Applicability of BSFL products as ornamental fish and bird food

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Context

Valorising organic waste with the Black Soldier Fly Larvae (BSFL) is becoming increasingly popular, especially in lowand middle-income countries. The popularity links to the opportunity of using the harvested BSFL as an alternative to conventional feed. Given the newness of BSFL feed as well as the current processing scale, a promising market for revenue creation is the pet food sector . For Indonesia and other Asian countries popular pets are ornamental birds (OB) and ornamental fish (OF). OF and OB hobbyist and breeders often take part in contests where judges evaluate animals based on their physical appearance and behaviour. Therefore, OF and OB owner carefully select pet food products which could have a positive effect on the animal's behaviour and appearance. BSFL products are still new and their effect is not yet proven. For marketing BSFL products in the Asian pet food sector, thus more information on the effect of BSFL products on OF and OB is needed. To fill this research gap, we tested the applicability of BSFL products as pet food products by evaluating the effect on the animals in a contest-like setting. We looked at the OF and OB development using BSFL products compared to commercial products and then qualitatively evaluated data from an expert panel's subjective blind rating.

Principle of method

Selected OF and OB were fed with various BSFL products and commercial products. Similar to contest ratings, no exact measurements like weight, length, etc. were taken into account, but the animals were rated based on certain attributes like colour, body proportions and activity on a seven-pointscale by an expert panel. We used the principle component analysis (PCA) to analyse how the expert jury perceived the animals fed with different mixtures.

Animal selection

Three popular young OF were purchased: the Asian Arowana also called Arowana, the Siamese fighting fish or so called "Betta fish" and the Flowerhorn cichlid, called just Flowerhorn. Also, two types of baby OB were purchased: the Whiterumped Shama or Murai and the Long-tailed Shrike which is also called Cendet.



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In total four BSFL products have been tested (see figure 2): BSFL Pop (microwave dried BSFL), BSFL Crumble (oven dried and crushed BSFL), BSFL pellets (pellets containing 60% defatted BSFL meal) and BSFL mix (meal mixture containing 20% defatted BSFL meal).

BSFL product selection

The BSFL animals were fed with BSFL products and the control animals with a typically used feed for the respective species. The control feed chosen was based on the expert's recommendation. In pre-trials the most promising BSFL products were selected for each fish and bird species.

Figure 2: BSFL Products from left to right: BSFL pop (microwave dried), BSFL Crumble (oven dried and crushed), BSFL pellets (60% BSFL defatted meal) and BSFL mix (20% BSFL defatted meal).

Feeding trials overview

Table 1 gives an overview of all feeding trials conducted. In total we conducted four OF feeding trials and two OB trials. The number of animals fed with each feed type is listed in Table 1, including the number of animals that passed away during the trials in brackets. The Duration of the trials was based on the normal development time of the animal and on the availability of the expert panel. The Expert panel size was between 6 and 10 experts. For OF4 several BSFL products have been tested in different groups: The control feed (3 fish) was a commercial pellet (50%) combined with a common

worm (50%) and the treatments included either replacement of the worm by BSFL POP (3 fish) or BSFL crumble (3 fish) or the replacement of the pellet (3 fish) with the BSFL pellet. For OB1 and OB2, the birds received a BSFL mix together with BSFL POP. 100% of the feed was replaced with BSFL products for trials OF1, OF2 and OF3, only 50% for trial OF4 and 30% for trials OB1 and OB2. Feed was provided twice a day ad libitum. Fish were kept in aquariums and birds in cages according to the requirements of each species.

Table 1: Overview of all feeding trials conducted. Numbers in brackets indicate animals that passed away during the trial.

Trial	OF1	OF2	OF3	OF4	OB1	OB2
Type of animal	Betta fish	Betta fish	Arowana	Flowerhorn	Murai	Cendet
Duration (months)	2	3	3	2	2	2
Expert panel size	8	10	6	10	10	10
BSFL product	Crumble	Crumble	Рор	Pop, Crumble, Pellet	Mix + Pop	Mix + Pop
% BSFL	100%	100%	100%	50%	30%	30%
Control product	Waterflea	Pellet	Cricket	Pellet + Worm	Control mix + ant snack	Control mix + ant snack
#control	3 (0)	3 (1)	5 (0)	2 (1)	2 (0)	2 (0)
#Crumble	2 (1)	4 (0)	-	3 (0)	-	-
#Pop	-	-	5 (0)	2 (1)	-	-
#Pellet	-	-	-	3 (0)	-	-
#Mix + Pop	-	-	-	-	2 (0)	2 (0)





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Questionnaire development & experts

OF and OB, hobbyist and breeders from the respective communities were invited for a blind rating of the animals. Each animal was rated on a seven-point-scale by each expert for ten attributes for OF and eight attributes for OB. Each attribute was explained and discussed within the expert panel in order to achieve a consensus among the experts. In Appendix A the questionnaires used are listed in Table A.1 for the OF trials and A.2 for the OB trials.

Data analysis

Data collected from all four OF trials was combined in one data set, whereas all ratings per fish were listed in rows and the attributes in columns. The same was done for the OB trials. The mean score for each attribute per animal was calculated. Subsequently, a PCA was conducted using the software R (version 3.6.2) and following results were evaluated: eigenvalues, scree plot, and total variance explained. Based on the number of eigenvalues higher than 1, number of components that explain for most variance (80%) and the position of the knee in the scree plot, the attributes were reduced to a certain number of components, that capture most of the variation within the dataset (Lé & Worch, 2018). Then, the loadings of the attributes on certain components was analysed further with a varimax rotation for OF dataset and an oblimin rotation for the OB dataset. The rotated loadings gave a clear pattern of attributes which describe the extracted components. Finally, the PCA was visualized in a perceptual map, where each animal was presented as a dot in relation to the two extracted components.

Results

Results from the four OF trials are presented in a perceptual map in Figure 3. The PCA extracted two components, which together account for 80% of the variance within the dataset. Component 1 (65.4%) is displayed on the x-axis and compiles attributes related to fish body features, e.g. colour, body proportions or pattern. Component 2 (14.6%) is displayed on the y-axis and attributes related to fish behaviour, like activity or sensitivity had high loading on this component. Each point in the plot represents one fish fed with a certain product, which is indicated by colours. Points in shades of blue represent fish fed with the control feed, and points in shades of red/ yellow stand for fish fed with BSFL products. The distance between points indicates how different the animals were perceived by the expert panel, whereas the differences on component 1 are larger as it accounts for the biggest part of variation in the data.

No clusters can be identified, which means experts did not perceive BSFL fed fish clearly different compared to the control group. The only cluster like group are fish fed by crickets which all scored high on the fish body features component. Some fish fed with BSFL crumble stand out too, and scored very high on body features, meaning those fish were rated especially high on attributes like colour, body proportion or back fin development. Lastly, one BSFL POP fed fish stands out by its lower scoring on fish body features, indicating that this fish's body features were rated lower by the experts.



Figure 3: Perceptual map visualizing PCA results and showing each fish in relation to the component 1 (fish body features) and component 2 (fish behaviour). Different colours indicate different feed products used for the fish.



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Results from the two OB trials are presented with a per-

ceptual map in Figure 4. The PCA extracted also two com-

ponents, which together account for 96.6% of the variance

within the dataset. Component 1 (80.4%) is displayed on the

x-axis and attributes related to the bird feather features as

well as the bird's singing activity have high loadings on this

component. Component 2 (16.2%) is displayed on the y-axis

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and summarises the attributes appetite and body proportions. The position of the birds (dots) on the plot indicate how the experts perceive the birds. BSFL fed birds scored clearly higher for feather features and singing activity. The BSFL feed consisted of a BSFL mix and BSFL POP as a snack, which resulted in a better development compared to the control mix and ant snack.



Figure 4: Perceptual map visualizing PCA results and showing each bird in relation to the component 1 (bird feather features and singing activity) and component 2 (bird appetite and body proportions). Different colours indicate different feed products used for the birds.

Cost comparsion with commercial pet food

Table 2 gives an overview of average sales prices of popular pet food products opposed to the current sales prices of the tested BSFL products. BSFL products have a price advantage over other insect based pet food. However, prices of insect based pet food lie still above the average of the most popular commercial OF pellets and OB mixes. Nevertheless, the price range of OF pellets and OB mixes is wide and there are many high end product options, which lie in a similar or higher price category than BSFL products. The control pellet (Saki Hikari) used in this tiral was 8.2 USD per kg and the baby bird mix (AMS Handfeed Formula) was 19 USD per kg.

Table: 2: Price comparsion of commercial and BSFL pet food products.

Substitute product	Average sales pirce (USD/kg)	BSFL product	Current sales price (USD/kg)
Living insects	15	Fresh / Pop	0.5 / 15
Dried insects	17	Pop / Crumble	15 / 8.6
OB mix	1.5	Mix	11
OF pellet	5.8	Pellet	6.4
Ants eggs	21.4	Eggs / Crumble	53 / 8.6
Insect meal	22.2	Mix / Meal	14

Conclusions

None of the tested BSFL products negatively affected the animal's appearance. BSFL crumble showed even an improved effect on the fish's appearance compared to the control feed. BSFL crumble was the only product that could score higher on fish appearance than the best rated control animals fed with crickets. Crickets are like BSFL products insect based feed. Insects in general seem to be promising feed products for OF, which lead to a good body development. The BSFL POP and BSFL pellet fed fish were perceived similarly compared to fish fed with the waterflea or commercial pellets. The BSFL mix together with the BSFL POP had a positive effect on the bird's feathers as well as the bird singing activity. BSFL products are in the same price category as other insect based feed, but higher than commercial mainstream pellets. All these results show that the four tested BSFL products are applicable for the popular ornamental fish, "Arowana", "Flowerhorn" and "Betta fish" as well as the popular singing birds "Murai" and "Cendet" and can compete with high end commercial products.

References

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Annex A.1

Table: 2: Questionnaire for expert panels rating ornamental fish: «Betta fish», «Flowerhorn» and «Arowana».

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Question	Explanation	
The fish has healthy colour	1 – weak colors	
	7 – very strong colors	
The fish has rare pattern	1 – no pattern	
	7 – very rare pattern	
The fish skin color is shinny	1 – the skin is not shinny at all	
	7 – the skin is very shinny	
The fish body length looks good	1 – abnormal length of the body	
	7 – perfect body length	
The fish body proportion looks good	1 – abnormal body proportions	
	7 – perfect body proportions	
The back fin (Betta fish) / forehead (Flowerhorn)	1 – not fully developed body part	
/ mustache (Arowana) looks good	7 – very good developed body part	
The fish is fat	1 – fish is very skinny	
	7 – fish is very fat	
The fish is active	1 – fish is not active, sluggish	
	7 – fish is very active	
The fish has a good self-defense (Betta fish,	1 – The fish seems very week	
Flowerhorn) / aggressiveness (Arowana)	7 – The fish is ready to fight	
The fish has a good sensitivity	1 – The fish has week reactions	
	7 – The fish has strong reactions	

Annex A.2

Table: 3: Questionnaire for expert panels rating ornamental birds: «Murai» and «Cendet».

Question	Explanation		
The birds feather have a healthy color	1 – weak colors 7 – very strong colors		
The birds feather developed well, look healthy	1 – not developed well, unhealthy 7 – very well developed, healthy		
The birds feather color is shinny	1 – the feathers are not shinny at all 7 – the feathers are very shinny		
The birds singing voice is clear	1 – voice is not clear and nice 7 – voice is very beautiful		
The fish body proportion looks good	1 – abnormal body proportions 7 – perfect body proportions		
The bird is fat	1 – bird is very skinny 7 – bird is very fat		
The bird is active	1 – bird is not active, sluggish 7 – bird is very active		
The bird has a good appetite	1 – The bird has no appetite 7 – The bird has a lot of appetite		
The bird has a good sensitivity	1 – The bird has week reactions 7 – The bird has strong reactions		