edible, mealworms have a lower water footprint than pigs and chickens (Dobermann et al., 2017). Another study shows that chicken protein needs 50% more water, and beef even 5 times more to produce the same amount of animal protein compared to mealworm (Van Huis and Oonincx, 2017).

4.2.3 Pollution

CO2, other greenhouse gasses and NH3 are known to contribute to climate change, therefore, it is important to know how much of these gasses are produced by edible insects. More details about this can be found in table 3. Compared to pig protein, insects produce far fewer greenhouse gasses. In comparison with ruminants expressed per kg of mass gain, insects only produce 1% of the greenhouse gasses that ruminants produce. A study that compared 5 insect species to currently known animal protein species, also found that there is quite a difference among different edible insect species. CO2 production by insects depends on species, activity level, feeding status, temperature and stage of development. The production of NH3 was also lower in the different insects compared to conventional livestock (Oonincx et al., 2010).

Species	CH_4 (g/kg BM/day)	N_2O (mg/kg BM/day)	CO_2 eq. (g/kg BM/day)	NH_3 (mg/kg BM/day)
Pachnoda marginata (n = 4)	0.16±0.085 [a]	0.0±0.03 [a]	4.00±2.13 [a]	0.1±0.16 [a]
Tenebrio molitor (n = 4)	0.00±0.002 [b]	1.5±0.13 [b]	0.45±0.04 [b]	0.0±0.09 [a]
Blaptica dubia (n = 3)	0.08±0.021 [c]	0.3±0.24 [a]	2.12±0.57 [c]	3.0±1.63 [b]
Acheta domesticus (n = 4)	0.00±0.002 [c]	0.1±0.13 [a]	0.05±0.04 [b]	5.4±3.40 [c]
Locusta migratoria (n = 6)	0.00±0.017 [c]	8.0±13.50 [b]	2.37±4.02 [c]	5.4±1.65 [c]
Pigs	0.049–0.098	2.7–85.6	2.03–27.96	4.8–75
Beef cattle	0.239–0.283	N/A	5.98–7.08	14–170

BM = Body Mass;
N/A = Not Available;
Reported values for pigs and beef cattle were obtained from: [5] Aarnink et al., 1995; [49] Groot Koerkamp et al., 1998; [52] Demmers et al., 2001; [50] Nicks et al., 2003; [59] Beauchemin & McGinn, 2005; [48] Cabaraux et al., 2009 and [53] Harper et al., 2009. Mean values bearing different superscripts in a column differ significantly ($P<0.05$).

Table 3: CH4, N2O, CO2 eq. and NH3 production (average +/- SD) per kilogram of body mass per day for five insect species, pigs and beef cattle*. From: Oonincx, D., van Itterbeek, J., Heetkamp, M.J.W., van den Brand, H., van Loon, J.J.A., van Huis, A., 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. PLoS ONE 5, 10.1371/journal.pone.0014445.t002.*

In general, research shows that insect protein production pollutes less than conventional livestock species. But one has to keep in mind that some species require more energy because of their higher optimal temperature for instance. This can contribute greatly to their need for energy, causing greater greenhouse gas emissions. Keeping the insects at a lower temperature will produce less greenhouse gasses, cause less growth and longer production periods. It can even elicit death in insects which is even worse to produce sustainably. More research on the optimal production system has to be done to find the optimal combination of low pollution and the best growth results (Halloran et al, 2016).

Some insect species can produce large amounts of methane. Termites that are eaten in Africa have methane-producing bacteria in their gut. These methanogenic bacteria species have also been found in the hindgut of other insect species including almost all tropical representatives of cockroaches and scrap beetles. Nonetheless, environmental conditions influence the amount of CH4 that is produced by these bacteria as well. Thus, altering these conditions has the potential to optimize the systems toward less methane production (Halloran et al, 2016).

4.3 Practical aspects

4.3.1 Requirements for farming and processing insects

Currently, less than 10% of all edible insects are specifically raised to be eaten. The big majority is hatched from the wild, as most of them are eaten outside Western countries. There are different approaches to raising insects for consumption by humans or animals. The insects can be fully domesticated and reared in captivity. The second option is to raise them partially in captivity, modifying the habit to increase production. This second option contributes to food security and insect habitat conservation as well, but the first option is more efficient (Baiano, 2020).

It is important to work on a large scale to produce insect protein efficiently. Smaller-scale enterprises can presently mainly be found in developing countries, whereas Western countries try to focus on working on large-scale projects soon. Industrial sized businesses are upcoming for a few years, they are expected to be the main method of edible insect production in the future. Some of the methodology from the small-scale enterprises can remain the same, some aspects have to be modernised and redesigned. It is necessary to have a rearing environment that is suitable for specific species. It is important to include the right water and feed sources, environmental controls including the right temperature, maintenance of hygiene, disease control and a way to monitor and harvest the insects. All of this has to be done in a clean and safe working environment. As insects are interesting because of their sustainability, it is also interesting to focus on environmentally friendly working methods (Berggren et al., 2018).

For large-scale edible insect production, it is important to focus on the following elements (Berggren et al., 2018):

- Automatic feeding, cleaning, sorting and packing technologies.
- It is known that large groups of animals are related to a higher epidemiological risk for pathogens to thrive. Therefore, it is important to have large screening programs. In case a disease is present in the group, a higher number of insects will be affected.
- When restocking, it is necessary to evaluate the insect quality and safety aspects. The restocking will be from breeding lines and no or little wild-caught insects.
- It becomes more important to have a separate breeding and rearing stock.
- Advanced climate control systems are crucial.
- Large amounts of the right feed resources, and the right way of managing the waste that is produced by edible insect production.
- Practical requirements like a large storage, processing and packing facilities.

Over the past years, important improvements have been done in this field. Artificial rearing, better diets and controlled conditions for mass rearing have been developed. There is still room for advancement, in various aspects of the production of edible insects. The ideal insect for industrial production of food and feed would have high egg production and hatching rate, a short larval stage, optimum synchronisation of pupation, high weights of larvae or pupae, a high conversion rate and potential biomass increase per day, low vulnerability towards diseases, ability to live in high densities and high-quality protein content. The Black Soldier Fly meets these expectations, researchers are on a quest for more of such edible insect species. There are still advancements possible in making the process less manual, which is interesting as this makes the product cheaper as well. Ongoing further development of automatizing the process is essential for a more competitive price of edible insects (Dobermann et al., 2017).

4.3.2 Economical aspects

Regarding the threatening food shortages, insects can be seen as an interesting part of this complex puzzle to solve. There is a need for healthy, sustainable and inexpensive food to keep people nourished, as well to sustain the economy of any country (Naseem et al., 2021). The European insect industry is growing fast, the International Platform of Insects as Food and Feed announced that 1 billion US dollars have been invested in it. It is expected that it will be worth approximately 8 billion US dollars by 2030. It is expected that the number of insect producers will grow along with it (Van Huis et al., 2021).

Currently, the price of industrially produced insect protein is still high compared to conventional animal protein sources. Automating the process of farming and processing insects can make it more efficient and cheaper as well. As insect protein is relatively new in Europe, money is also necessary for innovation and research on this topic. This contributes to a more expensive product as well. These factors can change in the future, making insect based products cheaper (Dobermann et al., 2017).

Table 4: The current price of insect based pet food (per kg) and conventional protein based pet food.

Insect based dog food pricing			
Zooplus Greenwoods Insects (*Hermetia illucens*)[5]	Trovet LPD hypoallergenic dog food (insects)[6]	Sanimed intestinal dog (insect based)[7]	BugsForPets (Insect based)[8]
€4,17/kg	€7,04/kg	€5,00/kg	€7,95/kg
Non-insect based dog food pricing			
Lucky dog (ALDI)[9]	Pedigree adult with beef and vegetables[10]	Royal canin medium adult[11]	Edgar & cooper – Free run chicken[12]
€0.63/kg	€1,82/kg	€3,53/kg	€6,78/kg

[5] https://www.zooplus.nl/shop/honden/hondenvoer_droog/greenwoods/greenwoods_insects_dry/1092092?mkt_source=1121238&utm_source=pce&utm_medium=vergelijkbe&utm_content=Droogvoer&utm_term=Greenwoods&product_id=1092092.0&utm_campaign=pce

[6] https://www.pharmapets.be/nl/trovet-ipd-hypoallergenic-hondenvoer-met-insecten-3kg.html?utm_campaign=&utm_content=&utm_source=Vergelijk&utm_medium=CPC&utm_term=[29978-vet_3352960][c743760e-1b6a-4749-9e68-5d9a88dca4ed]

[7] https://www.medpets.be/sanimed+intestinal/?var=6931&gclid=Cj0KCQiAw9qOBhC-ARIsAG-rdn6YLpA8sFqp1p3GB498c5Ipu5Q1A29duB_dEwp8CfjRAO6x2_mIrMYaAv94EALw_wcB

[8] https://www.medpets.be/sanimed+intestinal/?var=6931&gclid=Cj0KCQiAw9qOBhC-ARIsAG-rdn6YLpA8sFqp1p3GB498c5Ipu5Q1A29duB_dEwp8CfjRAO6x2_mIrMYaAv94EALw_wcB

[9] https://www.aldi.be/nl/producten/assortiment/dierenvoeding/hondenvoer/droge-hondenvoeding-4625-1-0.article.html

[10] https://www.maxizoo.be/nl/p/pedigree-adult-met-rundvlees-en-groenten-15kg-1239156003/?utm_source=google&utm_medium=google_shopping&utm_campaign=BE-NL-SmartShopping

[11] https://www.petsplace.be/nl/royal-canin-medium-adult-hondenvoer-m-3182550708197-pps?weight_calc=10587&gclid=CjwKCAiA3L6PBhBvEiwAINlJ9NKIdsur3BgDmglZkTlof-dM0YiShVyLLJW6yCAFmMpe1P9Vdxf6lBoCHqYQAvD_BwE&gclsrc=aw.ds

[12] https://www.edgardcooper.com/products/dog-dry-food-chicken?variant=17682190663745&gclid=CjwKCAiA3L6PBhBvEiwAINlJ9LJVFDj-WaUvhG2mgVePB0L95Uat9kW4N0IgmhZjJdza-xY42nTRNxoCAIMQAvD_BwE

All last consulted on 16-2-22

4.3.3. Animal welfare

The European legislation on animal welfare is currently still focused on the vertebrate animals that are at present the most common farm animal species. EFSA concluded that these regulations should also apply to insects. Currently, the law is based on Brambell's 5 freedoms, namely the following;

1) The freedom from hunger and thirst
2) The freedom from discomfort
3) The freedom from pain, injury, and disease
4) The freedom to express normal behaviour
5) The freedom from fear and distress.

(Baiano, 2020).

Hunger and thirst can be prevented by providing the right amount of nutritious feed. The freedom from discomfort and the possibility to express normal behaviour has to do with suitable rearing densities and crowding. Contradictory to conventional livestock, quite some insect species prefer to be in high densities with kindred. The preferences differ among insect species (FAO, 2013). Points three and five of Brambell's five freedoms are harder to answer when it is about insects.

Little is known about whether insects can experience pain and discomfort. Research that was performed on a fruit fly demonstrated that this insect has the same genes for nociception as mammals. This proves that nociception is the same in at least some of the insect species (FAO, 2013). Nociception can be a response of nerve fibres to something potentially dangerous like pressure, heat, cold or chemicals (Van Huis, 2019). It is still unclear what role the higher nervous system has in this process. It could also be a reflex which does not include the higher nervous system (FAO, 2013).

In insect welfare, a distinction is often made between this process of nociception and pain. Pain is seen as a negative emotion perceived in the higher nervous system, the brain. Experiencing pain is linked to the number of neurons in the brain, but one cannot conclude that the mealworm with only 25000 neurons can feel less pain because of it compared to a human with 16 billion neurons. Because it is proven that insect brains have a very efficient functional organisation, this could help in compensating for their smaller number of neurons (Van Huis, 2019). Based on the current knowledge about this topic, we cannot be certain about insects being able to feel pain or not. Therefore, Eisenmann et al. (1984) proposed to give insects the benefit of the doubt as long as there is no conclusion about this. Thus, as a precaution, the farming and killing methods of insects should be chosen as if they would feel pain even though this is not proven yet. This way of thinking is still adapted to this day as there is no indisputable evidence about it thus far. The same goes for whether insects are sentient or not, people assume they are as long as we cannot rule out that they are not.

In the developing world where entomophagy is more common, animal welfare is less of a priority. Insects are sometimes eaten alive, boiled, fried or roasted. In the Western world, entomophagy is relatively new, and research has to be done to conclude what is the best way to humanely kill insects (Van Huis, 2019). Currently, the FAO (2013) recommends freezing or instantaneous techniques like shredding the insects as the most humane killing methods for edible insects. Shredding has the advantage that the insects are turned into an unrecognizable state, which most consumers prefer. Another technique that is applied in the Western world is dry-freezing, where freezing is combined with reduced pressure to extract the water from the insects.

4.3.4 Legislation in Europe

Edible insects are not a type of food regularly eaten by inhabitants of Europe before 15 May 1997, therefore it is categorised as a 'Novel food'. These novel foods follow the 'novel food legislation'. The European Union follows a precautionary approach to novel foods, this means these novel foods require pre-market approval before they can legally be sold in European countries (Lähteenmäki-Uutelaa et al., 2021). Currently, dried, frozen and powder yellow mealworm (*Tenebrio molitor*)[13], dried and frozen migratory locust (*Locusta migratoria*)[14] and dried, frozen and ground house cricket (*Acheta domesticus*)[15] are authorized.

Insects can be food for humans but also feed for farm animals or pets. A recent regulation from 2017 made it possible to use proteins from seven insect species including BSF to be used in feed for aquaculture animals (Lievens et al., 2021). Since September 2021, it is approved to feed insect protein to pigs and poultry.[16] European dogs and cats can be fed with insect-derived protein when it is from BSF, house crickets or yellow mealworms. Insect based pet food is the only type of feed where it is allowed to feed complete insects, it is not authorized in aquaculture, pig or poultry feed.[17]

It is prohibited to feed farmed animals, including insects in case of this law, with animal by-products such as slaughterhouse products, manure or waste streams in Europe. Nevertheless, several edible insect species could thrive on these sustainable types of possible feed. The feed of insects has to stay under the maximum level of several compounds to be allowed. Researchers show that at least some species can stay under these imposed safety standards as feed ingredients, even if they would have been reared in organic waste streams. More research has to be done to be able to tell more about other species (Lievens et al., 2021). This legislation is still under discussion and might change in the future.

[13] https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX%3A32022R0169&qid=1645193137950 Last consulted on 22-5-22
[14] https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX%3A32021R1975&qid=1645193220709 Last consulted on 22-5-22
[15] https://eur-lex.europa.eu/legal-content/NL/TXT/?uri=CELEX%3A32022R0188&qid=1644941138441 Last consulted on 22-5-22
[16] https://ipiff.org/insects-eu-legislation/ Last consulted on 22-5-22
[17] https://www.nweurope.eu/media/11080/policy-brief-eu-legislation-on-insects-as-food-and-feed-2.pdf Last consulted on 22-5-22

4.4 The opinion of pet owners

4.4.1 Entomophagy

Entomophagy is a long- accepted habit in many ethnic groups in Africa, Asia, South America, Mexico and other non-Western countries around the world (Naseem et al., 2020). The potential to help in feeding the world and the fact that insects are more sustainable than conventional protein sources are the main reasons that the Western world is thinking of entomophagy. Most inhabitants are not used to eating insects yet. In the Western world, people have associated insects with a sense of dirtiness, disgust and danger for a long time (Looy et al., 2014). another survey among Western consumers presented that only 20% of the meat eaters think he/she is ready for entomophagy (Verbeke, 2015).

This is slowly starting to change towards a situation where some people are willing to try entomophagy. A study among Belgian consumers showed that 77.7% of them were willing to eat insects. After they had tried the insect based dish, adults were more willing to eat insects in the future (Caparros Megido, 2014). A study among Dutch and Australian consumers also showed some potential for entomophagy. The researchers asked the participants to fill in a survey on this topic before and after eating insects. Before consumers had eaten insects, they were neutral about entomophagy. After they had eaten the insects, they were slightly but significantly more positive about it. This study also showed that people might not yet be aware of the advantages of insects as food, this creates possibilities for the promotion of entomophagy (Lensvelt and Steenbakkers, 2014).

These studies also showed that people do not know a lot about entomophagy in general. Most participants did not see any risks in entomophagy, but some were still hesitant because they felt like insects are unhygienic and that insects might carry bacteria or diseases (Lensvelt and Steenbakkers, 2014). Conclusively, one could summarize that the conclusion of studies on the readiness of Western consumers to do entomophagy is quite divergent.

4.4.2 Feeding insect based pet food

The amount of research that has been conducted on the perspective of pet owners on feeding their pet insect based pet food, is scarce. A South Korean study on this topic shows that 55.6% of the pet owners visiting a pet hospital in South Korea had heard of insect based pet food before. Almost half of the respondents had the intention to buy insect based pet food for their pets, the other half did not. The positive aspects that potential buyers mainly thought of were the good nutritional value and low allergenicity of insects. On the other hand, the pet owners that declined to buy it felt a strong aversion which was their main reason for not buying it (Bae et al., 2020). Entomophagy is more accepted in South Korea, therefore the results cannot display the perspective of Western pet owners accurately.

A Belgian study among farmers, stakeholders and citizens focussed mainly on insects in farm animal food. These researchers also questioned the attitude towards insects in pet food. It turns out the participants relatively preferred insects in feed for fish, poultry and pigs, rather than insects in pet food. There was a significant difference among the groups of participants, as stakeholders were more positive about insects in pet food compared to farmers (Verbeke et al., 2015). Another study from Belgium about insects in non-food implementations showed that interviewees are quite positive about insects in pet food. 56 out of 63 thought of it as something good. The participants that were not positive about it, thought of it as disgusting, impure and a risk to health (Lenaerts et al., 2019).

A study about the perspective of specifically Belgian and Dutch pet owners on feeding their dog and/or cat an insect based pet food has not been implemented yet.

4.4.3 Influencing factors on entomophagy in humans

Despite the negative associations with insects, part of the Western world is slowly starting to accept entomophagy. Various factors can influence the willingness of people who are still reluctant toward entomophagy. Researchers summed up seven influencing factors found in literature studies, of which price and quality turned out to be the most important ones to their Dutch and Australian participants. Other influencing factors were the benefits (which consumers often do not know much about), risks, naturalness, trust, attitude and culture. Insects are seen as a natural food by participants (Lensvelt and Steenbakkers, 2014).

Information about entomophagy is seen as trustworthy when it comes from scientific researchers, other consumers talking about their own experiences, the government and well-known relatives. It could be interesting to stimulate entomophagy by sharing more information about the advantages of insects, because most people still know little about it. More knowledge about entomophagy or being familiar with the concept has a positive influence on the willingness to eat insects (Tan et al., 2015; Verbeke, 2015; Woolf et al., 2019). A positive experience with eating insects is also beneficial to stimulating entomophagy. After such encounters with insects, people are more willing to eat insects again (Lensvelt and Steenbakkers, 2014; Woolf et al., 2019; Wendin and Nyberg, 2021). Those who have experienced eating processed insects, are more ready to eat unprocessed insects as well afterwards. A study concludes that processed foods may play a role for the acceptance of insect based products in the daily diet (Hartmann and Siegrist, 2016).

Some consumers are more ready than others for insects as a protein source among Western people. A study concludes that 20% of the meat consumers are ready for entomophagy. From the group of meat eaters, those who believe meat is healthy or focus on the taste of meat are less willing to eat insects. More ready to adopt insects as a protein source were those who planned to reduce their meat intake. This group is 4,51 times more willing toward entomophagy. This study also showed that male consumers are 2,17 times more open to eat insects compared to female consumers (Verbeke, 2015). Another study concludes that this is because of taste reasons (Tuccilo et al., 2020). The effect of food (technology) neophobia and the effect of familiarity are again confirmed (Verbeke, 2015).

Insects can be eaten as a whole or unrecognizably mixed into other dishes or products. A study showed that consumers also seemed to be willing to try insects as a whole. After actually doing this as a part of the study, they were generally positive about the texture of the insect (Lensvelt and Steenbakkers, 2014). Other studies concluded differently, noticing that consumers preferred unrecognizable insects over recognizable ones (Schösler et al., 2012; Elzerman et al., 2013; Cicatiello et al., 2016,). This was also shown in another study, as well as the fact that consumers prefer to buy insect based products that are available in the market, familiar to them and similar to their conventional counterparts (Lombardi et al., 2019).

The willingness to try insect based products also depends on the type of product. It turns out consumers are more willing to eat insect based pasta than insect based cookies. Researchers suggest that this might be because people do not want to risk a bad taste when they are specifically looking for a hedonic food like cookies. This may also be because insects are generally seen as a protein substitute, which makes sweet preparations inappropriate (Shelomi, 2015; Tan et al., 2015).

5. Research

5.1 Problem statement

Insects can be an interesting protein source in pet food, but little is known about the current opinion of Belgian and Dutch dog and/or cat owners on their willingness to buy and feed their pet insect based pet food.

5.2 Objective

The objective of this research is to gain insight into Belgian and Dutch dog and/or cat owners' opinions on insect based pet food. As well as whether the opinion is influenced by factors such as knowledge or experience with entomophagy, how worried pet owners are about climate change, their diet and more. This research will also analyse whether it can be linked to a certain profile.

5.3 Hypothesis

The hypothesis of this study is that pet owners are still a bit reticent about insect based pet food. This hypothesis is based on limited research that has been completed on this topic, in other Western countries (Caparros Megido et al., 2014; Lensvelt et al., 2014; Verbeke et al., 2015; Cicatiello et al., 2016; Kostecka et al., 2017).

5.4 Materials and methods

5.4.1 Survey

To gain insight into the opinion of Belgian and Dutch pet owners on insect based pet food, a survey (Microsoft office 365) has been developed in Microsoft Forms. To promote a high number of responses, the survey was conducted in Dutch to cover the Netherlands and Dutch-speaking Belgians. The questionnaire can be found in the appendix. The online surveys were sent out in two rounds. The first round was aired officially on October 7th and received the maximum of 200 answers within less than 24 hours. Because of this, a second round was started on the 28th of October. Again the maximum of 200 respondents was reached soon (November 2nd). The questionnaire was spread through social media; mostly Belgian and Dutch Facebook groups focussing on pets, as well as a group for veterinarians and students related to Ghent University, the authors' network and LinkedIn. Pet owners were motivated to answer the survey, by giving away one free nutritional advice by the nutrition team of Ghent University.

The questionnaire contains a total of 40 questions. First, all participants had to answer general questions about themselves. Personal information, their diet, grocery shopping, point of view on climate change and knowledge and experience in eating insects. Then all dog owners got a list of questions starting with information about the dog, the current diet of the dog(s) and questions about feeding insect based dog food or snacks. After that, all cat owners received the same type of questions about their cat(s). It was possible for people with dogs and cats to only answer this list of questions about dogs and answer that their opinion was not different about cats. Or in case they did have another opinion, they could also check that they were not willing to explain any further about it. This was done to prevent participants from dropping out halfway.

Of all 40 questions, 24 questions were multiple choice with one option, 13 questions were multiple choice with more than 1 option and 3 questions were open. A Likert scale was used in 9 questions. Microsoft Forms enables the option to make answering questions obligatory to finish the survey. Thus, it was not necessary to exclude incomplete surveys afterwards. Due to privacy reasons, respondents were not bound to fill in their mail addresses. This was only necessary in case they would like to win the prize, wanted to know the results of this study or participate in another one. In some multiple choice questions, owners could fill in their own answers as well.

5.4.2 Statistical analysis

In this statistical analysis, participants had to be an inhabitant of Belgium or The Netherlands and owner of a dog and/or cat at the moment of answering the survey. For the statistics, SPSS (IBM) version 27 was used. Comparing 2 non-parametric groups including one numerical variable and one categorical or 2 catagorical variables combined, the Man U Whitney test was used. To compare more than 2 groups, non-parametric data were compared with the Kruskal Wallis test and posthoc testing. In the posthoc testing an adjusted standardized residual to a p-value was conducted to compare it to the Bonferroni p-value to know whether a result was significant or not. Most of the data in the current study were categorical and non-parametric.

5.5 Results

5.5.1 Respondent population

Four hundred Belgian and Dutch participants answered the survey completely. Forty-one of them were male (10,25%), 358 female (89,5%) and 1 person was identified as 'other' (0,25%). One hundred fifty-five respondents were under 30 years old (38,75%), 129 were between 30 and 50 years old (32,25%), 116 participants were 50+ years old (29%). Out of all respondents, 274 did not have a link to veterinary medicine apart from being a pet owner (68,5%) and 126 did (31,5%). The respondent population is presented in pie charts in figure 3.

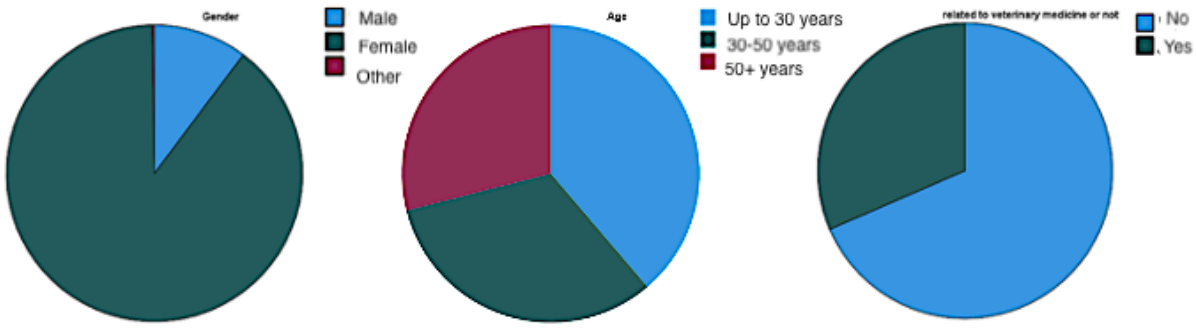
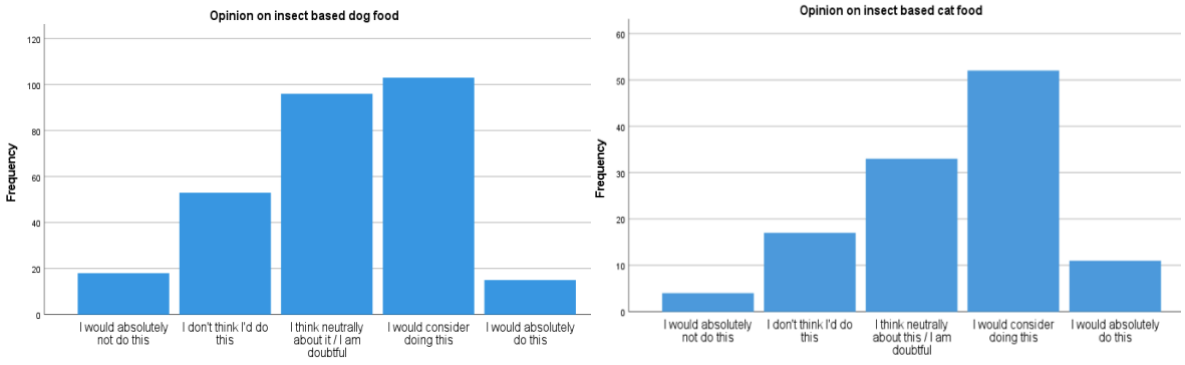


Figure 3: SPSS27 Respondent description.

5.5.2 Willingness to feed insect based pet food and snacks

Concerning the question about the opinion of feeding insect based food to dogs and cats, most people answered "I would consider doing this", 36,14% and 44,44% for dogs and cats respectively. More details about the answers to these questions can be found in figures 4 to 7.



Figures 4 and 5: SPSS27 data on pet owners' opinion on insect based pet food dogs versus cats.

Opinion on insect based dog food					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I would absolutely not do this	18	4,5	6,3	6,3
	I don't think I'd do this	53	13,2	18,6	24,9
	I am neutral about this	96	23,9	33,7	58,6
	I would consider doing this	103	25,7	36,1	94,7
	I would absolutely do this	15	3,7	5,3	100,0
	Total	285	71,1	100,0	
Missing	System	116	28,9		
Total		401	100,0		

Figure 6: SPSS27 data: The willingness to feed insect based dog food.

Opinion on insect based cat food					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I would absolutely not do this	4	1,0	3,4	3,4
	I don't think I'd do this	17	4,2	14,5	17,9
	I am neutral about this	33	8,2	28,2	46,2
	I would consider doing this	52	13,0	44,4	90,6
	I would absolutely do this	11	2,7	9,4	100,0
	Total	117	29,2	100,0	
Missing	System	284	70,8		
Total		401	100,0		

Figure 7: SPSS27 data: The willingness to feed insect based cat food.

Comparing these answers to those for respondents' opinion on 50/50 insect based protein combined with conventional protein, pet owners were more prone to feed the 50/50 type of insect based food. The mean of feeding insect based dog food was 3,15/5, the mean of feeding 50/50 insect/conventional protein dog food was 3,45/5. The mean of feeding insect based cat food was 3,42/5, whereas feeding 50/50 insect/conventional protein was slightly higher with 3,64/5.

The survey also questioned the participants about their opinion on pet snacks based on insect protein. Details of the results can be found in figure 8 and 9. Approximately 2/3rd of both, dog (67,0%) and cat (69,2%) owners, answered yes to feeding insect based snacks. When asked for conditions to this answer, the most important factor was whether the participants' pet liked the taste (33,3%). The second and third terms that were noticed were the price of the product (not more expensive than other pet snacks) (21,6%) and owners preferred the insects in an unrecognizable state (10%). Out of all pet owners, 48,6% preferred non-recognizable insects over recognizable ones in pet food. For 49,3% of the pet owners it did not influence their opinion. Only 8 out of 400 respondents preferred recognizable insects (2%).

Opinion on insect based dog snacks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	13	3,2	4,7	4,7
	Doubtful	67	16,7	24,3	29,0
	Yes	185	46,1	67,0	96,0
	Only when.. (see next question)	11	2,7	4,0	100,0
	Total	276	68,8	100,0	
Missing	System	125	31,2		
Total		401	100,0		

Figure 8: SPSS27 data: The willingness to feed insect based dog snacks.

Opinion on insect based cat snacks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	8	2,0	6,8	6,8
	Doubtful	17	4,2	14,5	21,4
	Yes	81	20,2	69,2	90,6
	Only when.. (See next question)	11	2,7	9,4	100,0
	Total	117	29,2	100,0	
Missing	System	284	70,8		
Total		401	100,0		

Figure 9: SPS27 data: The willingness to feed insect based cat snacks.

5.5.3 Advantages and disadvantages from the owner perspective

A question about the advantages that owners linked to insect based pet food, showed the following results; first: More sustainable (56,3%); second: Friendlier towards the production animal (insects instead of conventional livestock) (39,5%); third: I do not know about advantages of insect based pet food (18,5%). Less answered options were: 'I can't think of any advantages', 'More natural', 'I think my pet likes it' and 'Healthier'. Participants were asked about disadvantages about insect based pet food they could think of as well. The first disadvantage: It is too expensive (34,5%); the second: It is too unfamiliar (31,8%); third: I do not know about disadvantages of insect based pet food (17,8%). Other options were: 'I think my pet does not like the taste', 'Less healthy compared to conventional protein sources', 'I think it is nasty', 'Not natural', 'I do not see any disadvantages', 'Potentially dangerous for my pet' and 'Less animal friendly towards the production animal'.

5.5.4 Influencing factors on the willingness to feed insect based food

Respondents gave themselves a grade from 1-7 for their knowledge of humans eating insects. 1 is no knowledge, 7 is expert level. When comparing these with the willingness to feed insect based dog food, there was a significant link ($p < 0,01$) that went both ways. Participants that claimed to have less knowledge (2/7), are significantly less prone to feed insect based pet food. Those who said they have a lot of knowledge (6/7) of this topic, answered that they would absolutely feed insect based dog food significantly more often. When comparing the score on knowledge with the willingness to feed insect based cat food, there was not a significant link. Details can be found in figure 10.

Respondents also had to answer the same type of question about their knowledge of pets eating insect based pet food. There is again a significant link between more knowledge about insect based pet foods and willingness to feed insect based dog food ($p < 0,01$). But in this case the link between less knowledge and being less willing to consider insect based pet food did not exist. In cats there was again no significant link ($p = 0,810$).

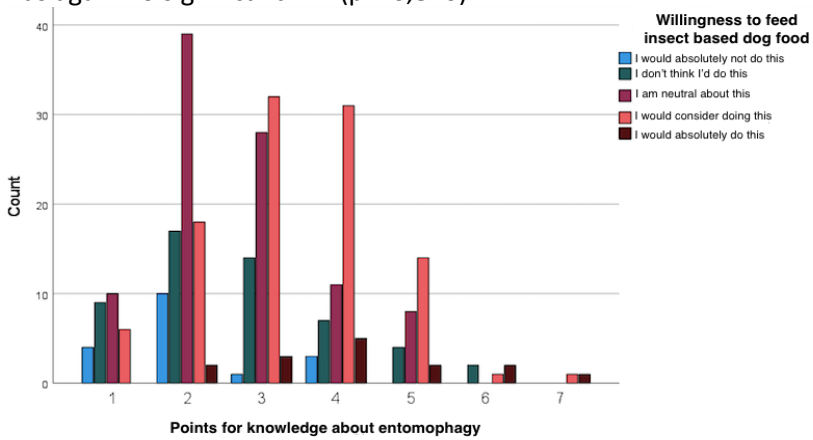


Figure 10: SPSS data: Relationship between knowledge about entomophagy and feeding insect based dog food.

There was no significant relationship between the experience of eating insects and feeding insects to a cat (p = 0,794) nor dog (p = 0,398). Respondents that did not like the taste of insect based food, were significantly less willing to feed insect based dog food or cat food (dog: p = 0,025; cat: p = 0,035). This link was not significant the other way around; when participants liked the taste of insects themselves, they were not always prone to feed insects to their pets.

When questions related to climate change were asked, respondents that were worried turned out to be significantly more open to feeding insect based dog (p <0.01) and also more ,although not significantly, insect based cat food (p = 0,037>0,002)*. Those who filled in that they are willing to take action against climate change were also more willing to feed insect based dog (p<0,01) food, but not cat food (p = 0,213). Dog owners who were not willing to take action were also significantly less willing to feed insect based dog food (p<0.01). This was not the case for cat owners (p = 0,213). The results of the combination of these questions is shown in figure 11.

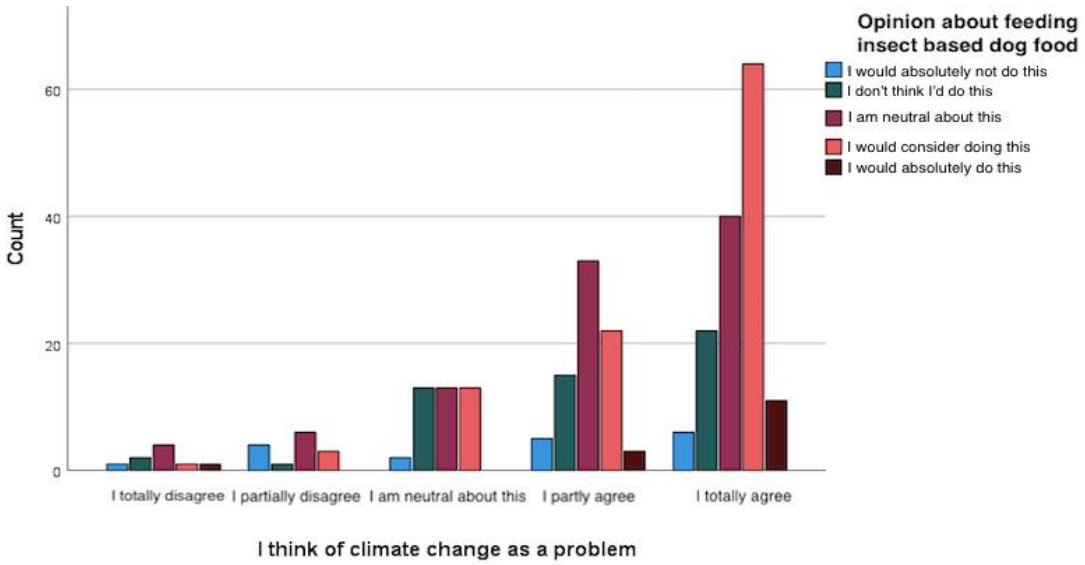


Figure 11: SPSS 27 data: Relationship between thinking of climate change as a problem and feeding dogs insect based pet food.

Those who considered climate impact when grocery shopping or in their diet, were not more prone to feed insect based pet food. There was no influence on the different ways of sustainable grocery shopping such as shopping for local products (Dog owner: p=0,234; cat owner: p=0,295) or focussing on sustainable groceries (Dog owner: p = 0,421; cat owner: p = 0,136). There was no influence in consuming a vegan (Dog owner: p = 0,643; cat owner: p = 0,457), vegetarian (Dog owner: p=0,025*; cat owner: p = 0,429), pescatarian (Dog owner: p = 0,006*;cat owner: p = 0,056) or flexitarian diet (Dog owner: p = 0,35; cat owner: p = 0,464) either.

Participants that were not into feeding insect based dog food already, would not pay more for this type of dog food (p<0.001). Those who were willing to feed insect based dog food were more ready to pay more for it as well. This was not the same for cats (p = 1,08). See figure 12 and 13.

*Some P-values are under 0,05 and still not significant because it has to be under the adjusted p-value. This comparison to the Bonferroni p-value is part of posthoc testing after a Mann U Whitney test in cross tabs, SPSS 27.

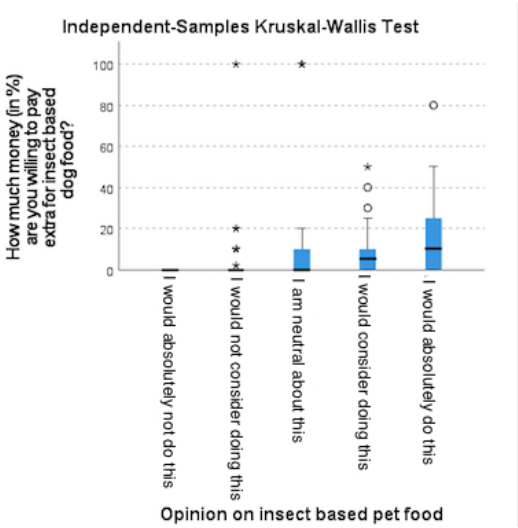


Figure 12: SPSS data: The amount people are willing To pay extra. Combined with the opinion on insect Based dog food.

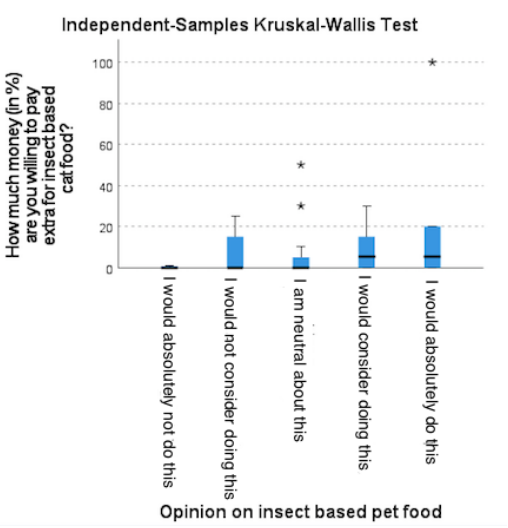


Figure 13: SPSS data: The amount people are willing to pay extra, combined with the opinion on insect Based cat food.

A combination of different respondent descriptives did also have an influence. Female veterinarians are more willing to feed insect based dog food (p = 0,003), not cat food (p = 0,144). Male veterinarians and non-veterinary related pet owners did not. See figure 14 for details.

Opinion on insect based pet food x Relation to veterinary medicine (male/female)

			related to veterinary medicine or not					
			No		Yes		Total	
Gender			N	%	N	%	N	%
Male	Opinion on feeding insect based dog food	I would absolutely not do this	2	8,7%	0	0,0%	2	7,1%
		I don't think I'd do this	2	8,7%	3	60,0%	5	17,9%
		I am neutral about this	8	34,8%	1	20,0%	9	32,1%
		I would consider doing this	8	34,8%	1	20,0%	9	32,1%
		I would absolutely do this	3	13,0%	0	0,0%	3	10,7%
	Total		23	100,0%	5	100,0%	28	100,0%
Female	Opinion on feeding insect based dog food	I would absolutely not do this	15	8,1%	1	1,4%	16	6,2%
		I don't think I'd do this	36	19,4%	12	16,9%	48	18,7%
		I am neutral about this	70	37,6%	17	23,9%	87	33,9%
		I would consider doing this	60	32,3%	34	47,9%	94	36,6%
		I would absolutely do this	5	2,7%	7	9,9%	12	4,7%
	Total		186	100,0%	71	100,0%	257	100,0%

Figure 14: SPSS data: The opinion on insect based pet food combined with the relationship to veterinary medicine and gender.

5.6 Discussion

5.6.1 Hypothesis

Based on research that has been conducted on this topic in other Western countries (Caparros Megido et al., 2014; Lensvelt et al., 2014; Verbeke et al., 2015; Cicatiello et al., 2016; Kostecka et al., 2017), it was expected that pet owners are still a bit reticent about insect based pet food. The outcomes of these studies varied between them, but the data from the current study aligned with the general conclusion. Forty-one% and 54% of the participating dog and cat owners respectively, would consider buying it or were even convinced of doing this already. The remaining participants were neutral about it or not willing to feed insect based pet food. These results showed that there is indeed still some restraint towards insect based pet food, but around half of the participants were open to feeding insect based pet food.

5.6.2 Respondent population

One of the main achievements in the current study was the high number of questionnaires that were evaluated (n=400). This allowed to gain a trustworthy insight into pet owners' perspectives on insect based pet food. Remarkably, only 10% of the respondents were male. This could partly be explained because of the authors' living environment and community. The large majority of the veterinary medicine students and an increasing amount of the graduated veterinarians are females (van Cleven et al., 2017). When the relation between the willingness of feeding insect-based dog food and the respondent profile was evaluated, female veterinarians, but not male veterinarians or non-veterinary related owners, was statistically significant (p=0,003). Therefore it was not expected that this ratio would make the results less trustworthy. On the other hand, another study concludes that males are over 2 times more likely to accept eating insects than females (Verbeke, 2015).

The representation of the different age groups was circa equivalent. The group of participants under 30 years old was the biggest, this could also be explained because of the authors' living environment and community. This also clarified the ratio of those related to veterinary medicine versus those who are not, 31,5% respectively 68,5%. There was no significant difference between their points of view.

5.6.3 Influencing factors

Several factors can influence the opinion of pet owners on feeding insect based pet foods. Other studies about insect based pet food or human food presented several of them, these are described in part 4.4. These studies found relations to the price, quality, (knowledge of) the benefits, risks, naturalness, trust, attitude, culture, having experience or being familiar with eating insects, how the experience was, knowledge about entomophagy, the form, the product the insects are in, gender, thoughts about meat, whether they are considering to reduce meat intake and neophobia of food technology. This current study contained questions to gain more insight into the influence of the forms of the insect, knowledge about entomophagy in humans and pets, having the experience of entomophagy and how participants felt about it, how worried the participant is about climate change, the costs, gender, age, link to veterinary medicine, the % of insect protein and whether the insect is recognizable or not.

5.6.3.1 The form

Approximately half of the participants would (consider) feeding insect based pet food to their pet(s). Participants were also asked about feeding insect based snacks, they were generally more willing to feed insect based snacks compared to food. This difference might have had to do with the idea that snacks do not have to contribute to the nutritional needs. A study about the willingness to pay for insect based human food concluded that people are more willing to pay for staple foods that are based on insects compared to hedonic foods (Lombardi et al., 2019). Snacks for dogs and cats could be comparable to hedonic foods for humans from an owner's perspective. Another theory is that insect based snacks could be combined with regular animal protein food, which makes the share of insect protein in the diet smaller. The fact that more pet owners were willing to give 50% animal protein 50% insect protein pet food compared to 100% insect protein pet food, supports this theory.

5.6.3.2 Knowledge and experience with eating insects

The results of this present study showed that there is a significant link between the knowledge degree about entomophagy and the willingness to feed insect based dog food. Other studies about the link with knowledge of entomophagy and being familiar with its concept, concluded the same (Tan et al., 2015; Verbeke, 2015). This link was not significant for insect based cat food. Neither link between knowledge about pets eating insects.

Other studies concluded that the experience of entomophagy will encourage a positive attitude towards entomophagy (Lensvelt and Steenbakkers, 2014; Woolf et al., 2019). The results of the present study did not correspond with these findings. In the present study, only those who have had a negative experience with entomophagy, were less willing to feed insect based dog food. The link between the experience of entomophagy and a positive attitude was not significant. However, the p-value of this link was relatively close to being significant in the current study. Another cause that could have influenced the different conclusion might be because it is about feeding pets now. Or another possibility is, that the difference is because the respondents of the other studies were from Australia and the United States. The study with participants from the United States also had a small sample size that could have influenced the outcome (Woolf et al., 2019).

5.6.3.3 Concerns about climate change

Pet owners who are more worried about climate change were also more willing to feed insect based dog food. This is not significant for cat food but there seems to be a trend. Dog owners who intended to take climate action were also more open to feeding insect based dog food. Again, the same trend was seen for cats but it was not significant. Other studies on the link between worries about climate change and entomophagy in humans found that the sustainability of insects can be an important factor for the acceptance. These researchers also concluded that the sustainability is not the most critical factor (Wendin and Nyberg, 2021). Another study found a significant relationship between trying to eat less meat and willingness to eat insects (Verbeke, 2015). Another study found that consumers who have more knowledge about the benefits of entomophagy, are more willing to implement it in their life (Tan et al., 2015; Verbeke, 2015). The relationship might even be stronger when knowledge of the benefits of insect based pet food for the climate would also be considered.

Owners who followed a diet that takes the effects on the climate into consideration were not significantly more open to insect based pet food. These more sustainable diets include vegetarian, vegan, pescatarian or flexitarian diets. Another study aligning with this topic concluded differently; those who plan to reduce their meat consumption, are over 4,5 times more likely to do entomophagy (Verbeke, 2015). This is of course not the same as feeding insects to a pet, but based on this result one could expect a more significant link. Some of the diet preferences were close to

being significant, especially consumers following the pescatarian diet. This could also partly explain the outcome. Also, consumers can have different reasons apart from sustainability to follow these more sustainable diets.

5.6.3.4 The financial aspects

Participants that were more into feeding insect based dog food, were also more willing to pay more for it. This is the same the other way around, those who were not into it were also significantly less into paying extra for it. This influence of the financial aspect was also found in another study that was evaluating the influence of the price on Dutch and Australian consumers performing entomophagy (Lensvelt and Steenbakkers, 2014). This influence was again not significant in cats both ways.

5.6.3.5 Female veterinarians

The results showed that female veterinarians were more open to feeding insect based dog food compared to the other groups. This was not observed in feeding insect based cat food. There is no clear explanation for this result. A possible explanation for the difference in male versus female veterinarians is that the group of male veterinarians in the respondent population was small, making it less trustworthy. The difference between females with a link to veterinary medicine and those who do not, might be found in the fact that knowledge of entomophagy has a significant influence. The amount of theory about this topic is limited in veterinary medicine, yet general knowledge about animal nutrition and physiology could also influence the perspective.

5.6.4 Validity of the research

The internal validity of this present study can be seen as moderate. A questionnaire was used, therefore making it dependent of the answers of random participants. complete surveys of 40 questions were used. But pet owners may have exaggerated some of their perspectives and answers. Or the other way around, where they could have downplayed their views. This survey was among other channels, spread through social media. This can make it less valid because some categories of respondents may be underrepresented like the elderly.

The survey was also shared in breed-specific Facebook groups, which lead to a great number of respondents but might also have influenced the trend of the received answers. Another possible influencing factor is that the authors' community contains relatively more veterinarians and females. This respondent ratio can also influence the outcome of this research, although the result did not show this specifically. The survey received 400 complete answers, this could be considered a high enough number of participants. This leads to a good external validity. Albeit, more respondents would make it even better.

5.6.5 Limitations of this study

More possible influencing factors on the willingness to feed insect based pet food could have been explored in case there would have been more questions added. However, the survey already contains 40 questions for pet owners with dogs and cats. Adding more questions might lead to fewer or incomplete results or maybe less considered answers. One question that could have been interesting to add is how people think about entomophagy for themselves instead of their pet(s). This would make existing data more useful to compare. Owners that have a dog and a cat, only had to answer the questions for their dog. It was decided that it was possible for these owners to not answer the same question for their cat as well except when voluntarily. This way of working was chosen to prevent participants from quitting halfway leading to fewer responses. The consequence of this choice is that there are less answers for cats. Which made it more difficult to find statistical

significance. Financial limitations were present as the survey programme only allowed 200 responses for free. After that it was necessary to pay to receive more. It was possible to reach 400 participants without payment because the complete survey was written again to gain another 200 responses.

5.6.6 Suggestions for the follow-up of this study

In case of a follow-up, the author would recommend trying to gain even more responses. The questionnaire that was used for this study was a good basis, but the question described in 5.5.5 about entomophagy could add more value to the dataset. The knowledge about insect based pet food is growing fast. By the time a follow-up study would be conducted, there might be even more interesting topics to add to the survey. Other studies showed that the perspective on entomophagy can change when people have had the experience . It would be interesting if this could also be conducted in pet food.

5.6.7 Conclusion

Forty-one% and 54% of the participating dog respectively cat owners would consider buying insect based pet food or were even convinced to buy it already. The latter group was neutral (about 1/3rd) or not (+/- 1/6 in cat owners, ¼ in dog owners) willing to feed insect based pet food. Several factors such as more or less knowledge of insect based pet food, a negative experience with it, the level of worrying about and action against climate change and the respondent profile of female veterinarian showed an influence in the willingness of offering insect based pet food. In conclusion, several factors play a role in the inclusion of insects in a pet diet and more actions should be taken to sensitive or introduce this alternative in the near future.

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5.8 Appendix

Survey on insect based pet food (Dutch)

1) Wat is uw leeftijd?
    a. Onder de 30 jaar
    b. 30-50 jaar
    c. 50+ jaar
2) Wat is uw geslacht?
    a. Man
    b. Vrouw
    c. Anders
3) Heeft u een link met de diergeneeskunde anders dan huisdiereneigenaar? (Bijv. Dierenarts(assistent), student diergeneeskunde,…)
    a. Ja
    b. Nee
4) Kies maximaal 4 van de onderstaande zaken die u het meest belangrijk vindt wanneer u voeding koopt voor uzelf (en uw gezin);
    a. Of het gezond is
    b. De prijs van de voeding
    c. De smaak
    d. De duurzaamheid van de voeding
    e. Of het biologisch is
    f. Of het lokaal geproduceerd is
    g. Of er niet te veel suikers in zitten
    h. Of het vetarm is
    i. Of er niet te veel calorieën in zitten
    j. Of er niet te veel bewaarmiddelen in zitten
    k. Of het vers is
    l. De nutriscore op de verpakking
    m. Anders,..
5) Volgt u zelf een specifiek dieet?
    a. Nee
    b. Ik probeer gewicht te verliezen en pas mijn dieet daar op aan
    c. Vegetarisch
    d. Veganistisch
    e. Flexitarisch (minimum 1dag per week geen vlees of vis)
    f. *Pescotarisch (geen vlees, wel vis)*
    g. *Low carb/Atkins/ketogeen dieet*
    h. *Gluten vrij dieet*
    i. Anders,..
6) In hoeverre bent u het eens met de volgende stelling: ‘Ik zie klimaatverandering als een probleem’?
    a. Helemaal mee oneens
    b. Beetje mee oneens
    c. Neutraal
    d. Beetje mee eens
    e. Helemaal mee eens
7) In hoeverre probeert u uw acties en keuzes op het gebied van voeding aan te passen om het klimaat te sparen?
    a. Helemaal niet

b. Een heel klein beetje
c. Een beetje
d. Redelijk veel
e. Zo veel als mogelijk

8) Geef een punt voor uw kennis over het eten van insecten (door mensen) op een schaal van 1 (nooit van gehoord) tot 7 (als u denkt hier alles van te weten)
   a. 1 *(Vertakking naar vraag 10)*
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
9) Heeft u ooit een product met insecten erin gegeten?
   a. Nee *(Vertakking naar vraag 11)*
   b. Ja, eens of enkele keren in mijn leven
   c. Ja, gemiddeld meer dan 2 keer per jaar
10) Hoe vond u het product met insecten erin?
   a. Helemaal niet smakelijk
   b. Redelijk onsmakelijk
   c. Matig smakelijk
   d. Redelijk smakelijk
   e. Heel smakelijk
11) Geef een punt voor uw kennis over het voeren van insect gebaseerde voeding aan huisdieren op een schaal van 1 (nooit van gehoord) tot 7 (u denkt hier alles van te weten)
   a. 1 *(Vertakking naar vraag 13)*
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7
12) Waar heeft u opgevangen dat insect gebaseerde honden- en kattenvoeding bestaat?
   a. Sociale media
   b. TV of radio
   c. Boek/tijdschrift
   d. Andere mensen hebben mij erover verteld
   e. Een reclame
   f. Mijn dierenarts
   g. Fokker, dierenspeciaalzaak of andere professional
   h. School
   i. Ik weet het niet of kan het mij niet meer herinneren
   j. Anders,..
13) Hoe veel honden heeft u?
   a. Geen *(Vertakking naar vraag 25)*
   b. 1 hond
   c. 2 honden
   d. 3 of meer honden
14) Wat is het voornaamste doel van uw hond(en)?
   a. Gezelschapsdier(en)
   b. Werkhond (bijvoorbeeld schapendrijver, politiehond, waakhond,…)

c. Showhond
d. Dekreu / Fokteef
e. Andere,..

15) Wat voor type voeding geeft u uw hond(en) momenteel?
a. Traditionele brokken/korrels incl. koudgeperste brokken
b. Nat voer
c. Semi-moist voer
d. Granenvrij voer
e. Vegetarisch of veganistisch voer
f. Een specifiek medisch diervoeder gerelateerd aan een ziekte/aandoening
g. Zelfbereide voeding
h. KVV / BARF
i. Een mix van..
j. Anders,..

16) Waarom heeft u voor het specifieke voeder gekozen?
(Meerdere opties mogelijk)
a. De prijs van de voeding
b. Specifiek dieet gebaseerd op de ziekte/aandoening van mijn huisdier
c. Percentage vlees in de voeding
d. Positieve reviews online
e. Aangeraden door mijn dierenarts
f. Aangeraden door de fokker, dierenspeciaalzaak of andere professional
g. Omdat ik denk dat deze voeding gezonder is
h. De duurzaamheid van het specifieke voeder
i. Mijn hond(en) vind(t/en) het lekker
j. Gewoonte
k. Ik heb mezelf ingelezen over hondenvoeding en heb daar mijn keuze op gebaseerd
l. Anders,..

17) Hoe denkt u over het voeren van een (volgens de Europese richtlijnen) compleet voer dat alleen uit insecten bestaat als eiwitbron, in plaats van conventioneel vlees-eiwit?
a. Ik zou dit absoluut niet doen
b. Ik zou dit niet zo snel doen
c. Ik ben hier neutraal of twijfelachtig over
d. Ik zou dit wel kunnen doen
e. Ik zou dit absoluut doen

18) Wat denkt u van het voeren van een hondenvoer dat voor 50% bestaat uit insecten eiwit en voor 50% uit conventioneel vlees-eiwit?
a. Ik zou dit absoluut niet doen
b. Ik zou dit niet zo snel doen
c. Ik ben hier neutraal of twijfelachtig over
d. Ik zou dit wel kunnen doen
e. Ik zou dit absoluut doen

19) Hoe veel % van de originele prijs zou u extra betalen voor insect gebaserde hondenvoeding? Vul alstublieft alleen cijfers in. Wanneer u niet meer zou betalen, vul dan 0 in;
→ Invulvraag

20) Welke (mogelijke) voordelen ziet u in het voeren van insect gebaseerde voeding aan uw huisdier(en)?
a. Duurzamer
b. Natuurlijker
c. Gezonder
d. Ik denk dat mijn huisdier(en) het lekker vind(t/en)

e. Diervriendelijker voor het productiedier (insect in plaats van rund/varken/kip..)
f. Ik zie geen voordelen
g. Ik weet het niet
h. Anders,…

21) Welke (mogelijke) nadelen ziet u in het voeren van insect gebaseerde voeding aan uw huisdier(en)?
a. Niet natuurlijk
b. Te duur
c. Minder diervriendelijk voor het productiedier (insect in plaats van rund/varken/kip..)
d. Ik vind het vies
e. Ik denk dat mijn huisdier(en) het niet lekker vind(t/en)
f. Het is te onbekend
g. Minder gezond ten opzichte van reguliere diervoeding
h. Mogelijk gevaarlijk voor mijn huisdier(en)
i. Ik zie geen nadelen
j. Ik weet het niet
k. Anders,..

22) Zou u er voor open staan om snacks gebaseerd op insecten aan uw dier(en) te geven?
a. Ja *(Vertakking naar vraag 24)*
b. Nee *(Vertakking naar vraag 24)*
c. Twijfelachtig *(Vertakking naar vraag 24)*
d. Alleen wanneer,… (zie volgende vraag)

23) Wat is / zijn uw voorwaarden voor het voeren van insect gebaseerde snacks aan uw dier(en)?
a. Het mag niet duurder zijn dan normale snacks
b. Het moet een klein formaat hebben
c. Laag in calorieën
d. Niet herkenbaar als insect
e. Dat mijn dier(en) het lekker vind(t/en)
f. Alleen wanneer ze bewezen gezond en veilig zijn
g. Anders,..

24) Is er voor u een verschil in diervoeding met wel of niet herkenbare insecten erin?
a. Nee, het is voor mij gelijk
b. Ja, ik geef de voorkeur aan diervoeding waar de insecten nog herkenbaar zijn
c. Ja, ik geef de voorkeur aan diervoeding waar de insecten niet meer in terug te herkennen zijn

25) Hoe veel katten heeft u momenteel?
a. Geen *(Vertakking naar vraag 39)*
b. 1 kat
c. 2 katten
d. 3-6 katten
e. 7-10 katten
f. Meer dan 10 katten

26) Wat is het voornaamste doel van uw kat(ten)?
a. Gezelschap
b. Showkat
c. Fokkerij
d. Andere,..

27) Wat voor type voeding geeft u uw kat(ten)?
a. Traditionele brokjes/korrels
b. Natvoer
c. Semi-moist diervoeding

d. Granenvrij
e. Vegetarische of veganistische diervoeding
f. Een specifieke medisch diervoeder gerelateerd aan een ziekte/aandoening
g. Zelfgemaakt
h. KVV / BARF
i. Mijn kat vangt (een deel van) zijn/haar eten
j. Een mix van,..
k. Anders,..

28) Waarom heeft u voor het specifieke diervoeder gekozen? (*Meerdere opties mogelijk)*
a. De prijs van de voeding
b. Specifiek dieet gebaseerd op de ziekte/aandoening van mijn huisdier
c. Percentage vlees in de voeding
d. Positieve reviews online
e. Aangeraden door mijn dierenarts of dierenspeciaalzaak
f. Ik maak de voeding zelf omdat ik denk dat dit gezonder is
g. De duurzaamheid van het specifieke voeder
h. Mijn kat(ten) vind(t/en) het lekker
i. Gewoonte
j. Ik heb mezelf ingelezen over kattenvoeding en heb daar mijn keus op gebaseerd
k. Ik denk dat het gezond is voor mijn huisdier
l. Anders,..

29) Heeft u naast kat(ten) ook (een) hond(en)?
a. Ik heb alleen (een) kat(ten) *(Vertakking naar vraag 39)*
b. Ik heb (een)kat(ten) en ook (een) hond(en)

30) Heeft u een andere mening over het voeren van insecten aan katten ten opzichte van aan honden?
a. Nee, dat is voor mij gelijk *(Vertakking naar vraag 39)*
b. Ja, ik wil daar graag meer over toelichten in een paar meerkeuzevragen
c. Ja, maar ik wil dit niet meer verder toelichten *(Vertakking naar vraag 39)*

31) Hoe denkt u over het voeren van een (volgens de Europese richtlijnen) compleet voer dat alleen insecten bevat als eiwitbron in plaats van conventioneel vlees-eiwit?
a. Ik zou dit absoluut niet doen
b. Ik zou dit niet zo snel doen
c. Ik ben hier neutraal of twijfelachtig over
d. Ik zou dit wel kunnen doen
e. Ik zou dit absoluut doen

32) Wat denkt u van het voeren van een kattenvoeder dat voor 50% bestaat uit insect en voor 50% uit conventioneel vlees-eiwit?
a. Ik zou dit absoluut niet doen
b. Ik zou dit niet zo snel doen
c. Ik ben hier neutraal of twijfelachtig voer
d. Ik zou dit wel kunnen doen
e. Ik zou dit absoluut doen

33) Hoe veel % van de originele prijs zou u extra betalen voor insect gebaseerde kattenvoeding? Wanneer u niets meer zou willen betalen, vul dan 0 in;
→ Invulvraag

34) Welke (mogelijke) voordelen ziet u in het voeren van insect gebaseerde voeding aan uw huisdier(en)?
a. Duurzamer
b. Natuurlijker
c. Gezonder

d. Ik denk dat mijn huisdier(en) het lekker vind(t/en)
e. Diervriendelijker voor het productiedier (insect in plaats van rund/varken/kip..)
f. Ik zie geen voordelen
g. Ik weet het niet
h. Anders,…

35) Welke (mogelijke) nadelen ziet u in het voeren van insect gebaseerde voeding aan uw huisdier(en)?
a. Niet natuurlijk
b. Te duur
c. Minder diervriendelijk voor het productiedier (insect in plaats van rund/varken/kip..)
d. Ik vind het vies
e. Ik denk dat mijn huisdier(en) het niet lekker vind(t/en)
f. Het is te onbekend
g. Minder gezond ten opzichte van reguliere diervoeding
h. Mogelijk gevaarlijk voor mijn huisdier(en)
i. Ik zie geen nadelen
j. Ik weet het niet
k. Anders,..

36) Zou u er voor open staan om snacks gebaseerd op insecten aan uw kat(ten) te geven?
a. Ja *(Vertakking naar vraag 38)*
b. Nee *(Vertakking naar vraag 38)*
c. Twijfelachtig *(Vertakking naar vraag 38)*
d. Alleen wanneer.. (zie volgende vraag)

37) Wat is / zijn uw voorwaarden voor het voeren van insect gebaseerde snacks aan uw kat(ten)?
a. Het mag niet duurder zijn dan normale snacks
b. Het moet een klein formaat hebben
c. Laag in calorieën
d. Niet herkenbaar als insect
e. Dat mijn dier(en) het lekker vind(t/en)
f. Alleen wanneer ze bewezen gezond en veilig zijn

38) Is er voor u een verschil in kattenvoeding met wel of niet herkenbare insecten erin?
a. Nee, het is voor mij gelijk
b. Ja, ik geef de voorkeur aan diervoeding waar insecten nog herkenbaar zijn
c. Ja, ik geef de voorkeur aan diervoeding waar insecten niet meer in terug te herkennen zijn

39) Hartelijk bedankt voor uw deelname aan deze enquête! Deze enquête is wanneer u dat wenst anoniem. Indien u echter graag informatie ontvangt over de resultaten van deze enquête en/of kans wilt maken op gratis voedingsadvies van specialisten van de universiteit Gent, dan mag u hieronder uw e-mail invullen. U zal verder geen reclame of andere mails ontvangen. Vul hier uw e-mail in:
→ Invul vraag

40) Mogen wij u in de toekomst contacteren voor andere survey over de voeding van uw huisdier?
a. Ja (deze optie is alleen mogelijk wanneer u uw mailadres heeft ingevuld)
b. Nee