Small-scale drying methods for Black Soldier Fly Larvae

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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 a source of protein and fat for animal feed as an alternative to conventional feed. For easier storage, transport and selling, further processing of the harvested BSFL such as sanitizing, drying and defatting may be required. This factsheet provides detailed manuals for four simple drying methods using small-scale and low-cost equipment.

Principle of drying

Freshly harvested BSFL contain ± 70% water and ± 30% dry matter and have a high water activity of 0.9. Water activity is a measure for the free water in the product which is available for microorganism, whereas a water activity lower 0.6 inhibits growth of any bacteria and yeasts (Man, 2002). The high water activity make the fresh larvae highly susceptible to lipid oxidation, enzymatic degradation and microbiological spoilage (Rahman, 2007). Removal of water and thereby reducing water activity inhibits microbial and enzymatic activity and thus, makes the product storable. By evaporation of water, the remaining nutrients in the product become more concentrated, which means dried larvae have a higher protein content compared to fresh larvae (see *Table 1*).

Table 1: Quality parameters for fresh and dried BSFL

Quality parameters	Unit	Fresh larvae[1]	Dried larvae[1]
Protein (with conversion factor 6.25)	%	10.2 ± 1	36.4 ± 5
Fat	%	7.2 ± 2	36.2 ± 5
Fibre	%	3.2 ± 1	13.5 ± 4
Ash	%	1.8 ± 0.5	7.0 ± 4
Carbohydrates	%	1.4 ± 1	6.2 ± 2
Moisture content	%	76.5 ± 3	2.6 ± 0.8
Water activity	-	0.9 ± 0	0.4 ± 0.1

[1] Mean ± SD of three replicates of BSFL reared on fruit waste

Mass balance as process control

The percentage output yield of dried larvae in relation to fresh larvae is an important measure for controlling the drying process. The percentage output yield is the mass of dried larvae divided by the mass of fresh larvae and lies typically between 25-35%. The 70% mass reduction is the result of water evaporation. A lower reduction and thus an output yield higher than 35% implies that the drying process is not yet completed.

Dried BSFL products

Sensory aspects of the dried larvae are one key aspect that determines its market value, especially for the pet food market. Characteristic texture and shape of the end-product depends on the drying technique applied. During rapid dehydration, the water within the larvae evaporates quickly, which leads to a pressure build up within the larvae and ultimately to an instantaneous pressure release resulting in puffed and crispy larvae. During slow dehydration processes the water evaporates slowly and the larvae shells shrink steadily until a constant weight is reached. This end product is less voluminous, and its texture is hard and stiff. The more bulky and voluminous product obtained by rapid dehydration is more appealing to customers and thus has a higher market value. An example of fresh larvae as well the two type of products is shown in *Figure 1*.

Fresh larvae

Slowly dehydrated larvae

Rapidly dehydrated larvae

Figure 1: fresh BSFL, slowly dehydrated BSFL and rapidly dehydrated BSFL

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Overview of different drying methods

Table 2: Process related parameters of different drying methods

Parameter	Microwave heating	Sand roasting (pan)	Sand roasting (drum)	Oven heating
Output shape	Crispy, puffed	Crispy, puffed	Crispy, puffed	Hard, stiff
Output colour	Yellowish	Yellowish/brown	Yellowish/brown	Dark brown
Output bulk density	110-130 g/l	110-130 g/l	110-130 g/l	220-230 g/l
Energy source	Electricity	Gas	Gas	Gas
Heat medium	Electromagnetic waves	Sand	Sand and hot air	Hot air
Material temperature	Max. 180°C	Max. 180°C	Max. 150°C	Max. 65°C
Batch size	0.25 kg	0.7 kg	4 kg	30 kg
Drying time	15 minutes	15 minutes	30 minutes	24 hours
Throughput	0.9 kg/h	2.5 kg/h	6.2 kg/h	1.2 kg/h
Space usage	0.4 m^2	0.4 m^2	2 m^2	1 m^2
Energy usage / kg dried larvae	3'700 Watt	0.9 kg LPG gas	0.7 kg LPG gas	0.7 kg LPG gas
Investment	Very low	Very low	Medium	Low
Labour	High	High	Medium	Low

Table 2 compares four drying methods in terms of several process related parameters. Microwave heating and sand roasting are fast dehydration processes whereas oven heating is a slow dehydration process ant thus, leading to a different and less attractive product in terms of shape, colour and bulk density. But oven heating is a passive process which does not require high labour or investment. Microwave heating results in a high-quality product, is an efficient process and investment and space usage are very low. The downsides are high labour and electricity costs as well as the small batch size. The products of sand roasting and microwave are comparable, but the colour of sand roasted larvae is typically a bit darker due to the roasting. Moreover, some sand might remain in the product after sieving. Sand roasting can be done in a very small-scale application using a pan, which is labour intensive, but investment and space usage are very low. Sand roasting is also possible in a rotating drum, which leads to a higher throughput and thus increases the efficiency of gas usage and labour time, however higher investment and more space are required.

Option 1: Microwave heating

Microwave heating results from the conversion of electromagnetic energy to thermal energy by the increased motion of water molecules inside the fresh larvae (Berk, 2009). The water inside the larvae is turned into steam rapidly which increases the vapour pressure on the larvae shell until the larvae puffs. However, excess steam generated during the process can lead to damp and non-puffed larvae. This can be prevented by drying in 3 cycles of 5 minutes with a short break in between for letting the steam escape. Equipment necessary is listed in *Table 3*.

Table 3: Equipment for microwave drying BSFL

Equipment	Specification
Kitchen microwave	Model: NNST651MMPQ - Panasonic
Volume:	32 L
Power:	1000 Watt
Microwave plate	Diameter: 30 cm
Scale	Accuracy: +/- 1 g
Heat gloves	-

Step by step manual for microwave heating:

1. Weigh 250 g fresh larvae
2. Add fresh larvae on to a ceramic plate and distribute evenly
3. Microwave cycle 1 - 5 minutes - at highest power (1000 Watt)
4. Open the microwave for 20 seconds and let the steam escape
5. Microwave cycle 2 - 5 minutes - at highest power (1000 Watt)
6. Open the microwave for 20 seconds and let the steam escape
7. Microwave cycle 3 - 5 minutes - at highest power (1000 Watt)
8. The drying process is completed when the following indicators are true for the majority of the larvae:
   - o crispy texture
   - o puffed shape
9. If not all indicators are true start microwave cycle 4: 2-3 minutes – at highest power (1000 Watt)
10. Remove larvae from the microwave
11. Weigh the dried larvae
12. Check if the yield lies within the accepted range: 25-35%

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Option 2: Sand roasting in a pan

Sand roasting is a traditional technique widely used by street food vendors and villagers in Asian countries like India, Indonesia or China for making value-added snacks from cereals or nuts. The heat energy is transferred via conduction using sand as a heat medium (Kora, 2019). The sand prevents burning and uneven heating, but functions as an efficient heat transfer medium. This method can be applied as a fast dehydration method for BSFL. Equipment and materials necessary is listed in *Table 4*.

Table 4: Equipment and material for sand roasting BSFL in a pan

Equipment & materials	Specification
Wok pan	Material: stainless steel / aluminium
Diameter	30 cm
Gas stove Model	Rinnai - RI 511 A
Stirring spoon	Material: stainless steel / heat safe plastic
Metallic strainer	Material: stainless steel
Mesh size	4 mm
Sand	Size: 0.8-1.5 mm
Scale	Accuracy: +/- 1 g
Heat gloves	-

Step by step manual for sand roasting in a pan:

1. Preheat 700 g of sand in a wok pan for approximately 15 minutes, until the sand reaches a temperature of 200°C
2. Add 700 g of fresh larvae
3. Roast the larvae under continuous stirring for approximately 15 minutes
4. The drying process is completed when the following indicators are true for the majority of the larvae:
   - o crispy texture
   - o puffed shape
5. Separate the larvae from the sand using a metallic strainer
6. Weigh the dried larvae
7. Check if the yield lies within the accepted range: 25-35%

Figure 2: Sand roasting in a pan using direct fire as heat source.

Option 3: Sand roasting in a drum dryer

The same concept as for sand roasting in a pan is used for sand roasting in a drum. The design of the drum is similar to a coffee or nut roasting drum dryer. The rotating drum is heated directly from the bottom. A mesh layer inside the drum separates the larvae from the sand. Only by starting the rotation, the sand will be continuously mixed with the larvae. The heat is transferred from the burner to the drum and then to the sand and the air within the drum. Via sand and hot air the heat is transferred to the larvae. By stopping the rotation, the larvae are removed from the mesh while the sand remains in the drum. Dried larvae are sieved to separate remaining sand attached to the larvae. Equipment and materials necessary are listed in *Table 5*.

Table 5: Equipment and material for sand roasting BSFL in a rotating drum.

Equipment & materials	Specification
Drum dryer	Custom (CV. Dempo Laser)
Gas stove	Type: NP-burner
Ladle	Material: stainless steel
Sieve	Dimensions: 20 x 30 x 5 cm
Material	stainless steel
Sand	Size: 0.2-0.5 mm
Scale	Accuracy: +/- 5 g
Heat gloves	-

Step by step manual for sand roasting in a drum dryer:

1. Preheat 6 kg of sand in the rotating drum
2. Stop the rotating motor and add 4 kg of fresh larvae
3. Start the rotation again and roast the larvae for approximately 30 minuets
4. The drying process is completed when the following indicators are true for the majority of the larvae
   - o crispy texture
   - o puffed shape
5. Scoop out the dried larvae using a ladle
6. Separate remaining sand from the dried larvae using a sieve
7. Weigh the dried larvae
8. Check if the yield lies within the accepted range: 25-35%

Figure 3: Rotating drum with (A) and without (B) removable mesh cylinder.

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Option 4: Oven heating

Oven heating uses hot air as a heat medium and larvae are slowly dehydrated at 65°C. Low temperature drying prevents the loss of valuable nutrients and baking or burning of the larvae. The larvae have to be killed before the process, e.g. by rapid boiling. To ensure even heating inside the oven a fan is recommended. If this is not sufficient, shuffling of trays during the drying process is required. Necessary equipment is listed in *Table 6*.

Table 6: Equipment for oven drying BSFL

Equipment & materials	Specification
Oven	Custom, (CV. Tunas Karya, Gas oven)
Gas stove	Model: Rinnai - RI 511 A
Thermostat	Model: TGW IL-80EM
Mesh trays	Dimensions: 65 x 45 x 3.5 cm, Mesh size: 4 mm
Scale	Accuracy: +/- 1 g
Heat gloves	–

Step by step manual:

1. Add 3 kg of freshly boiled larvae to each of the 10 mesh-trays
2. The larvae are dried during one night phase of 16 hours and two day phases of each 4 hours
3. The trays are shuffled in between phases according to the schedule bellow (see *Table 7*)
4. The process is completed when the following indicators are true:
   - o hard and dry texture
   - o shrunken shape
5. Weigh the dried larvae
6. Check if the yield lies within the accepted range: 25-35%

Table 7: Recommended shuffling schedule for oven heating

Tray	Position night phase	Position day phase 1	Position day phase 2
	16 h	4 h	4 h
A	10	6	8
B	9	7	3
C	8	1	4
D	7	9	5
E	6	10	2
F	5	3	9
G	4	2	1
H	3	8	10
I	2	4	6
J	1	5	7

Figure 4: Static gas oven

References

Berk, Z. (2009). Chapter 3 - Heat and Mass Transfer, Basic Principles. In Z. B. T.-F. P. E. and T. Berk (Ed.), *Food Science and Technology* (pp. 69–113).

Kora, A. J. (2019). Applications of sand roasting and baking in the preparation of traditional Indian snacks: nutritional and antioxidant status. *Bulletin of the National Research Centre, 43*(1), 1-11.

Man, D. (2002). *Food industry briefing series: shelf life.* London: Blackwell Science Ltd.

Rahman, M. S. (2007). *Food preservation: overview. In Handbook of food preservation* (pp. 3-17). Boca Raton, FL: CRC Press.