VETERİNER HEKİMLER DERNEĞİ DERGİSİ
JOURNAL OF THE TURKISH VETERINARY MEDICAL SOCIETY

ISSN: 0377-6395
e-ISSN: 2651-4214
Dergi ana sayfası:
Journal homepage:
http://dergipark.org.tr/vetheder

doi: 10.33188/ vetheder.909963

Derleme / Review

Insects usage in pets food

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MAKALE BİLGİSİ / ARTICLE INFORMATION:

Geliş / Received:
05 Nisan 21
05 April 21

Revizyon/Revised:
06 Ekim 21
06 October 21

Kabul / Accepted:
01 Kasım 21
01 November 21

Anahtar Sözcükler:
Böcekler
Ev hayvanları
Protein alternatifi

Keywords:
Insects
Pets
Protein alternative

ABSTRACT:

The world population is increasing swiftly and expected to reach 109 billion by 2100. As compared to population increment, food resources to feed a huge population are not increasing. Similarly, in the future country having enough food to feed its inhabitants will be considered more powerful. There are two main protein sources used by living beings which are from plant origin and animal origin. Furthermore, animal protein sources are more crucial for humans due to the presence of essential amino acids. It is a need of the time to find alternative sources to fulfill the requirements. The insect protein source is one of them especially for animal feed leading to the usage of that protein being consumed by animals in human food. Especially pets food companies use hygiene meat of human consumption standards which can be replaced with an insect-based protein source. Insects are a rich source of proteins (40-60%), lipids (14-37%), energy, vitamins, and minerals having variation with species (black soldier fly, mealworm, cricket, and locust) and developmental stage of life (larva, pupa, nymph and adult one). Many trials have been conducted by using insect meal as an alternative protein source in pet's food (dogs, cats, rabbits, reptiles, sugar gliders, birds, and ornamental fishes), which has been explained in this study. It can be concluded that insect-derived products can be used in pet food as an alternative source of protein to conventional protein sources (soybean meal, fish meal) with improved performance.

Ev hayvanlarının beslenmesinde böcek kullanımı

ÖZET:

Dünya nüfusu hızla artmaktadır ve 2100 yılına kadar 10,9 milyara ulaşması beklenmektedir. Nüfus artışına kıyasla bu büyük nüfusu besleyecek gıda kaynakları artışı senkronize değildir. Gelecekte vatandaşlarını beslemek için yeterli yiyeceğe sahip olan ülke güçlü olarak kabul edilecektir. Temel olarak, canlılar tarafından kullanılan bitki ve hayvan temelli iki ana protein kaynağı vardır. Hayvansal protein kaynakları, esansiyel amino asitlere sahip olması sebebiyle insanlar için ayrıca önemlidir. İhtiyaçları karşılamak için yeni alternatif kaynakların bulunması zaman gerektirmektedir. Özellikle hayvan yemlerinde protein kaynağı olarak kullanılan böcek, bunlardan biridir, böylece insanlar için protein kaynaklarında tasarruf sağlanır. Özellikle ev hayvanı mama şirketleri insan tüketimi standartlarında et kullanırlar ve böcek bazlı bir protein kaynağı bunlarla değiştirilebilir. Böcekler enerji, lipitler (%14-37), proteinler (%40-60), vitaminler ve mineraller bakımından zengin, çeşitli tür (siyah asker sineği, un kurdu, cırcır böceği ve çekirge) ve yaşam evresine (larva, pupa, nimfa ve yetişkin) sahip kaynaklardır. Bu çalışmada ev hayvanlarında (köpekler, kediler, tavşanlar, sürüngenler, şeker planörleri, kuşlar ve akvaryum) alternatif bir protein kaynağı olarak böcek unu kullanılan birçok çalışma açıklanmıştır. Böceklerden elde edilen ürünlerin alternatif bir protein kaynağı olarak, geleneksel protein kaynakları (soya küspesi, balık unu) yerine daha iyi performansla ev hayvanı mamalarında kullanılabileceği sonucuna varılabilir.

How to cite this article: Ahmed I, İnal F, Riaz R. Insects usage in pets food. Vet Hekim Der Derg 2022;93(1):87-98. DOI: 10.33188/ vetheder.909963

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1. Introduction

In 2030 world population is expected to reach 8.6 billion and until 2050 it will be 9.8 billion (1). Until 2050 animal-based protein sources need to be increased by 75% to fulfill the increasing protein requirements of the world (2). Current food production will be required in double amount to fulfill the nutritional demand of this huge population. Van Huis et al (3) stated that to support this huge production demand water and land resources are not enough because deforestation is at peak due to increasing population load in urban areas and expansion of cities, sustainable materials as an alternative source are need of the hour. Ways to produce food in the stress of global freshwater availability and greenhouse gas excessive production will be ecological consequences of this enhanced demand (4). A possible potential substitute to solve this issue can be insects and derived products. Like footprint of water for beef, pork, chicken, and mealworms are 112, 57, 34, and 23 L/g protein respectively indicating the lowest for insects (5). Similarly, the potential share in global warming is 77-175, 21-54, 19-37, and 14 kg of CO_2 for beef, pork, chicken, and mealworm consumable protein (6). Land usage is 142-254, 46-63, 41-51, and 18 m^2 for beef, pork, chicken, and mealworm respectively (4). These characteristics of insects make them suitable alternative protein sources to fulfill future feed demand compared to other commercial animal-based protein sources.

To sustain nutritional needs Food and Agriculture Organization (FAO) has classified insect consumption as a potential alternate (3). In comparison with livestock, insects have an optimal conversion ratio of feed along with a wide range of feed resources acceptance and less impact on the environment, which justifies the FAO announcement regarding entomophagy. Panini et al (7) classified insects as a rich source of energy, lipids, proteins, vitamins, and minerals, having variation with species (black soldier fly, mealworm, cricket, and locust) and developmental stage of life (larva, pupa, nymph and adult one). Consumers' demands for more appropriate diets resulted in the advancement of the pet food industry. The pet food industry is trying to fulfill these demands by utilizing novel sources for successful progression. Insects can be added to pet food for value addition due to many advantages like they can propagate on by-product waste and helps in the growth of circular economic status. Conventional sources of livestock provide 40-60% share of their body, whereas insects give 80%, resulting in fewer waste byproducts (3). Insects have been used as a successful replacement of conventional protein sources like soybean and fish meal in livestock feed (8). The pet food industry is also taking part in this new growing alternative protein source usage to fulfill customers' demands.

Generally, pet owners feed prime steaks to their dogs and cats but British Veterinary Association (BVA) recommending them to consume insect-formulated food due to their advantages. The BVA conducted some surveys from pet owners for insect-based food acceptability and obtained a positive response from the majority of owners. President of BVA Simon Doherty stated that insect usage in pet food is an excellent option because of their environment-friendly behavior. Meat being fed to pets should be fed to humans to fulfill the increasing demand for meat for a huge population. Some companies are producing pet food containing insect meal up to 40% in the UK. According to BVA 12% of all meat produced is consumed by pets which can be used for human consumption. It is a better approach to feed your pet on commercial food made of insect protein rather than meat prime steaks which are not nutritionally balanced to fulfill the dog's requirement. Propagation of insects doesn't require fertilizer/pesticide and a huge amount of water as compared with crops. Insect-based pet food is slightly expensive for time being because this idea is the new one and fewer people are involved in insect meal production (9).

It has been estimated that 68% of USA householders own a pet because it provides pet owners physiological as well as psychological advantages (10). In Turkey, the ratio of pets in homes is as follows; dogs 12%, cats 15%, fishes 16% and birds are 20%, as shown in Figure 1 (11). Pet owners are more curious regarding their food and its formulating ingredients due to some kind of allergies. Feed sustainability is mainly maintained by protein, which is a costly macronutrient of pet food as well as an important ingredient in terms of economic. Protein plays two important roles in pets' food; provision of carbon and nitrogen in turns of dispensable amino acid for energy, gluconeogenesis, and synthesis of other amino acids, and supply essential amino acids which cannot be formed in the body of cats and dogs. Taurine is additionally required in cat food (12). Skeletal and cardiac muscles are rich in Sulphur containing amino acid taurine (13), whereas bacteria, algae, and fungi contain a fewer amount of taurine. Taurine plays flowing roles in the animal body like immune and reproductive regulation, osmoregulation flux of calcium in cells, sustain myocardial

and retinal functioning, and bile acids articulation (13). Cardiomyopathy along with retinal degeneration are direct negative consequences of taurine deficiency in plasma and blood of carnivores (14), which emphasizes taurine essentiality for cats (12). Taurine minimum requirement standard has been established for cat diet like 0.1-0.2% on dry matter basis is set up by Association of American Feed Control Officials, 0.2-0.25% on dry matter basis is provided by The European Pet Food Industry Federation (15). As the human population is swiftly increasing there is competition for protein sources between animals and humans, which implies the importance of alternative protein sources to fulfill the increasing demand. The pet food industry competes with other industries like fish, human, and livestock production systems due to its strong interlinkage between these. The constantly increasing population of pets all over the world creates demand for high quality and quantity of the food as well as its importance. Rumpold and Schlüter (16) stated that insects can be a suitable alternative protein source for animals and humans and can be propagated on waste by-products (3). Demand for live insects to feed exotic pets especially in the reptiles' diet is increasing because having exotic pets like insectivores and different types of reptiles is a hot trend. Pet owners, shop owners, breeders at small and large levels demand a regular supply of fresh and clean insects. Due to this demand nowadays approximately 80% of cricket farms are selling live insects to pet owners.

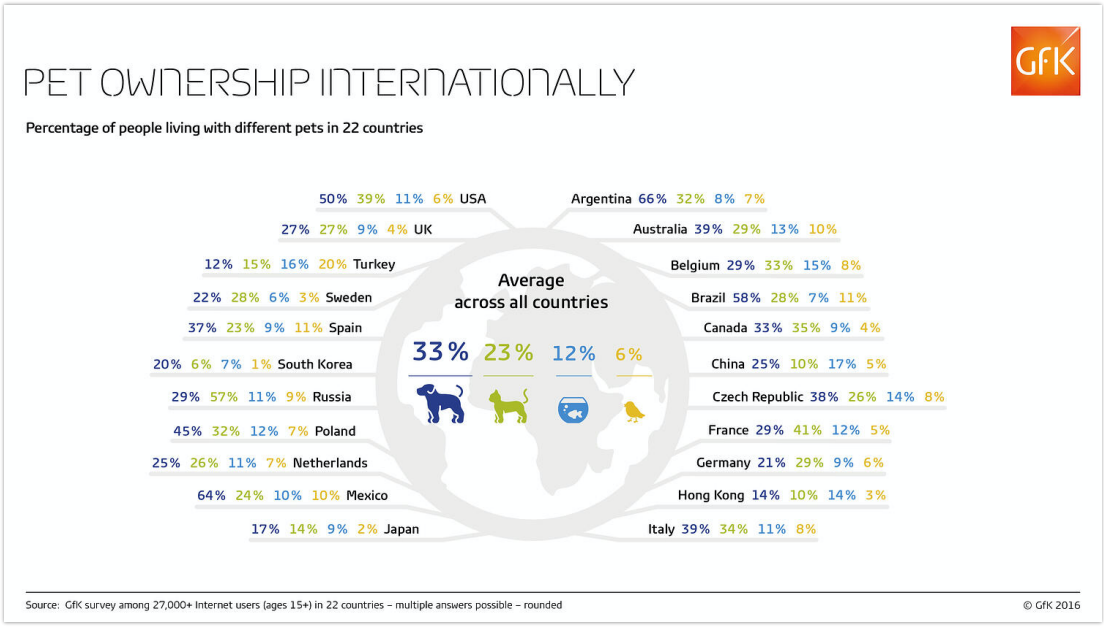

Figure 1: Pet ownership internationally

Şekil 1: *Dünya'da ev hayvanı sahipliği oranları*

Many companies are manufacturing insect-based dog foods like in Europe insect-based 12 foods are present in the market (17). These foods mostly contain dried yellow mealworms and black soldier flies or larvae with hypoallergic reactions in some products with minor outcomes. In nature, cats and dogs eat insects, which strengthens the idea of insect inclusion in pet food to enhance the acceptance rate. Currently, almost all pet food contains insect meal fractions. Replacement of conventionally used protein sources with insect-based protein can reduce allergic reactions in pets. Live insect feeding in dried or freeze-dried lyophilized form in exotic pets like, reptiles, rodents, birds and amphibians' food is a hot area of research and interest.

Verbeke et al (18) stated that the majority of people even from Europe and around the globe don't like to eat insects as food but they are willing to accept them as animal feed because conventional protein sources like soybean and fish meal are being out of range due to their increased consumption. The nutritional profile of different insects along with soybean meal, poultry meat meal, and fish meal are given in table 1 (19). In Europe a legislative regulation reference. 1069 was implemented in 2009, which classifies insect meal as a processed protein source and allows its

inclusion in livestock feed. Its inclusion in companion animal feed enhances its uptake, whereas decreases allergic reactions. Józefiak and Engberg (20) said that the addition of insects in animal feed has positive influences due to its chitin content and antimicrobial activity. To improve the palatability and acceptability of animal feed different kinds of aromatic compounds are added which resulted in increased cost of production. Whereas, the inclusion of insects can be used as an alternative to these compounds and controls the cost of feed production (21). Evaluation of insects as an alternative protein source in pet food is a topic of interest for the last few years (22) due to its increasing demand to fulfill large pet population need.

Table 1: Proximate composition (% DM), indispensable amino acid composition (% CP) of different insects, fish meal, and soybean meal (19)

Tablo 1: *Farklı böceklerin, balık unu ve soya küspesinin besin maddesi (%KM), amino asit bileşimi (% HP) (7)*

Parameter	HF	BSF	HC	YMW	MW	ACR	FM	SBM
CP	62.5	56.1	70.6	52.0	47.0	64.4	71.0	51.6
Fat	19.2	12.8	17.7	33.9	39.6	24.5	9.2	2.5
Ash	5.6	12.6	5.3	3.9	3.0	4.4	19.9	6.8
Lysine	6.2	5.4	5.8	5.5	5.3	4.0	7.4	6.2
Methionine	2.6	1.4	1.6	1.4	1.6	1.3	1.9	2.0
Threonine	3.8	3.6	3.6	4.0	4.1	3.1	4.0	3.9
Arginine	4.2	3.7	5.7	4.6	4.6	3.5	4.5	6.3
Histidine	4.8	4.4	3.4	5.1	4.8	4.5	3.4	3.1

HF; housefly, BSF; black soldier fly, HC; house cricket, YMW; yellow mealworm, MW; mealworm, ACR; Argentinian cockroach, FM; fish meal, SBM; soybean meal.

Bosch et al (19) and van Huis et al (3) concluded that different varieties of insects like cricket (tropical house, two-spotted, house), mealworms (yellow, lesser), cockroach (speckled, orange-spotted), beetle (black, sun), migratory locusts, wax moths, and housefly can be used in pets' diet.

2. Insect usage in dog's food

The taste of dog food made from black soldier fly larvae resembles a cheese and beef cocktail. Yora Pet Foods director Will Bisset stated that "Dogs love it". A 1.2 million US dollar increase in sales was observed during the first month (January) of sale, 2019. This food attracts the attention of all veterinary professionals and owners having pets. Big groups which deal with insects are as following; Agri-tech deals with mealworms and Agri-Protein deals with black soldier fly. Manager of Mars Petfood producers stated that alternative protein sources such as insects can be a great source for pet food in the future and claims Mars is the largest producer of insect-based pet food (23).

Some insect proteins and their digestibility in vitro trials showed that their amino acid contents are higher than dogs' requirements (19). Lisenko et al (24) supplemented 7.5 and 15% of the super worm, madagascar, and speckled cockroach in adult dog's diet. The results indicated that the canine diet can be supplemented up to 15% of 3 insect species, without influencing microbiota, fecal metabolites, and nutrient digestibility of dogs. Bohm et al (25) studied the influence of commercially available edible insect meals like crickets, mealworms, and locusts on clinically diseased dogs. There were 20 dogs with conditions like poor coat quality score, pruritis visual analog scale, and canine atopic dermatitis lesion index, which were fed the insect-based diet for 2 weeks. It can be concluded from the results of this study that insect-based diets can act as an effective alternative protein source in dogs having food intolerance conditions.

Kierończyk et al (26) conducted a trial to exam the olfactory appeal of different insect meals used as a dry powder in dog food. A total of 3 attempts were studied in the experiment and the food offered to them contains black soldier fly, Turkestan cockroach, mealworm, tropical house cricket, and commercially available food as a control diet. All foods were packed in transparent boxes with 5 holes on them for aromatic attraction. Dogs' approach to foods on a preference basis was observed and categorized on gender and inset species. Time limit criteria were fixed as 15 seconds and 3 attempts were noted as significant expression. Male prefers mealworms, whereas female prefers Turkestan cockroach. It can be stated on current trial bases that commercial dog food producers can use insects as aromatic additives to enhance the acceptability of food as insects are part of dogs' food in nature. Jarett et al (27) conducted a trial on 32 dogs by feeding 0, 8, 16, and 24% of cricket meal (assuming cricket meal as a novel source of fiber and protein for dogs) and determine the gut microbiomes from fecal samples. The results indicated that gut microbiome diversity of dogs fed cricket meal was the same as in dogs fed the control diet. In conclusion, cricket meals can be used as an alternate source of protein in a dog's diet.

Defatted black soldier fly larvae meal (DBSFLM) was supplemented in beagle dogs' diet to see its effect on dogs' health and immunity (22). Three levels (0,1 and 2%) of DBSFLM were fed to nine beagle females for 42 days. All dogs were injected 100 µg/kg of *Escherichia coli* lipopolysaccharides into the peritoneal cavity. The results indicated improved apparent total tract digestibility of dry matter and crude protein along with the enhanced antioxidative and anti-inflammatory activity of dogs fed DBSFLM. Maggot meal of housefly was supplemented in beagle dog food as a control diet containing 0% and 5% maggot meal for 42 days (28). It was reported that 5% of maggot meal can be included in dogs' diets as a high-quality alternative protein source without any adverse effect on the immune system and blood biochemistry.

Beagles were fed four diets containing 0, 8, 16, 24% of cricket meal in a 29 days trial (29). Control diet containing 0% cricket meal was supplemented with a chicken meal. The blood parameters and fecal profile throughout the trial showed that cricket meals can be added to adult dogs' diets without any negative influence on overall performance.

3. Insect usages in cat's food

Domestic feral cats prefer to live lonely and hunt different kinds of rodents along with reptiles, small birds, and a variety of insects. Around 1% of a cat's body weight is estimated to be consists of small prey (vertebrates). Insect species population increases swiftly and act as a supportive part to fulfill carnivores demand like cats but a minor percentage. Plantinga et al (30) stated that insects comprise 6% of cats diet and estimated dietary nutrient requirement of the cat as protein (52%), fat (46%) and carbohydrate (2%) by energy. Insects have great potential to fulfill these nutritional demands as a novel source of protein.

Lisenko et al (31) supplemented 7.5 and 15% of zophobas morio, Madagascar cockroach, and speckled cockroach larvae meal in feline diets. In conclusion, cats can digest well 15% of these three insect meals without any adverse effect on performance and gut health.

4. Insect usages in reptile's food

In 2005 black soldier fly larvae were introduced as a commercial feed for reptiles with the brand name Phoenix Worm®. It was introduced by a reptile food producer who was a herpeto culturist and facing the problem of reduced calcium (Ca) in the diet. Low Ca leading to Ca and phosphorous (P) imbalance, which is the main nutritional concern for live captative reptiles in commercially available food. Finke (32) reported that a major share of the insect market consists of mealworms with a 1:7 Ca to P ratio and crickets with 1:17 Ca to P. These Ca to P ratios have too much difference, whereas for the normal physiological function of reptiles it is recommended at a ratio of 1:1 or 1:3 (33). Raiti (34) describes the importance of Ca for body functions like bone strength, blood clotting, cardiac health, enzyme activity, cell signaling, muscle contraction, and neurotransmitter release. When the P ratio is too high as compared with Ca, the body initiate mechanism to fulfill the Ca need of the body by extracting Ca from bones leading to fragile and

soft bones. It affects mainly large bones with long length and softening of jawbones (33, 34). The vertebral column undergoes scoliosis, lordosis, and kyphoscoliosis as a result of bone deformation (33). These abnormalities resulted in diseased locomotion leading to malnutrition and dehydration. Stahl and Denardo (35) reported that poor muscle movements of gravid females due to Ca deficiency leads to dystocia and eclampsia.

4.1. Chameleon

Chameleon is predominantly omnivorous eating dark, leafy green vegetables along with a variety of insects, including mealworms, roaches, waxworms, and crickets (36). In San Diego global zoo pet chameleon is mainly fed on grasshoppers, crickets, and locusts for optimal growth and reproduction.

4.2. Turtle

Turtles are carnivores that mainly feed on worms, insects, fishes, mollusks, and frogs (37). Insects are the main part of their diet in the natural environment as well as a pet (38). Çiçek and Ayaz (39) stated that almost 84% of all stomach content consisted of insects during the breeding season. Crickets, blood worms, silkworms, shrimp, mealworms are mainly fed animal protein sources especially insect-based feed (40). Even live small insects are available at pet shops for little-sized pet turtles. Insects are rich in mineral content, which can easily fulfill the nutritional requirements of turtles.

5. Insect usages in bird’s food

Although parrots feed on fruits, seeds and beans sometimes they have been observed to eat invertebrates. Love birds can be categorized into entomophagous and phytophagous. Birds (parrots, finches, canaries) doesn't depend totally on vegetables but they also need animal-based protein source for their optimal growth and reproduction. Forshaw (41) stated that parrots show more insectivorous behavior as estimated earlier and consume insects as extra protein supplementation. Different species of parrot's forage on a variety of insects like Black parrot eats insects, Afzeliabijuga (42), Meyer's parrot feeds on caterpillars and insects (43), Ruppel's Parrot forages on spiders, caterpillars, and bugs (44). Grey-headed adult parrots consume some types of arthropods in their diets (45). Lovebirds with Black cheeks also consume invertebrates to fulfill foraging behavior (43). Fruits and grains are a great source of protein for almost all avian species but Rosy lovebirds didn't observe performing this activity (46). Symes and Perrin (45) observed that grey parrots were digging on bark and branches of trees, which can be attributed to insect search. Lovebirds eating leaves doesn't mean they also fed insects but insect feeding can be linked with low profile leaves and shrubs to fulfill deficient amino acid requirements. Parakeets consume mealworm pupae and larvae, beetles to meet the protein demand of adults especially during the breeding season (47).

In nature wild canaries consumes a different kind of seeds but seeds availability varies according to season. Although sometimes only seeds are unable to fulfill all kinds of requirements. In such a situation different types of insects are being consumed to satisfy birds' needs.

Generally, birds' diet doesn't comprise live insects except in special conditions like molting or breeding considered as avian stress conditions. Sometimes these are fed as treat. Waxworms and mealworms are easily available in chilled forms at pet shops. Similarly, different maggots, bugs, and crickets are also available commercially for birds. Before offering insects to birds thawing is recommended, if the size is larger and you want to offer to finches it can be ground or cut into small pieces. Waxworms are comparatively pulpy and soft which require more care during handling as compared with other worms. Initially, birds kept in captivity sometimes doesn't recognize live insect as food but gradually becomes familiar.

6. Insect usages in rabbit's food

Several studies have been performed on the inclusion of insects in poultry, pigs, and dogs' diet. Their finding cannot be implemented on rabbits because they have different physiology of digestion being a hindgut fermenters. In 1987 first study was performed in rabbits by adding silkworm pupae as a replacement for soybean meal (48). In the last few years, insect fat (BSF and mealworm) is used as an alternative energy source in rabbits' diets (49).

Zotte et al (50) executed a digestibility trial on hybrid rabbits by feeding four diets containing two fat sources linseed and BSF fat at two levels 30 and 60 g/kg of feed. There was a reduction in hind leg fatty acid profile and PUFA was observed by feeding BSF fat. The 12:0 and 14:0 saturated fatty acids were higher in rabbit meat-fed BSF but it can be altered by changing the substrate fatty acid profile on which BSF propagated. Spranghers et al (51) stated that lauric acid always remains abundant fatty acid in muscles of animals fed BSF fat as an energy source because of the endogenous lipogenic pathway. Lauric acid has the advantage that it can easily be metabolized and used as energy in rabbits and can act as a microbial modulator in the intestine.

Martins et al (49) conducted a trial by feeding four diets containing two levels of BSF and linseed fat at low 30 g/kg and high 60 g/kg levels on rabbits. They stated that BSF fat can be used as an alternative source of energy in rabbits' diets without influencing the nutritive value of the diet, carcass traits, growth performance, and digestive tract incidences.

Rabbits were fed a control diet with 1.5% soybean oil along with four more diets containing two oil sources (black soldier fly and mealworm oil) at two levels (50% and 100%) as a replacement for soybean oil (52). The latter authors concluded that the replacement of soybean oil with black soldier fly and mealworm oil doesn't hinder the physiological parameters of rabbits. The gut development, growth performance, serum biochemistry, and nutrient digestibility didn't influence negatively showing that black soldier flies and mealworm oil are a suitable alternative to soybean oil up to 1.5%.

Three experimental diets control, containing 4% of mealworm larvae and silkworm pupae meal in 55 days experiment were fed to New Zealand White rabbits (53). It was concluded that rabbit growth performance, chemical composition, and overall quality of the meat were not influenced negatively. Summarizing that mealworm and silkworm pupae meal can be included in rabbits' diet as a feed ingredient.

7. Insect usages in sugar gliders food

Marsupial, omnivorous and nocturnal are general characteristics of sugar glider which feeds on plants as well as a variety of insects and is kept as pets. To approach insect's nature has gifted them enlarge incisor along with a fourth digit to extract and feed on embarked insects. Many studies have been performed on sugar gliders in Australia indicating that they have extraordinary ability of adaptation according to external environmental available resources (54). They consume approximately 40-60% of their diet as spiders and insects during summer and spring to fulfill increased protein requirements during reproduction.

Sugar glider consumes approximately 15% of insects as part of their diet especially during the breeding season (55). Mealworm larvae, beetle, cricket, and moth provide protein and fat to a sugar glider. Sometimes they consume spiders that contain taurine, which helps in growth and development.

8. Insect usage in aquarium fish food

Fish meals or other fish by-products are completely or partially replaced by insect meals in fish feed. Fish science has declared insect meal as a novel alternative animal protein source in fish feed. It has the following benefits; insects are part of their natural feed; fishes easily digest insect-based diet with minimum waste production (less frequency of tanks cleaning) and it replaces the fishmeal ingredient usage in fish feed creating a sustainable friendly ocean environment. On the fish science site, Dr. David Pool stated that fish meal can be replaced with insect meal in goldfish feed. To fulfill omega fatty acid requirements salmon oil or other essential oil supplementation is mandatory.

In some trials, partial replacement of fishmeal is recommended rather than a complete replacement for optimal results in tropical aquariums.

Goldfishes are omnivores (eats a variety of artificial and live feed) and strong natured which even can survive in bad quality water. In nature plant and animal-derived matters (crustaceans and insects' fragments and their debris) fulfill the protein requirements of goldfish (56). Ortega and Reyes (57) stated that naturally goldfish sexually mature between 12 to 24 months of age and their young ones (40-100 g weight) can be fed on insects like blood and earthworm.

Shrimps were fed with earthworms which resulted in maturation induction in them, it can be attributed to the presence of unsaturated fatty acids which speeds up maturation in shrimps (58). Feed-induced maturation in fishes due to earthworm feeding is attributed to prostaglandin-like substances in it which trigger gonadal maturation in them (59). Gonadal maturation as a result of earthworm feeding leads to improved performance of fishes.

Clownfish is a very famous aquarium fish, propagates and spawns easily in the laboratory making it ideal for experimental purposes and having complete genomic data (60). It is a very famous aquarium fish, propagates and spawns easily in the laboratory making it ideal for experimental purposes and having complete genomic data (61). Ornamental fish diets have high prices, which creates a need for alternative cheaper diets by using cheaper ingredients. Vargas-Abúndez et al (62) conducted a trial on clownfish by feeding 0, 25, 50, and 75% of black soldier fly larvae meal as substitution of fish meal and studied its influence on spectroscopic, morphological, molecular, biochemical, and main biological reactions. It was concluded that survival rate, growth performance, and stress response were not influenced negatively. Although the fatty acid composition of fish was manipulated as per insect meal profile.

Davis et al (63) added their point of view regarding the inclusion of insect meals especially the black soldier fly meal and its nutritional profile. The later author defines a fatty acid profile of black soldier fly (BSF) meal as it contains 25% mono and polyunsaturated fatty acid and approximately 70% of saturated fatty acids. A vital unsaturated fatty acid called omega-3 fatty acid is very important for fishes, which is deficient in black soldier fly meal fat content as compared to other sources naturally consumed by fish-like marine algae. Overall BSF meal contains approximately 36% of crude fat which is deficient in omega-3 fatty acid resulting in its reduced importance as an ideal alternative fat source. Therefore, their fat extraction was recommended. There are different methods to extract fat like mechanical pressing which reduces fat content to 20%, however, chemical extraction like hexane reduces fat content to 5 to 8% and protein content also increases up to 53%, which is considered better for aqua diets.

Globally, aquarium fishes have huge commercial values, guppies are one of them. They can easily breed in the aquarium and have a beautiful appearance. In its natural habitat, the guppy feeds on small invertebrates, algae, and other plant material (64). Fernando et al (65) stated that for optimal reproductive development these kinds of feeds are insufficient for breeding stock. Similarly, Morimoto (66) describes the importance of feed on aquatic organisms' different parameters like no, composition, and hatchability of eggs hatched per clutch. Breeding stock nutrition influences egg production, gonadal development, larval survival rate, and fecundity, which highlights the importance of nutrition for broodstock. Growth rate and reproduction performance are greatly dependent on dietary lipid and protein content (67). Adil et al (68) conducted a trial on guppies by feeding five diets to guppies and observed their influence on growth performance and reproductive activity. Five diets were formulated as tetramine fish flake (control), blood worm, locust, rhino beetle, and flour worm based. Fishes fed blood worms, rhino beetle and flour meal had greater growth performance as compared with other fishes fed other diets. Guppies fed blood worms obtained higher ovary weight and fry production as compared with other diets. These results indicated that insects can be used in guppies' diets for better outcomes in fishes in terms of growth and reproduction.

Conclusion

It is concluded from the above-cited literature that insect-derived food can be used in pet food as an alternative source of protein in replacement of conventional protein sources with improved performance. An insect-based diet has been examined in dogs, cats, rabbits, reptiles, sugar gliders, birds, and ornamental fishes. Further research is required to investigate the optimal level and form of insect-derived products on different parameters (growth performance, gut

health and morphology, total track and ileal digestibility of protein, immunity, chemical profile of blood) of pets. Allocation of insect species to different pets with their advantages and disadvantages should be studied in detail.

Conflict of Interest

The author declared no conflict of interest.

Funding

No financial resource has been received during the execution of the study.

Authors' Contributions

Motivation / Concept:
Control/Supervision:
Literature Review:
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Critical Review:

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An ethical statement was received from the authors that the data, information and documents presented in this article were obtained within the framework of academic and ethical rules and that all information, documents, evaluations and results were presented in accordance with scientific ethics and moral rules

References

1. Fasolin LH, Pereira RN, Pinheiro AC, Martins JT, Andrade CCP, Ramos OL, Vicente AA. Emergent food proteins–Towards sustainability, health and innovation. Food Res Int 2019;125:108-586.
2. Alexandratos N, Bruinsma J. World agriculture towards 2030/2050: the 2012 revision. ESA Working Paper No. 12-03; 2012.
3. Van Huis A, Van Itterbeeck J, Klunder H, Mertens E, Halloran A, Muir G, Vantomme P. Edible insects: future prospects for food and feed security. FAO Forestry Paper 2013; 171.
4. Miglietta PP, De Leo F, Ruberti M, Massari S. Mealworms for food: a water footprint perspective. Water 2015;7:6190-6203.
5. De Vries M, de Boer IJM. Comparing environmental impacts for livestock products: A review of life cycle assessments. Livest Sci 2010;128:1-11.
6. Oonincx DGAB, De Boer IJM. Environmental impact of the production of mealworms as a protein source for humans–a life cycle assessment. PloS ONE 2012;7:e51145.
7. Panini RL, Freitas LEL, Guimarães AM, Rios C, da Silva MFO, Vieira FN, Fracalossi DM, Samuels RI, Prudêncio ES, Silva CP. Potential use of mealworms as an alternative protein source for Pacific white shrimp: Digestibility and performance. Aquacu 2017;473:115-120.
8. Makkar HPS, Tran G, Heuzé V, Ankers P. State-of-the-art on use of insects as animal feed. Anim Feed Sci Technol 2014;197:1-33.
9. Harrabin R. Insect-based food 'better for pets than top steak. BBC news (Science) [Online new] 2019 [2021 April 04]; Available from: https://www.bbc.com/news/science-environment-49450935.
10. Association, American Pet Products. 2019–2020 APPA National Pet Owners Survey. Stamford, CT: American Pet Products Association; 2019.

11. Growth for Knowledge. Man's best friend: global pet ownership and feeding trends. [Online]. 2016 Nov 22 [Cited 2020 Jan 18]; Available from :https://www.gfk.com/insights/mans-best-friend-global-pet-ownership-and-feeding-trends.

12. National Research Council. Nutrient requirements of dogs and cats. Washington, D.C; National Academies Press; 2006.

13. Sanderson SL. Taurine and carnitine in canine cardiomyopathy. Vet Clin N Am-Small Pract 2006;36:325-1343.

14. Pion PD, Kittleson MD, Rogers QR, Morris JG. Myocardial failure in cats associated with low plasma taurine: a reversible cardiomyopathy. Sci 1987;237(4816):764-768.

15. Federation European Pet Food Industry. Nutritional guidelines for complete and complementary pet food for cats and dogs. Belgium. FEDIAF Bruxelles; 2013.

16. Rumpold BA, Schlüter OK. Nutritional composition and safety aspects of edible insects. Mol Nutr Food Res 2013;57(5):802-823.

17. Beynen AC. Insect-based petfood. Creature Companion 2018; 40-41.

18. Verbeke W, Spranghers T, De Clercq P, De Smet S, Sas B, Eeckhout M. Insects in animal feed: Acceptance and its determinants among farmers, agriculture sector stakeholders and citizens. Anim Feed Sci Technol 2015;204:72-87.

19. Bosch G, Zhang S, Oonincx DGAB, Hendriks WH. Protein quality of insects as potential ingredients for dog and cat foods. J Nutr Sci 2014;3:e29.

20. Jozefiak A, Engberg RM. Insect proteins as a potential source of antimicrobial peptides in livestock production. A review. J Anim Feed Sci 2017;26:87-99.

21. Chen M, Chen X, Nsor-Atindana J, Masamba KG, Ma J, Zhong F. Optimization of key aroma compounds for dog food attractant. Anim Feed Sci Technol 2017;225:173-181.

22. Lei XJ, Kim TH, Park JH, Kim IH. Evaluation of supplementation of defatted black soldier fly (Hermetia illucens) larvae meal in beagle dogs. Ann Anim Sci 2019;19(3):767-777.

23. Kelly R. There's a fly in my kibble! Insect-based pet food takes off. VINNEWS Service. [News Online] 2020 [2020 Jan 25]; Available from: https://news.vin.com/default.aspx?pid=210&Id=9557654&useobjecttypeid=10&fromVINNEWSASPX=1.

24. Lisenko K, de Godoy M, Oliveira M, Silva T, Fontes T, Costa D, Lacerda R, Ferreira L, Gonçalves T, Zangeronimo M. PSXIII-26 Compositional analysis and effects of dietary supplementation of insect meals on nutrient digestibility and gut health of adult dogs. J Anim Sci 2018;96:158-159.

25. Böhm TMSA, Klinger CJ, Gedon N, Udraite L, Hiltenkamp K, Mueller RS. Effekt eines Insektenprotein-basierten Futters auf die Symptomatik von futtermittelallergischen Hunden. Tierarztl Prax Ausg K: Kleintiere/Heimtiere. 2018;46:297-302.

26. Kierończyk B, Rawski M, Pawełczyk P, Różyńska J, Golusik J, Mikołajczak Z, Józefiak D. Do insects smell attractive to dogs? A comparison of dog reactions to insects and commercial feed aromas–a preliminary study. Ann Anim Sci 2018;18:795-800.

27. Jarett JK, Carlson A, Serao MR, Strickland J, Serfilippi L, Ganz HH. Diets with and without edible cricket support a similar level of diversity in the gut microbiome of dogs. Peer J 2019;7:e7661.

28. Hong Y, Zhou J, Yuan MM, Dong H, Cheng GQ, Wang YJ, Xia JY, Zhang L. Dietary supplementation with housefly (Musca domestica) maggot meal in growing beagles: hematology, serum biochemistry, immune responses and oxidative damage. Ann Anim Sci 2020;20:1351-1364.

29. Kilburn LR, Carlson AT, Lewis E, Serao MCR. Cricket (*Gryllodes sigillatus*) meal fed to healthy adult dogs does not affect general health and minimally impacts apparent total tract digestibility. J Anim Sci 2020;98(3):1-8.

30. Plantinga EA, Bosch G, Hendriks WH. Estimation of the dietary nutrient profile of free-roaming feral cats: possible implications for nutrition of domestic cats. Br J Nutr 2011;106:S35-S48.

31. Lisenko K, Saad F, Oliveira M, Silva T, Costa D, Dias D, Damasceno M, Oliveira L, Junior SRS, Zangeronimo M, deGodoy MRC. PSXIII-25 Use of insect meal an alternative protein source in feline nutrition. J Anim Sci 2018;3:158.

32. Finke MD. Complete nutrient composition of commercially raised invertebrates used as food for insectivores. Zoo

Biol 2002;21(3):269-285.
33. Boyer TH, Scott PW. Nutrition. In: Divers SJ, Stahl SJ 3rd. ed. Mader's Reptile and Amphibian Medicine and Surgery. Elsevier. 2019. p. 201-23.
34. Raiti P. Endocrinology. 835-848 In: Divers SJ, Stahl SJ Eds. Mader's Reptile and Amphibian Medicine and Surgery. Elsevier, St. Louis, MO; 2019.
35. Stahl SJ, DeNardo DF. Theriogenology. 849-893 In: Divers SJ, Stahl SJ Eds. Mader's Reptile and Amphibian Medicine and Surgery. Elsevier, St. Louis, MO; 2019.
36. Kubiak M. Chameleons. In: Kubiak M, Editor. Handbook of Exotic Pet Medicine. (NJ):Wiley; 2020. p. 263-81.
37. Ernst CH, Barbour RW. Snakes of Eastern North America. Virginia. George Mason University Press; 1989.
38. Rawski M, Mans C, Kierończyk B, Świątkiewicz S, Barc A, Józefiak D. Freshwater turtle nutrition–a review of scientific and practical knowledge. Ann Anim Sci 2018;18(1):17-37.
39. Çiçek K, Ayaz D. Food composition of the European pond turtle (Emys orbicularis) in Lake Sülüklü (Western Anatolia, Turkey). J Freshwater Eco 2011;26(4):571-578.
40. Alataş MS, Özdemir Ö. Kırmızı Yanaklı Su Kaplumbağası El Kitabı. Ankara: Nobel Akademik Yayıncılık; 2020.
41. Forshaw JM. Parrots of the world.3rd ed. NHBS,UK. Lansdowne Editions; 1989.
42. Juniper T, Parr M. Parrots: A Guide to Parrots of the World. London:Christopher Helm Publisher; 1998.
43. Warburton LS. The ecology and conservation biology of the Black-cheeked Lovebird Agapornis nigrigenis in Zambia. (Doctoral dissertation); 2003.
44. Selman RG, Hunter ML, Perrin MR. Rüppell's Parrot: status, ecology and conservation biology. Ostrich 2000;71:347-348.
45. Symes CT, Perrin MR. Feeding biology of the greyheaded parrot, Poicephalus fuscicollis suahelicus (Reichenow), in Northern Province, South Africa. Emu-Aust Ornithol 2003;103:49-58.
46. Maclean GL. Ornithology for Africa: a text for users on the African continent: University of Kwazulu Natal Press; 1990.
47. Indian Ringneck Parrots. Indian Ring-neck Parrot. [Online]. 2020 [2020 Jan 15]; Available from: www.avianweb.com/indianringneck.html.
48. Carregal RD, Takahashi R. Use of silkworm (Bombyx mori L.) chrysalis meal as a replacement for soyabean meal in the feeding of growing rabbits. Rev Soc Bras Zoot 1987;16:158-162.
49. Martins C, Cullere M, Dalle ZA, Cardoso C, Alves SP, Bessa RJB, Freire JPB, Falcão-e-Cunha L. Incorporation of two levels of black soldier fly (Hermetia illucens L.) larvae fat or extruded linseed in diets of growing rabbits: effects on growth performance and diet digestibility. Czech J Anim Sci 2018;63:356-362.
50. Zotte AD, Cullere M, Martins C, Alves SP, Freire JPB, Falcão-e-Cunha L, Bessa RJB. Incorporation of Black Soldier Fly (Hermetia illucens L.) larvae fat or extruded linseed in diets of growing rabbits and their effects on meat quality traits including detailed fatty acid composition. Meat Sci 2018;146:50-58.
51. Spranghers T, Ottoboni M, Klootwijk C, Ovyn A, Deboosere S, De Meulenaer B, Michiels J, Eeckhout M, De Clercq P, De Smet S. Nutritional composition of black soldier fly (Hermetia illucens) prepupae reared on different organic waste substrates. J Sci Food Agric 2017;97:2594-2600.
52. Gasco L, Dabbou S, Trocino A, Xiccato G, Capucchio MT, Biasato I, Dezzutto D, Birolo M, Meneguz M, Schiavone A. Effect of dietary supplementation with insect fats on growth performance, digestive efficiency and health of rabbits. J Anim Sci Biotechnol 2019;10:4.
53. Kowalska D, Gugołek A, Strychalski J. Evaluation of slaughter parameters and meat quality of rabbits fed diets with silkworm pupae and mealworm larvae meals. Ann Anim Sci 2020;20:551-564.
54. Van Tets IG, Whelan RJ. Banksia pollen in the diet of Australian mammals. Ecography 1997;20:499-505.
55. Smith AP. Diet and feeding strategies of the marsupial sugar glider in temperate Australia. J Ani Ecolo 1982;149-166.
56. Gowsalya T, Kumar J, Stephen S, Betsy CJ. Influence of earthworm meal as alternative protein source in goldfish Carassius auratus. J Aquac Tropics 2016;31:91.
57. Ortega-Salas AA, Reyes-Bustamante H. Initial sexual maturity and fecundity of the goldfish Carassius auratus

(Perciformes: Cyprynidae) under semi-controlled conditions. Rev Biol Trop 2006;54:1113-1116.
58. Keong W. Worms: a potential feed source for cultured aquatic animals. The Adv 2000;3:82-83.
59. Ramu K. Worm Culture's important role. Fish Farmer 2001;15:31.
60. Olivotto I, Di Stefano M, Rosetti S, Cossignani L, Pugnaloni A, Giantomassi F, Carnevali O. Live prey enrichment, with particular emphasis on HUFAs, as limiting factor in false percula clownfish (Amphiprion ocellaris, Pomacentridae) larval development and metamorphosis: molecular and biochemical implications. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 2011;159:207-218.
61. Marcionetti A, Rossier V, Bertrand JAM, Litsios G, Salamin N. First draft genome of an iconic clownfish species (Amphiprion frenatus). Mol Ecol Resour 2018;18:1092-1101.
62. Vargas-Abúndez AJ, Randazzo B, Foddai M, Sanchini L, Truzzi C, Giorgini E, Gasco L, Olivotto I. Insect meal based diets for clownfish: Biometric, histological, spectroscopic, biochemical and molecular implications. Aquac 2019;498:1-11.
63. Davis S, Ramm K, Ju ZY, and Soller F. Insects as a feed ingredient in aquafeeds. World Aquac 2017;9:61-63.
64. Dussault GV, Kramer DL. Food and feeding behavior of the guppy, Poecilia reticulata (Pisces: Poeciliidae). Can J Zool 1981;59:684-701.
65. Fernando AA, Phang VPG, Chan SY. Diets and feeding regimes of poeciliid fishes in Singapore. Asian Fish Sci 1991;4:99-107.
66. Morimoto H, Watanabe Y, Yamashita Y, Oozeki Y. Effects of maternal nutritional conditions on number, size and lipid content of hydrated eggs in the Japanese sardine from Tosa Bay, southwestern Japan. 1994 Oct. 11-14. Paper presented at the Int. Workshop: Survival Strategies in Early Life Stages of Marine Resources. Yokohama Japon; 1994.
67. Suting PS, Mandal SC, Patel AB. Effect of different dietary lipid sources on growth and reproductive performance of guppy (Poecilia reticulata). Isr J Aquac ISR 2013;65:1-6.
68. Adil S, Şişman T, İncekara Ü. An investigation on the growth and reproductive performance of Poecilia reticulata (Peters) (Cyprinodontiformes: Cyprinidae) fed diets with dried insects. Mun Ent Zoo 2014;9:638-644.