# PROMOTING SUSTAINABLE ANIMAL FEED: BLACK SOLDIER FLY LARVAE

## EXPERIMENTATION RESULTS

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KOPERNIK

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## SUMMARY

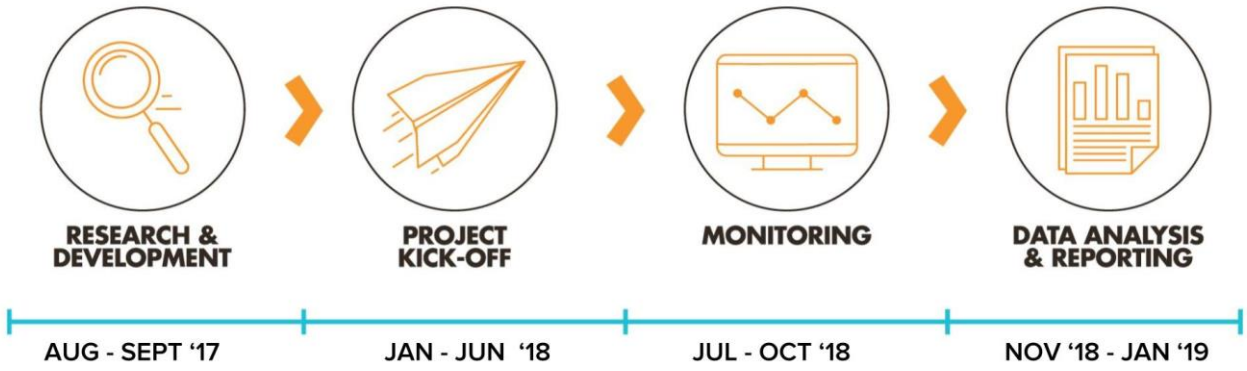
A sustainable alternative for duck feed is important for duck owners in Bali. The most common duck feed is a mix of bran (rice husk, corn and other grain) as the carbohydrate and a concentrate (a protein-based nutritional supplement). Duck owners in Bali do not know how to produce this feed themselves, and rely on sourcing the concentrate from Java, making them vulnerable to excessive shipping fees and price fluctuations.

Black soldier fly larvae (BSF) or *Hermetia illucens* are a harmless species of insect that can provide an alternative protein-based feed for animals, including ducks. The larvae converts organic waste to a rich fat-based protein, reducing organic waste accumulation by approximately 50 percent as well as eliminating house flies. In this experiment, Kopernik partnered with Made Kusuma from the Black Soldier Fly Farm Bali to rear the BSF and feed the ducks with various feed compositions. Control A were given bran + concentrate, Control B were given bran + vegetable waste, Treatment A were given bran + the equivalent grams of BSF larvae, and Treatment B were fed with bran + double the grams of BSF larvae. We investigated whether the BSF larvae was a compatible alternative to the currently used concentrate for duck feed by measuring a) the weight of the ducks for each feed composition over a 40-day period, b) the nutritional content of the BSF larvae, and c) the economic viability of the solution.

The results showed that:

- The ducks fed bran and double quantities of BSF larvae were the heaviest among all groups, with an average weight of 1.57kg on day 40 (compared to bran and concentrate with an average weight of 1.45kg);
- The BSF larvae were more nutritious than the common concentrate used by farmers with 61 percent protein content, 27 percent fat, and 31 percent crude fiber (compared to 37-39 percent protein, 2-3.5 percent fat, and 6 percent crude fiber for the concentrate);
- Rearing BSF is more economical than buying concentrate, provided duck owners have at least 140 ducks (over a 40 day period) to offset the initial investment to build the BSF facility as well as additional labor costs required to maintain it.

# TIMELINE




# CONTEXT

Duck owners in Bali currently have only one option for duck feed, a mix of bran (made from rice husks, corn and other grains) and concentrate (a protein-based nutritional supplement). Duck owners report this as problematic for two primary reasons. First, large-scale duck owners in Bali do not have the know-how to produce this feed[1] and must purchase it from outside Bali, meaning that they are left vulnerable to inconsistent sourcing, excessive shipping fees, and price fluctuations when there is a supply disruption. Secondly, the bran and concentrate is expensive, affecting their duck farming profit. The concentrate costs approximately IDR400,000 (~US$27.96) per 50kg sack (or about IDR8,000 or ~US$0.56 per kg), while bran costs IDR4,000 (~US$0.28) per kg. To breed healthy ducks, ducklings need a diet containing 18 percent protein at two weeks of age which is then reduced to a 16 percent protein diet at five weeks[2]. Protein significantly impacts the ducks' productive and reproductive performance[3].

Black soldier fly (BSF) larvae, *Hermetia illucens,* are a harmless species of insect that is common to tropical and warmer temperate regions. Since adult BSF do not feed, or even have mouths, they are not unsanitary or a carrier of disease. Instead, adult BSF rely on body fat reserves left over from their larval stage[4]. BSF larvae can feed on different waste streams (organic, raw food waste, manure, slaughter waste).

Rearing BSF is considered an efficient way of addressing sustainable consumption and production problems as BSF larvae convert organic waste into a product with a 42 percent protein, 35 percent fat content, reduce manure accumulation by at least 50 percent and eliminate house fly breeding[5]. With essentially no energy requirements, BSF larvae is a very

[1] Based on interview with Pak Gusti, duck breeder in Klungkung on July 26, 2017.
[2] Managing a small duck flock. Agriculture and Agri-Food Canada.
[3] Fouad *et al. Journal of Animal Science and Biotechnology* (2018) 9:1
[4] Feedipedia. Black Soldier Flies (Hermetia illucens), retrieved from https://www.feedipedia.org/node/16388 (August, 2017)
[5] Sheppard *et al.* (1994). A value added manure management system using the BSF.

appealing option as a sustainable, inexpensive, and locally-produced alternative to conventional duck feed as well as a means to reduce organic waste.

In this experiment, Kopernik partnered with Made Kusuma from the Black Soldier Fly Farm Bali to rear the BSF and feed ducks with various feed compositions. We investigated whether BSF larvae is viable as duck feed, by measuring a) the weight of the ducks and b) the nutritional content of the BSF larvae, and c) the economic viability of this solution.

# HYPOTHESIS

We hypothesized that BSF larvae are a healthy and nutritionally comparable alternative protein to the current duck feed used in Bali. We also hypothesized that due to the low production cost of BSF larvae, duck owners would save money compared to sourcing their duck feed from their current suppliers.

# METHODOLOGY

Kopernik rapidly tests innovative solutions in last mile contexts in order to determine their potential to reduce poverty effectively. In these experiments Kopernik adopts a lean approach, collecting and analyzing small-scale data to learn the effectiveness of the solutions. In this project, we compared four duck feed combinations (Figure 1), which are:

- Treatment A were fed bran and the equivalent amount of BSF larvae to meet the same quantity of concentrate;
- Treatment B were fed bran and double the amount of BSF larvae as Treatment A (to explore more variants in the experiment's result);
- Control A were fed bran and concentrate, to replicate the current duck feed practice;
- Control B, were fed bran and vegetable waste, to replicate the usual practice by small, subsistence duck owners.

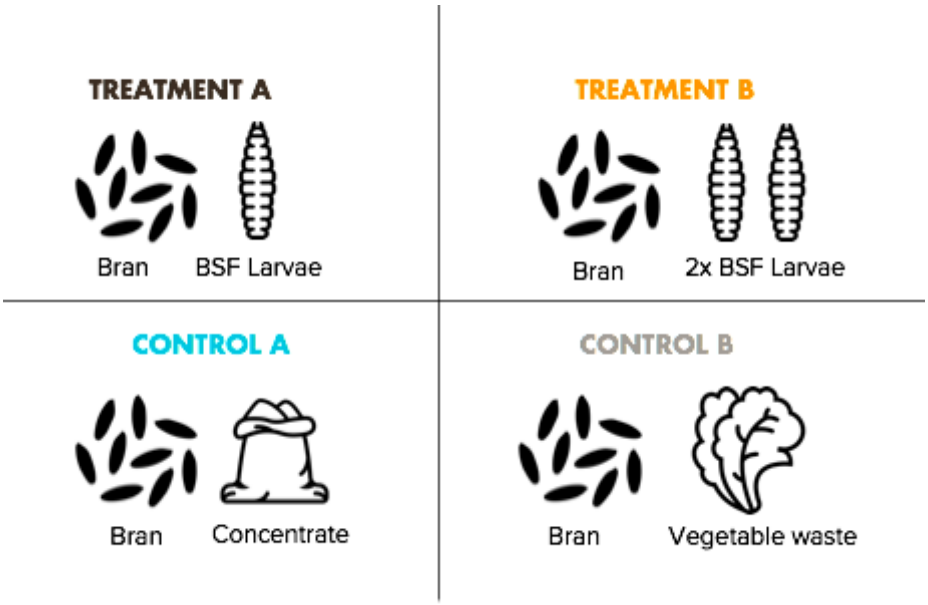



*Figure 1: The feed composition provided to each group in this experiment*

Made Kusuma is a BSF larvae farmer in Bali who partnered with us to rear the BSF and feed the ducks the various types of feed. Each feed combination was fed to 29 ducks. The data was collected every four days for 40 days, the standard time for ducks to grow to maturity and be ready for sale. The indicators measured for each group were, the:

- weight of the ducks;
- different costs for the four varieties of feed[6]; and
- selling price for each duck once they reached maturity.

We also took a sample of the BSF larvae fed to the ducks to measure its nutritional value in the laboratory, gaining a better understanding and context for the experiment's results.

# FINDINGS

## THE WEIGHT OF THE DUCKS

To explore the feeds' effect on the duck's growth, we randomly picked 10 ducks in each group and measured their weight twice a week for 40 days. All the ducks started with the same initial weight of approximately 400 grams. After a week, we found that the ducks' weight in each group started to differ. Control A (concentrate) and Treatment B (double BSF) increased their weight more rapidly compared to Treatment A (normal BSF) and Control B (vegetable waste).

[6] The price of BSF will be calculated based on the cost involved in rearing the larvae from this experiment because there is no current market price for brown larvae BSF that is used as animal feed.

On the tenth day, we found that most of the ducks in Control B (vegetable waste) experienced sickness due to nutrient deficiency. As a result, their average weight had decreased by 25 percent from their initial weight. We also found a duck in that group had died. Considering this situation, we began to add concentrate and BSF to their feed composition. After adding these nutrients to the group's feed their weight began to improve.

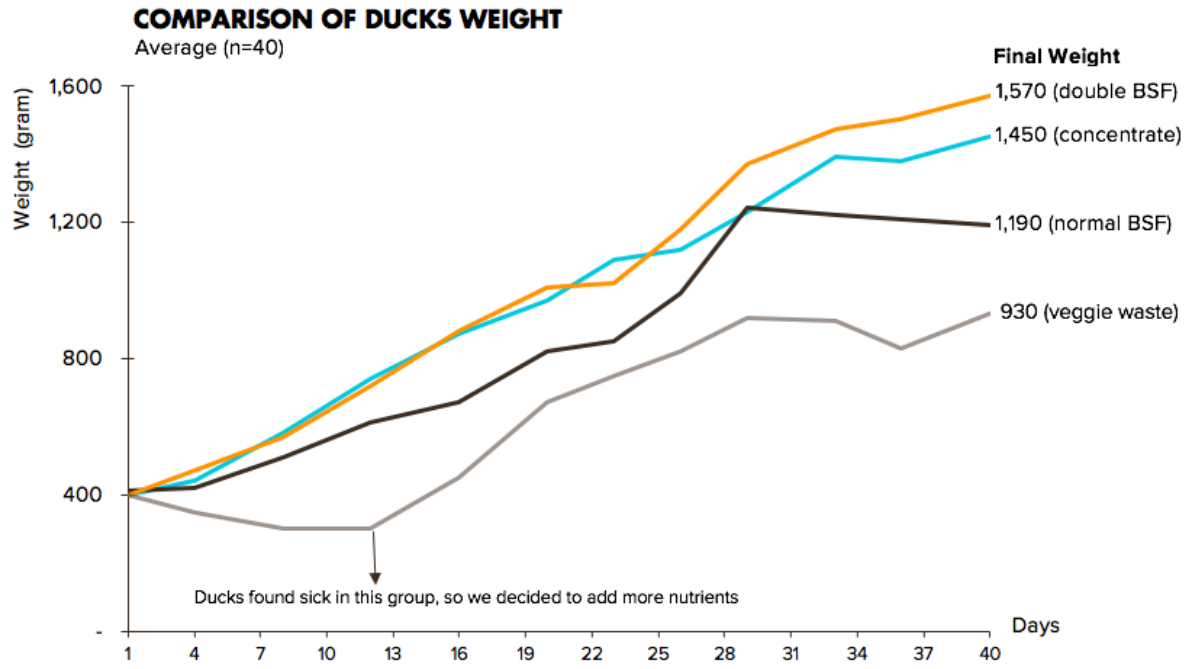



*Figure 2: Comparison of ducks weight across all groups*

In week two, the average duck weight in Control A (concentrate) and Treatment B (double BSF) were heaviest with almost the same weight of 880 grams. However, in week three, the average ducks' weight in Treatment B surpassed the traditional feed group. This pattern continued until the end of the 40 days' data collection period, resulting in Treatment B being the heaviest amongst all groups, with an average weight of 1.57kg as compared to 1.45kg in Control A (concentrate).

When the ducks were sold, our local partner actually received the same price for the ducks from Control A (concentrate), Treatment A (normal BSF) and Treatment B (double BSF) of IDR55,000 (US$3.87) per duck despite their differing weights. This was because our local partner sold the ducks to a middleman who on-sells the ducks to customers who use them as offerings for Balinese Hindu religious ceremonies. These customers are not interested in the weight of the ducks and just choose a duck from its average physical appearance. The ducks in Control B (vegetable waste) looked significantly smaller compared to the other three groups, and the middleman bought those ducks for IDR35,000 (US$2.46). When we investigated further, we found that the situation would be different if our local partner sold the ducks to restaurants, who would be much more careful in assessing the ducks, including their weight.

# COST COMPARISON ACROSS THE FOUR FEED COMPOSITIONS

To investigate costs, we calculated the total amount of feed given to each group:

- Treatment A received 56 kg of bran and 56 kg of BSF larvae;
- Treatment B received 56 kg of bran and 112 kg of BSF larvae;
- Control A received 56 kg of bran and 56 kg of concentrate;
- Control B received 56 kg of bran, 26.5 kg of vegetable waste — since one of the ducks died on day nine, we added 7.8kg of bran and 9.8kg of BSF larvae starting from day 10 to day 40.

Since there is no current market price for BSF larvae that is used for animal feed, we calculated the price of BSF based on the initial investment needed to build the breeding facilities, transportation costs to pick up the organic waste and the labor cost to rear the larvae and maintain the facilities.

We found that Control B (vegetable waste) was the cheapest feed amongst them all, as expected, however, this figure does not take into account the cost of the additional concentrate and BSF larvae we unexpectedly had to give this group due to malnutrition. This group should therefore be discounted from the experiment. Observing the cost in the other three groups, we found that for feeding 29 ducks, Control A (concentrate) cost US$47.04, while the BSF groups 2 and 3 cost US$232.68 (Figure 3), nearly five times more expensive.

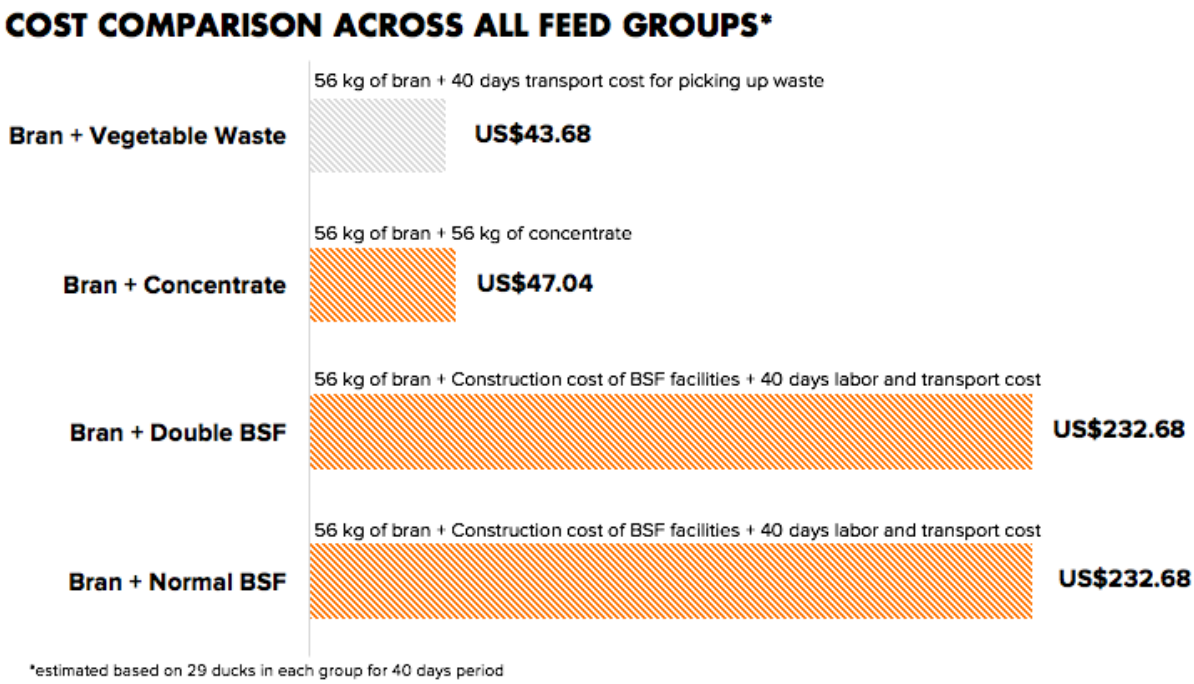



*Figure 3: Costs of feeding 29 ducks in each group for 40 days*

It is important to acknowledge however that while the cost for the BSF groups are indeed more expensive as it includes the initial investment for building the BSF facilities and costs for labor and transportation, this is a once-off cost of investment and would be offset by multiple rounds of breeding. Based on our interviews and observation, it costs a minimum of

IDR1.5 million (US$104.84) to build a simple BSF breeding facility and IDR40,000 for daily labor and maintenance. As well, the transportation costs to collect the waste to feed the BSF were included.

While this seems expensive as an upfront cost, the break-even point is manageable for a duck owner of more than 140 ducks over a 40-day interval, the standard time for ducks to grow to maturity and be ready for sale. At this point, the cost between bran and BSF is equalised (Figure 4). For a small, subsistence, duck owner with less than 140 ducks, BSF will not be immediately profitable due to the bigger initial investment and cost to maintain the facilities. However, over a period of one year, they will recover their costs with only 80 ducks and over six months, with 88 ducks.

The only ongoing cost of BSF larvae production is the cost of transport to deliver the waste needed to feed the larvae. This could be eliminated if the facility is at a location that also produces waste. We can see in Figure 4 that the bran + BSF larvae has a narrower cost line in the graph compared to bran + concentrate, as the additional cost to produce more BSF larvae is much smaller than continuously buying more concentrate to feed more ducks. We should also consider that the cost calculation might be different if a farmer did not employ additional labor to maintain the facility and/or does not have to pay cost to transport the waste.

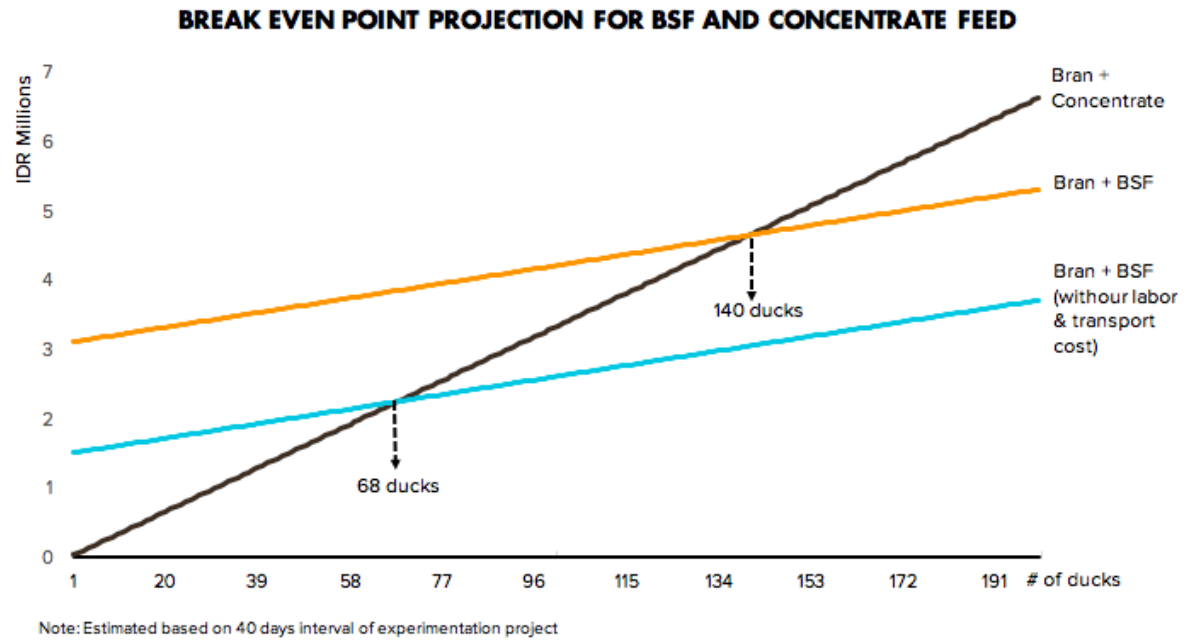



*Figure 4: Projection of number of ducks needed (breakeven point) for BSF costs to equal concentrate*

# PROTEIN TEST RESULTS

To better assess the BSF larvae potential as an alternative animal feed, we commissioned a protein test examining the nutrition content of our larvae. The test was conducted by the Food Engineering Laboratory at Udayana University, Bali. Based on the results, we found that our BSF larvae had 61 percent protein content, 27 percent fat, and 31 percent crude fibre. Another experiment conducted by researchers from Bogor Agricultural University (Institut Pertanian Bogor) found that their BSF larvae had 31 - 34 percent protein content,

and 30 - 34 percent fat content[7]. The difference found in the nutritional content of these two BSF larvae samples might be influenced by the type of waste fed to the larvae. In the same experiment, they also found that the highest larvae growth according to its length, width and body weight resulted from larvae fed organic waste from a restaurant, which included slaughterhouse blood waste[8]. Meanwhile, our BSF larvae were fed pig manure from pigs who eat the organic waste from restaurants too.

We compared the nutrient content found in the larvae with a standard concentrate, the most common brand used by duck owners, “Comfeed”. From the product catalogue, we found that this concentrate contains 37-38 percent protein content, 2-3.5 percent fat, and 6 percent crude fibre[9]. This means our BSF larvae is more nutritious than the traditional concentrate used by duck owners in Bali and the average BSF larvae produced.

**COMPARISON OF NUTRIENT CONTENT BETWEEN BSF LARVAE AND CONCENTRATE**

| Feed Type | Protein | Fat | Crude Fiber |
|---|---|---|---|
| BSF Larvae (%)* | 61 | 26.8 | 30.9 |
| Typical Concentrate (%) | 37-39 | 2-3.5 | 6 |

*based on the laboratory result conducted at Udayana University, Bali

# CONCLUSION

This experiment proves that BSF larvae are a healthy and nutritionally comparable alternative protein to the current duck feed used in Bali. The results of the laboratory test showed that our BSF larvae have 61 percent protein content, 27 percent fat, and 31 percent crude fiber. Meanwhile, the typical concentrate used by duck owners in Bali contains only 37-39 percent protein, 2-3.5 percent fat and 6 percent crude fibre.

In terms of the weight, the group fed with double the amount of BSF larvae (Treatment B) were the heaviest amongst all groups with an average weight of 1.57 kg. This was followed by Control A, fed by concentrate (1.45 kg), and Treatment A, fed by one portion of BSF (1.19 kg). Control B fed by vegetable waste only were on average, 0.93 kg but needed to be supplemented by BSF after day 10. Despite these differences in weight, there was actually no difference in price for the ducks sold from groups 1, 2, and 3. This was because the buyer was a middleman who was selling the ducks as offerings for Balinese ceremonies

[7] Lena Monita • Surjono Hadi Sutjahjo • Akhmad Arif Amin • Melta Rini Fahmi (2017). Pengolahan Sampah Organik Perkotaan Menggunakan Larva Black Soldier Fly (*Hermetia illucens*). Jurnal Pengelolaan Sumber Daya Alam dan Lingkungan, Vol. 7 No. 3 (Desember 2017): 227-234
[8] Ibid
[9] Katalog Pakan Ternak (2009)

and therefore the weight of the duck did not matter. If they were sold to a restaurant however, we assume the weight difference would influence the price.

Acknowledging the initial investment needed to build the BSF breeding facility, ongoing labor costs and the transport cost to obtain food waste to feed the BSF, we found that a duck farmer needs at least 140 ducks to make the cost of feeding their ducks with BSF and bran equal to the cost of feeding them with concentrate and bran for 40 days. This means that for a small subsistence duck farmer who has less than 140 ducks, rearing BSF for their duck feed, may not be immediately economical unless they can minimize the cost of labor and transportation by building and tending the BSF breeding facility themselves and having sufficient waste in their houses to feed the larvae.

**TESTIMONIAL**

*"This experiment helped me to confirm that BSF larvae can be an alternative protein feed for small duck breeders in the villages. I also learned how much quantity of BSF larvae needs to be given to my ducks to obtain a competitive weight compared to the traditional concentrate. In the future, it would be great to explore more on the production cost of rearing BSF larvae in order to give a better recommendation for people who are interested in this solution".*
- Made Kusuma, Founder of BSF Larvae Farm Bali

# RECOMMENDATION

Based on the results of this experiment, Kopernik recommends to:

- Further investigate the viability of adopting BSF larvae as animal feed in an integrated facility that has sufficient waste supply such as an integrated waste bank, hotel, and/or restaurant.