Fractioning of Black Soldier Fly Larvae into protein meal and fat

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Context

Valorising organic waste with the Black Soldier Fly Larvae (BSFL) is becoming increasingly popular, especially in low- and middle-income countries. The popularity links to the opportunity of using the harvested BSFL as an alternative to conventional feed. BSFL protein meal and fat are potential raw materials to include in animal feed products as an alternative protein and fat source. This factsheet provides information on how BSFL can be fractioned into protein meal and fat.

Principle of mechanical fat extraction

BSFL larvae contain around 30% fat based on dry matter. High fat contents may be unfavourable, since standardized animal feeds usually require a low fat content. Moreover, a high fat content makes the product more susceptible to lipid oxidation which can result in unpleasant flavour and texture. Further processing of BSFL into pellets or other processed products may be difficult, as high amounts of fat could cause smearing and blocking of machines. Fractioning results in BSFL protein meal with an enhanced protein content and shelf life as well as BSFL fat. One simple and efficient way to defat BSFL is the mechanical extraction by a screw press typically used in oil extractions of nuts and seeds. The screw press operates at 100°C and squeezes the fat out of the larvae and produces a press cake and a press liquid. After further refining processes, BSFL protein meal is yielded from press cake and BSFL fat from the press liquid

The amino acid profile of BSFL protein meal was analysed for larvae reared on fermented soybean waste and is shown in comparison to soybean meal and fish meal in *Table 1*. The protein content was measured by Kieldahl method using a conversion factor of 6.25. However, several studies suggest using a lower conversion factor due to high amounts of non-protein nitrogen in BSFL such as chitin (Matthäus et al., 2019). Thus, protein contents presented here overestimate the actual protein content.

The fatty acid profile of BSFL fat was tested for larvae reared on fruit waste and is shown in comparison to coconut fat in *Table 2*. The fatty acid composition of BSFL fat is influenced by the waste source used as shown by Ewald et al., (2020). Differences in fatty acid composition has an effect on the consistency of the fat. Higher contents of saturated fatty acids, especially Lauric acid, increases the melting point of the fat. Therefore BSFL fat can be in solid or liquid form at room temperature.

Table 1: Amino acid profile of BSFL, soybean and fish meal

	Unit	BSFL meal[1]	Soybean meal[2]	Fish meal[2]
Crude protein	**%**	**56.00**	**50.00**	**64.50**
Arginine	%	2.09	3.17	3.84
Histidine	%	1.47	1.26	1.44
Isoleucine	%	1.84	1.96	2.56
Leucine	%	2.90	3.43	4.47
Lysine	%	3.33	2.76	4.56
Methionine	%	0.66	0.6	1.73
Cysteine	%	0.10	0.68	0.61
Phenylalanine	%	1.71	2.26	2.47
Tyrosine	%	2.40	1.55	1.88
Threonine	%	1.94	1.76	2.58
Tryptophan	%	0.76	0.59	0.63
Valine	%	2.60	1.93	3.06

[1] BSFL reared on soybean waste (1 replicate), [2] National research council (2012)

Table 2: Fatty acid profile of BSFL fat and coconut fat

Fatty acid	Unit	BSFL fat[1]	Coconut fat[2]
Lauric C12:0	%	50.3	50
Myristic C14:0	%	10.6	16
Palmitic C16:0	%	13.4	8
Palmitoleic C16:1	%	4.0	-
Stearic C18:0	%	2.8	3
Oleic C18:1	%	12	14
Linoleic C18:2	%	3.75	1.75
Linonlenic C18:3	%	1.87	0.2
Saturated fatty acids -	%	77.6	70
Monounsaturated fatty acids -	%	16.7	18
Polyunsaturated fatty acids -	%	5.73	4

[1] BSFL reared on fruit waste (2 replicates), [2] Anon (2001)

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Dry processing versus wet processing

There are two processing pathways for fractioning BSFL using a screw press: dry processing and wet processing which are illustrated in the processing flow chart in *Figure 1*. The overall yield of meal from fresh BSFL is with 17% higher for dry processing compared to 10% for wet processing (see Table 3). The nutritional composition the protein meal is comparable for the two processing pathways, however the fat extraction efficiency tends to be a bit higher for wet processing which results in a higher protein content (see *Table 3*).

Table 3: Processing parameters for dry and wet defatting process of BSFL

Processing parameter	Unit	Dry processing[1]	Wet processing[1]
Moisture content of input material	%	3 ± 1	75 ± 3
Yield of press cake from input	%	68 ± 7	23 ± 5
Yield of press liquid/crude BSFL fat from input	%	29 ± 6	73 ± 5
Moisture content of press cake	%	3 ± 1	59 ± 2
Yield of meal from fresh larvae	%	17 ± 3	10 ± 2
Yield of BSFL fat from fresh larvae	%	3 ± 1	-
Protein (with conversion factor 6.25)	% dm	56 ± 6	59 ± 4
Fat	% dm	14 ± 3	12 ± 3
Fibre	% dm	11 ± 4	12 ± 9
Ash	% dm	12 ± 3	9 ± 2
Carbohydrates	% dm	11 ± 4	12 ± 9

[1] Values presented as mean ± SD of three replicates of fractioning BSFL into protein meal and fat. BSFL were reared on fruit waste. Drying was performed with a microwave.

While for dry processing BSFL are dried before pressing, for wet processing fresh BSFL are directly pressed. Dry processing results in 68% dry press cake and 29% crude BSFL fat. The press cake can be grinded to BSFL protein meal directly and the crude BSFL fat can be further refined by a filtration or decanting step. Fat refining separates the fat from solids, which can account for up to 40% of the mass of crude BSFL fat. Wet processing produces 23% of a wet press cake and 73% of press liquid, which is a mixture of water, solids and fat. Further drying and grinding of the press cake is required to reduce its moisture content and particle size. The separation of the press liquid is more difficult and advanced equipment like a centrifuge would be needed. This process is not covered in this factsheet, however to increase the yield of wet processing a recovery of solids from the liquid fraction would be required.

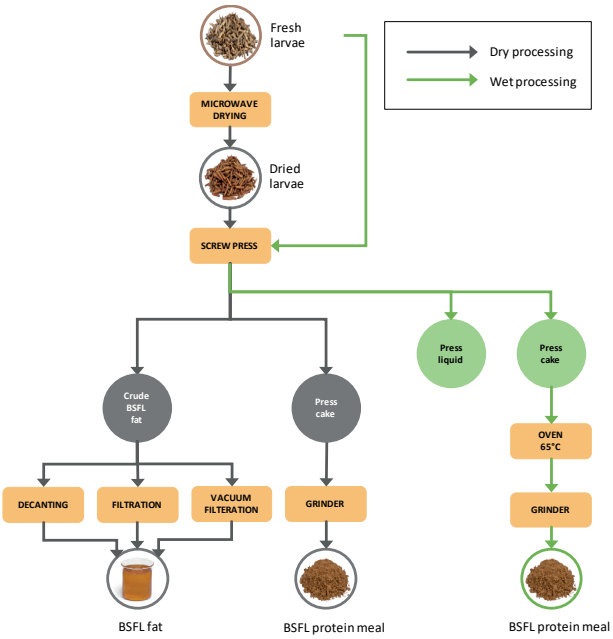

Figure 1: Processing flow diagram for BSFL fractioning

Effect of input material on fat extraction efficiency

Fat extraction from oven dried larvae is less efficient, resulting in a significantly higher fat content of the meal (see *Figure 2*). Reasons for that could the texture and especially the moisture content of the input material (Beerens, 2007). Whereas microwaved larvae have a light texture and puffed shape, oven dried larvae are hard and stiff. The moisture content of oven dried larvae is typically a bit lower, due to long drying times. Low moisture content and hard textures make the cell walls less permeable, which decreases the oil yield.

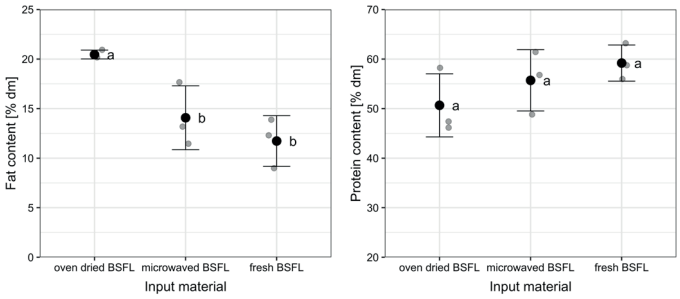

Figure 2: Fat and protein content of BSFL protein meal obtained from pressing oven dried, microwave dried and fresh BSFL. Results with different letters are significantly different from each other with a p-value < 0.05.

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Manual for operating mechanical screw press (wet and dry processing)

The screw press is operated in the same way for wet and dry processing. However, the processing time for fresh larvae takes more time. The microwave dried larvae are very light and easy to press, whereas wet larvae are heavy and not only fat but also water has to be released which increases the processing time. Necessary equipment is listed in *Table 4*.

Table 4: Equipment for BSFL pressing

Equipment	Specifications
Screw press	Model: Vevor DL-ZYJ10B Capacity (dry): 5 kg dried BSFL / h Capacity (wet): 3 kg fresh BSFL / h Power: 2200 Watt
Containers	5 L, stainless steel for press cake 3 L, stainless steel for press liquid
Allen key[1]	-
Scale	Accuracy: +/- 1 g
Heat gloves	-

[1] for dismantling the screw press

Step by step manual for BSFL fractioning (wet and dry processing)

1. Fresh or dried larvae are prepared and weighed
2. The oil-press is turned on (blue switch) and heated up (green button: HEAT) to 100°C
3. The containers are placed under the respective openings: the big container at the end of the screw press and the small container under the opening at the beginning of the screw.
4. Start the screw (green button: SQUEEZE)
5. The larvae are added little by little to the hopper (approximately 100 g at a time).
6. After all larvae are pressed and the release of press liquid and press cake has stopped the machine is stopped (red button: STOP)
7. Empty the remaining material from the press (orange button: CEANING)
8. Weigh the press-liquid and the press-cake

Step by step manual for dismantling and cleaning the screw press (should be done after each usage)

1. Wait until the machine has completely cooled down
2. Loosen the screws of the tube
3. Remove the screw from the outer tube
4. Clean the screw and the tube with water

Manual for drying wet press cake

Wet processing results in a press cake with a high moisture content of around 55-60% and thus, drying is required. It is recommended to dry below 65°C to prevent the loss of valuable nutrients and unfavourable reactions, such as burning. Necessary equipment is listed in *Table 5*.

Table 5: Equipment for drying wet press cake

Equipment	Specification
Oven	Custom, (CV. Tunas Karya, Gas oven)
Gas stove	Model: Rinnai - RI 511 A
Thermostat	Model: TGW IL-80EM
Trays	Dimensions: 65 x 45 x 3.5 cm, Material: stainless steel
Scale	Accuracy: +/- 1 g
Heat gloves	-

Step by step manual for drying wet press cake:

1. Place 4 kg press cake evenly on to each oven tray
2. Dry over night at 65°C for 12-16 hours
3. Collect and weigh the dry press cake
4. Check if the yield is around 40-50%

Manual for grinding dry press cake

To ensure a fine and homogenous particle size of the BSFL protein meal, the dry press cake has to be grinded down to a mesh size of 100 to 200 µm. Necessary equipment is listed in *Table 6*.

Table 6: Equipment for grinding dry press cake

Equipment	Specification
Grinder	Model: AGR-GRP-180
Capacity	60 kg press cake / h
Power	1800 Watt
Container (for collecting meal)	-
Brush(for cleaning)	-
Fabric bag (for collecting dust)	-
Scale	Accuracy: +/- 1 g

Step by step manual for grinding dry press cake:

1. Place a container under the meal outlet and cover the other outlets with a fabric
2. Start the grinder
3. Continuously add dry press cake to the hopper until all is grinded down to meal
4. After usage: clean the inlet and outlet of the grinder using the cleaning brush

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Manual for crude BSFL fat refining

Solids can account for up to 40% of the total BSFL crude fat mass. The solids consist mainly of fat and protein and can be separated from the BSFL fat by a filtration or decanting step. As BSFL fat can be solid at room temperature, refining should be performed directly after pressing when the press liquid is still warm. In a solid state separation of fat from solids is not possible using filtration or decanting.

A) Filtration

Filtration recovers all solids whereas fat passes through a filter. A simple and passive set up using e.g. coffee filters is able to separate the solids from the fat. The filtration process can be supported by a vacuum pump which can increase the filtration speed. Nevertheless, filtration is a slow process which can take up 5 to 15 hours per kg crude BSFL fat. Necessary equipment is listed in *Table 7*.

Table 7: Equipment for BSFL crude fat filtration

Equipment	Specification
Filter	Filter paper pore size: 100 µm
Alternative	Coffee filter
Funnel	Buchner funnel, Alternative: plastic funnel
Container (for fat collection)	Erlenmeyer, Alternative: plastic bottle
Vacuum pump & connection tube	Model: DOA-P504-BN, Cast, Power: 300 Watt
Alternative	no pump, passive filtration
Strainer	Mesh size: 0.5 mm
Scale	Accuracy: +/- 1 g

Step by step manual for filtering crude BSFL fat:

1. Place the filter paper on top of the funnel and place the funnel on top of the Erlenmeyer for collecting the refined fat
2. Connect the Erlenmeyer to the vacuum pump with a tube
3. Wet the filter paper with a little bit of water
4. Pass the crude BSFL fat through the strainer on top of the filter paper and the funnel
5. Turn on the vacuum pump
6. Let the crude BSFL fat filter through
7. Collect the refined BSFL fat and discard the filter paper and residue

Alternative if no vacuum pump is available:

- Use a coffee filter instead of filter paper
- Place the funnel on top of any kind of container and let the fat passively filter through the coffee filter

B) Decanting

As the solids sediment, the BSFL fat can be separated from the solids by decanting. The fat is collected by inserting a tube into the fat fraction. After an initial suction with the aid of a syringe the fat automatically flows via tube into the collection container. This process is quicker compared to filtration. However, unsettled solids are not separated using this methods. Necessary equipment is listed in *Table 8*.

Table 8: Equipment for decanting BSFL crude fat

Equipment	Specification
Tube	Diameter: 0.5 cm, material: plastic
Syringe Material	plastic
Container (for fat collection)	plastic bottle
Scale	Accuracy: +/- 1 g

Step by step manual for decanting BSFL fat:

1. Place the crude BSFL fat on a table
2. Place an empty container for the refined BSFL fat collection on a lower level, e.g. on the floor
3. Attach the syringe to one end of the tube
4. Place the other end of the tube in the upper layer of the crude BSFL fat
5. Induce suction by pulling the syringe
6. Remove the syringe and let the fat flow into the collection container
7. The tube end inserted in the crude fat is lowered constantly until the settled solids are reached and the process is stopped

References

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Illustration - Screw pressing of BSFL

Figure 3: Screw pressing of BSFL (A) into press cake and press liquid (B) and further grinding of press cake into BSFL protein meal (C).

Illustration - Oil refining options

Figure 4: Oil refining options: A) Passive filtration set up, B) Filtration set up using a vacuum pump, C) Decanting set up