Process efficiencies in black soldier fly larvae composting

– Evaluation of process parameters of food industry waste treatment using Hermetia illucens

Tobias Eisert

Swedish University of Agricultural Sciences, SLU
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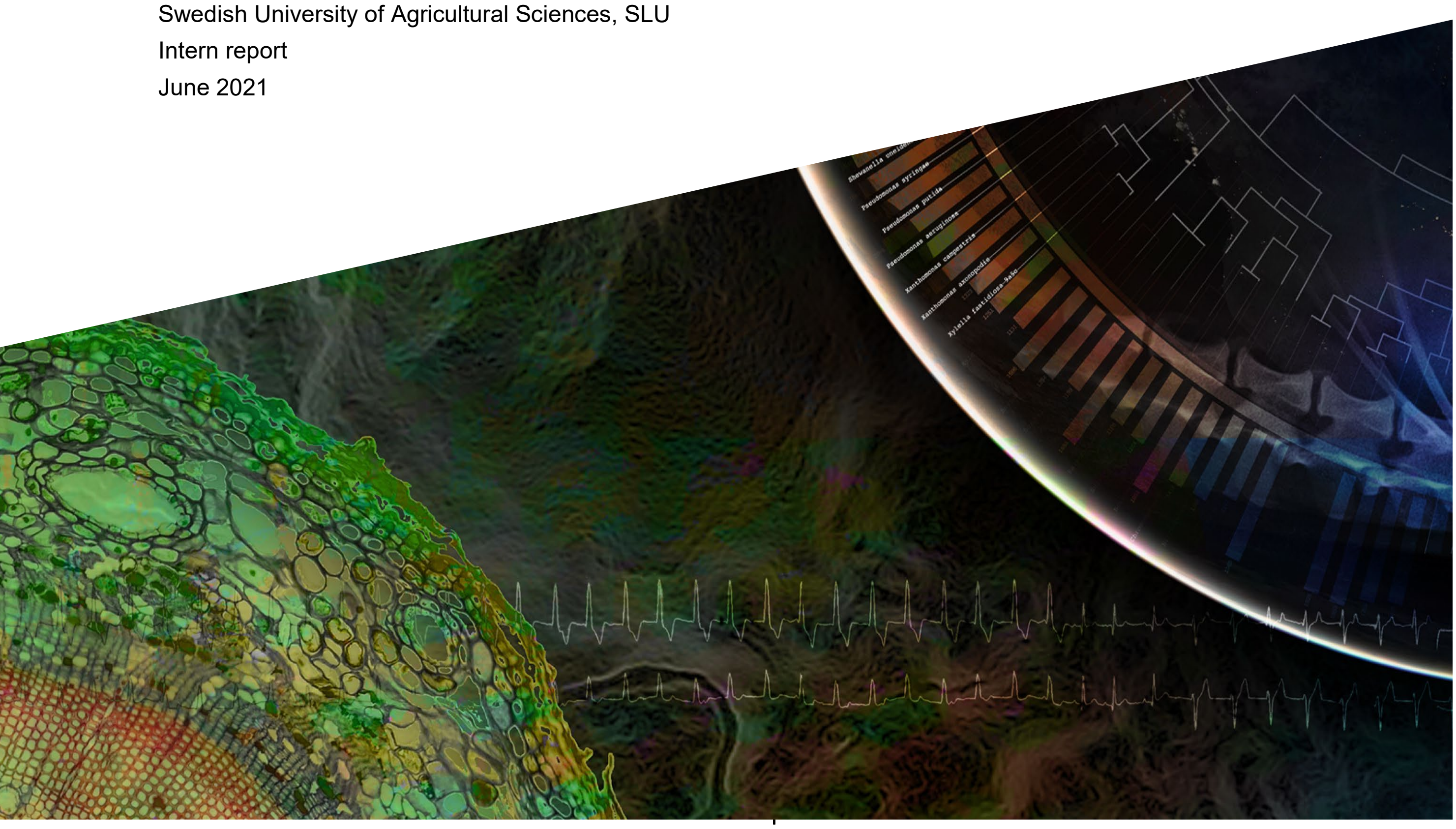

Abbreviations

Denotation	Unit	Explanation
BSF		Black soldier fly
m	g	Mass
TS	g / %	Total solids
VS	g / %	Volatile solids
WW	g / %	Wet weight
5TFiD		5 ton fisk i disk (5 ton fish in the counter)
SLU		Swedish University of Agriculture Sciences
Trial I		Feeding for box 1 – 18 (before change of feeding)
Trial II		Feeding for box 19 – 30 (after change of feeding)
L		Larvae
R		Residue
S		Substrate (Feeding: bread and vegetables)
BCE	%	Bioconversion efficiency

Comment:

In this report are commas used to separate decimal numbers and not points.

1. Introduction

The world population is growing, and mankind produces more and more organic waste. In addition, the world population is getting wealthier which leads to even more waste. 44% of the waste is green waste or food waste (Kaza et al. 2018). There are different options to reuse organic waste. Producing biogas or composting are just some of them. This report is focusing on the reuse of waste from food industry. There are various examples where this kind of waste occurs. In Sweden exists an agreement which is called the take back agreement. This arrangement between the industry and the stores causes return rates in bigger supermarkets of 5-6 % and in small stores up to 14 % (Alisher Ismatov 2015). Most of the bread would still be fine to eat as it is before the best before date but the agreement forces to take back the bread that was not sold.

In the future, the fish supply cannot be the same as it was until now. The fish stocks are in danger and the demand is rising. Aquaculture is one response to the declining fish stocks. But still aquaculture is not automatically sustainable, as it is polluting the waterbodies with nutrients, chemicals, and pharmaceuticals (Jon Olaf Olaussen 2018). Another big issue is the feed in aquacultures which is often soy, cereals, or wild caught fish. All these mentioned fish feed are standing in concurrence with the food production for the growing world population (Njord 2021) and this is leading to price increases (Wang and Shelomi 2017). The fish industry is today looking for alternatives to replace the traditional feed for aquaculture production and Black soldier fly (BSF) larvae meal and oil are considered as a good alternative due to the high protein (42 %) and fat (29 %) content (Wang and Shelomi 2017). The residues can be used to improve the soil quality in horticulture (Wang and Shelomi 2017).

The biggest advantage of Black soldier fly larvae compared to other insects is the capability of converting waste into something valuable while closing nutrient loops and reducing pollution and costs. They can be fed with many materials from food waste to manure and convert in waste available nutrients into valuable insect biomass (Wang and Shelomi 2017).

Black soldier fly larvae are tropical insects and require a temperature of 27 – 32 °C for an optimal efficiency (Da Silva and Hesselberg 2020). In a climate like in Sweden, a controlled environment is needed as earlier trials of the Black soldier fly group at the Swedish University of Agricultural Sciences (SLU) showed. Without a controlled environment, the efficiency was unreliable. Possible solutions could be mobile treatment facilities with a climate regulation.

The purpose of this report was to provide insights into the impact of different temperatures on the treatment efficiency of Black solider fly larvae compositing; first to assess the differences within a mobile treatment facility and then to evaluate the impact on the treatment process. A second focus was on the impact in changing the composition of the input into the treatment on the process efficiency.

2. Background

Hermetia illucens (Diptera: Stratiomyidae) has its origin on the American continent and migrated then throughout the subtropics and tropics between 45 °N and 40 °S (Diener 2010). One advantage of the Black soldier fly is that the adult fly (Figure 1b) does not eat and only relies on body fat. This means that *Hermetia illucens* is not considered a vector for diseases (Diener 2010).

The adult black soldier fly (*Hermetia illucens* L.; Diptera: Stratiomyidae*)* is ready to mate two days after emerging from the pupal case. The following days, the female lays between 500 and 900 eggs near or in organic waste. The eggs need around four days to hatch. The hatched larvae need 13 to 18 days to pass through all six instars (Figure 1a). In sub-optimal conditions, including feed intake and temperature, it can also take longer as the larvae adapt to the available food amount and adjust their growing rate. The finished larvae are now dispersing from the feed and search for dry sheltered sites. The skin darkens and within develops a pupa. The prepupal stage takes roughly 7 days. For the pupation process around 14 days are needed. The adult fly relies on the fat stocks of the larvae state and only needs water (Diclaro II and Kaufman 2009).

a) b)

Figure 1. Pictures of a) black solider fly larvae in bread-vegetables substrate b) the adult stage.

2.1. Aim

The purpose of this study was to determine the impact of the temperature and the composition of the feeding on the process efficiency of Black soldier fly composting by using food industry waste as substrate.

3. Methods and materials

3.1. Materials

The experiments took place in a container which is used for Black soldier fly larvae production and the data were collected in the running treatment process. The container was standing in Uppsala on the campus of the Swedish University of Agricultural Sciences.

The feed used in the treatment was reclaimed bread and vegetables cuttings both waste from food industry.

The treatment itself took place in plastic boxes which were open on the top. The boxes were then put into special racks leaving 3 cm between the boxes to allow air flow. In each stack fit 11 boxes. The size of the boxes was 56 x 37 x 12 cm.

The hatchlings / young larvae for the larvae biomass production were produced in the in the laboratory of the Environmental Engineering group for BSF research.

3.2. Methods

The project with the name "5 ton of green fish on the counter" is aiming to produce at least 5 ton of environmentally friendly rainbow trout by using nutrient streams that already exist, means without importing any new nutrients into the Baltic basin. At the same time, the project is supporting the development of recycle-based feed and the circular economy in Sweden (SLU 2021).

The Black soldier fly larvae for the project were produced in a mobile treatment facility in Uppsala on the campus of SLU. The container had a full climatization to allow an efficient treatment. As the Black soldier fly is a tropical insect, the required conditions could not be met without a heating and isolation in Sweden.

In the beginning of each treatment were 15000 hatchlings added to each box. To count the larvae, 3 small samples were counted and with the weight and the number of the samples the weight per 15000 larvae was calculated.

For the assessment of the process efficiencies, in total 30 treatment boxes of the production in the container have been analysed in the laboratory and followed up (Figure 2). Temperature and humidity were measured over the boxes every 5 min during the whole treatment time of roughly 14 days. The used sensor was Tinytag.

Before the experiment started, a naming system was set up to keep track of the location in the box in the treatment place and to see if placing the boxes close to the door or to the ventilation influenced it.

Figure 2. Picture of the stacks in the container.

The bottom boxes were named with location of the stack in the container and an ‘a’ in the end. The same applies for the middle box and the top box. Inside the container the aimed temperature was 27 °C and the relative humidity below 40 %.

As a pre-treatment, the bread (Figure 3b) and the vegetables (Figure 3c) were milled with a milling machine (Figure 3a). This was done to get a homogeneous material to lower the variation of the input and to get a residue that is better for the sieving process.

a) b) c)

Figure 3. Picture of a) the milling machine; b) the milled bread; c) milled vegetables.

To get a closer look at the input, samples of the bread and the vegetables were taken. Total solids and volatile solids content were calculated.

To define the accuracy of the feeding, 30 boxes were weighed and compared with the theoretical calculated feed load.

The hatchlings were added to the treatment boxes which contained already the first feeding. For the experiments, 30 boxes were run and analysed in total. The first 18 (box 1 – 18), so 6 stacks, were called trial I, the other 12 boxes (box 19 – 30), so 4 stacks, were called trial II. Trial I and trial II got different feedings as displayed in Table 1.

In trial I, were 6 boxes per position analysed (in total 18 for trial I) and in trial II were 4 boxes analysed per position (in total 12 for trial II).

For the feeding of the bread and the vegetables, a scoop of roughly 1 L was used. By doing samples an average weight per scoop of bread and vegetables was determined. This simplified the feeding process very much as it could be done by counting the scoops instead of weighting the feed at each time.

Table 1. Input in wet weight [g] and numbers [#]. Feeding of trial I and trial II. Composition of feeding 1, 2, and 3.

	Bread	Vegetables	Total	Larvae [#]
Box 1 – 18 (I)	5524	5598	11122	15000
Box 19 – 30 (II)	4603	6531	11135	15000
Feeding 1 (I)	3175	3217	6392	
Feeding 1 (II)	2116	4290	6406	
Feeding 2 (I+II)	1587	1609	3196	
Feeding 3 (I+II)	1587	1609	3196	

Feeding 1 was done the same day as the larvae were added. Feeding 2 and feeding 3 took place usually around day 7 for feeding 2 and on day 9 for feeding 3.

The ventilation-dehumidifying system was necessary to avoid escaping of the larvae because with high air humidity the larvae could crawl on the walls of the boxes. To dry the residue and make it sievable, the air conditioning system was also vital, without the residue would have stayed sticky.

In the end of the treatment, when the stack was ready for harvesting, the boxes were analysed. The total weight was taken. The boxes needed to dry out to become harvestable. A treatment time of 14 days was aimed. The dryer the boxes, the easier the separation of the larvae from the residue was. The sieving process was divided into an active and a passive part. With a hand sieve (Figure 4b), diameter sieve 20.5 cm, mesh size 5.5 mm), the residue was separated from the larvae. The larvae fraction was then put on a coarse sieve (format 56 x 37 cm, mesh size 6 mm) to allow the larvae to pass through. Black soldier fly larvae are photophobic. This characteristic made that they crawled through the sieve and left the coarse residue on top of the sieve.

a) b)

Figure 4. Pictures of a) the two fractions after the separation; b) the hand sieve used to separate the larvae from the treatment residue.

After the active sieving by hand and passive sieving, the 2 different fractions (Figure 4a), larvae and residue) were sampled to analyse the material regarding purity and other information such as average size of the larvae. Before the sampling it was always insured that the material was mixed just before.

Sampling larvae: Three samples of roughly 10 g were used to sample the larvae fraction. For each sample total weight, weight of residue, and number of larvae were taken.

Residue sampling: One sample of 100 – 200 g was used for the sampling of the residue. Total weight, weight of larvae in the sample, and weight of the pure residue fraction was taken.

The separation of the larvae and the residue of the samples was done by using lab-tweezers.

The so gained information was then used to define the definitive amount of residue and larvae by applying the percentage of purity to the initial fraction weight. The average weight per larva was determined for every box as well as total solids, volatile solids, water, and ash content of the residue and the larvae. Considering the average weight per larvae and the input of 15000 larvae in the beginning, the survival could be calculated.

For the dry matter content, the material was dried for 48 hours at 70 °C (by freezing the larvae first). The weight of the ash was available after burning the samples at 500 °C for 8 hours.

3.3. Calculations

Following equation were used: For the BSF, the material reduction and bioconversion efficiency (BCE) was calculated as followed:

$$BCE\ (\%) = \frac{m_{larvae}}{m_{input}} * 100$$

Where m input is initial substrate (feed), and m larvae is larvae biomass.

BCE is the bioconversion efficiency and represents the efficiency of the process regarding input of substrate and output in form of larvae biomass. Higher values are considered being better then lower values.

The equation can be used to calculate the bioconversion efficiency based on wet weight, on total solids or on volatile solids.

For the statistical analysis, the program Minitab was used.

Different data were checked for significant differences between the levels.

1. Average temperature of the levels
2. Output in form of larvae biomass of the levels
3. Differences due to the change in feeding (difference between trial I and trial II)

All statistical data were checked for normal distribution by doing an Anderson Darling Test before further processing. The confidence interval was set at 95 %. If not stated differently, the values follow a normal distribution.

To check for significant differences between the levels, an Anova test in Minitab was done by using a confidence level of 95 % followed by a post-hoc test Tukey's HSD (honestly significant difference).

To search for correlations between the temperature and the bioconversion efficiency a regression line was done in Minitab with checking for normal distribution with the Anderson Darling Test before.

4. Results

A deviation was noticed (see appendix for raw data). The standard deviation of the starting composition was 412 g (Table 2).

Table 2: Theoretical feeding 1, average analysed feeding 1 and standard deviation

	Wet weight (g)
Theoretical feeding 1	6,406
Average analysed feeding 1 (n=30)	5,574±412

Table 2 shows the different weights of the calculated feeding 1 of trial II and the actual measured one with standard deviation.

Based on the analyses it was assumed that the feed load was 13,0 % lower than calculated. This percentage was also applied to the feedings during the treatment. Therefore, is the entire feed load only representing 87,0 % of the originally calculated amount. This is reducing the feed load for trial I from 12,784 g to 11,122 g, and for trial II from 12,798 g to 11,135 g. In table 3, the composition of the input can be found.

Table 3: Input into the treatment with WW for wet weight, TS for total solids, and VS for volatile solids.

	Trial I (n=18)	Trial II (n=12)
Input		
Bread* (g)	5524	4603
Veggies* (g)	5598	6531
Total* (g)	11122	11135
Larvae**	15000	15000
Substrate composition		
TS*	37,0%	32,2%
VS*	96,4%	96,1%
Ash*	3,6%	3,9%
Water*	63,0%	67,6%
Input/box		
WW* (g)	11122	11135
TS* (g)	4111	3579
VS* (g)	3965	3440
Ash* (g)	146	139
Water* (g)	7011	7555

**Calculated value, **aimed value.*

The values for trial I and trial II are calculated based on the composition of the bread and vegetables and considering the total feeding amounts of the two fractions (Table 3).

Table 4: Output of the treatment with WW for wet weight, TS for total solids, VS for volatile solids, and BCE for bioconversion efficiency. Average values with standard deviation. (ANOVA with Tukey method done within some lines).

Output	Trial I (n=18)	Trial II (n=12)
Larvae composition		
TS	38,7%±1,9	38,2%±1,1
VS	95,8%±0,2	95,7%±0,3
Ash	4,2%±0,2	4,4%±0,3
Water	61,3%±1,9	61,8%±1,1
Residue composition		
TS	74,3%±11,8	76,8%±5,6
VS	85,7%±4,1	85,2%±3,1
Ash	14,3%±4,1	14,8%±3,1
Water	25,7%±11,8	23,2%±5,6
Average Larvae output		
WW (g)	2094 ^{A}±409	2323 ^{A}±233
TS (g)	805 ^{A}±133	887 ^{A}±81
VS (g)	771 ^{A}±128	848 ^{A}±77
Ash (g)	34±6	39±5
Water (g)	1289±282	1437±157
BCE (%)	19,4^{A}±3,2 %	24,7^{B}±2,2 %
Average Residue output		
WW (g)	1984^{A}±592	1579^{B}277
TS (g)	1428 ^{A}±347	1211 ^{A}±222
VS (g)	1236 ^{A}±347	1037 ^{A}±225
Ash (g)	192±26	174±21
Water (g)	556±489	368±112

Table 4 is part of the mass balance and shows the output. The values for the individual boxes can be found in the appendix. In the result part were only average values used and differentiated into trial I

and trial II. The average values allow a comparison between the trials.
Significant differences between trial I and trial II (Table 4) were found for the bioconversion efficiency and for the output in form of residue in wet weight.

The average total input of volatile solids was lowered by 13.2 % between trial I and trial II. By changing the composition of the total feed load the output was increased by 10,0 %.

Table 5: Average output with standard deviation of the different positions of the boxes and trials with WW for wet weight in g and BCE for bioconversion efficiency (ANOVA with Tukey method done within the lines).

	Bottom		Middle		Top	
	Trial I	Trial II	Trial I	Trial II	Trial I	Trial II
Larvae (WW)	2407 ^{A}±335	2562 ^{A}±188	2061 ^{A,B}±356	2158 ^{A,B}±119	1814^{B}±291	2251 ^{A,B}±154
Residue (WW)	2091^{A}±583	1513 ^{A}±99	1956 ^{A}±511	1582 ^{A}±356	1889* ^{A}±461	1642 ^{A}±291
BCE (%)	21,6% ^{A,B,C}±1,8	26,7%^{A}±2,8	19,4% ^{B,C}±2,8	23,1% ^{A,B}±1,2	17,2%^{C}±2,4	24,1%^{A,B}±1,8

**not normally distributed*

Table 5 shows the average output divided into the different fractions and the bioconversion efficiency. The values are given for the different levels respectively the different trials including the standard deviation. The calculation considers the contamination of the fractions. For the final weight of the larvae in example, the residue in the larvae was subtracted and the larvae in the residue fraction added.

Significant differences were found for the larvae output between bottom (trial I and trial II) and top trial I. The output of residue did not show any significant differences. For the bioconversion efficiency the significant differences were between bottom trial II and middle trial I, bottom trial II and top trial I, and middle trial II and top trial I.

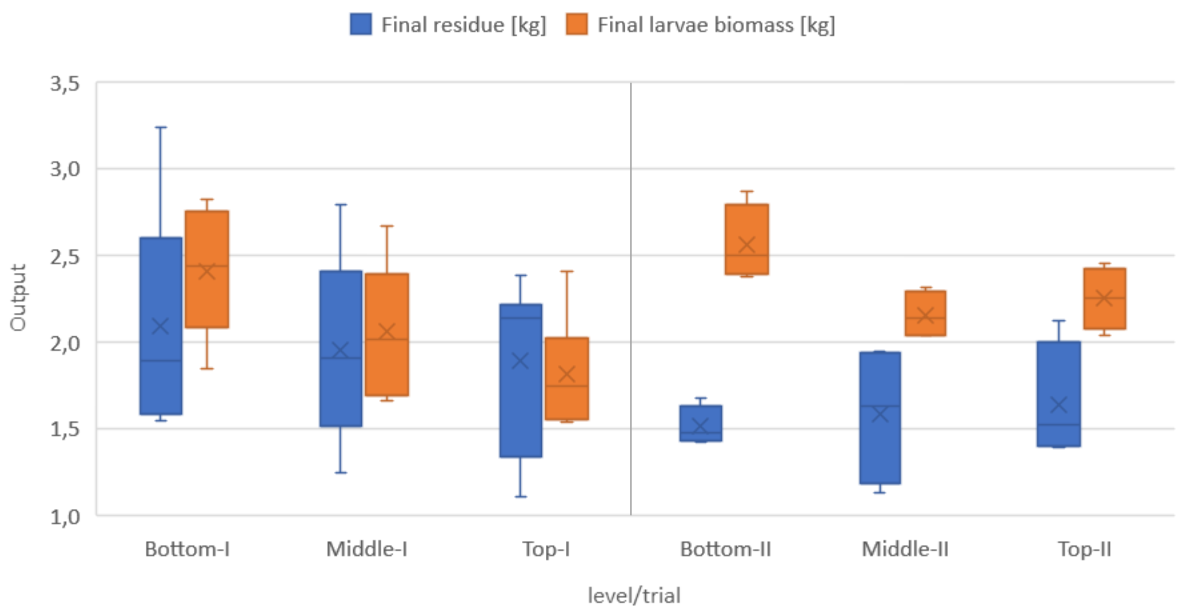

Figure 5. A schematic representation of the output in kg (with trial I and trial II).

Figure 5 shows the output of the different level within each trial. In trial I, the variation of the output of the different boxes was higher than in trial II. The output fractions had similar weights in trial I. After the change of the feeding, the output in form of larvae rose and the residue went down. Especially in trial II, the bottom box shows deviating values from the middle and the top box, but not in trial I.

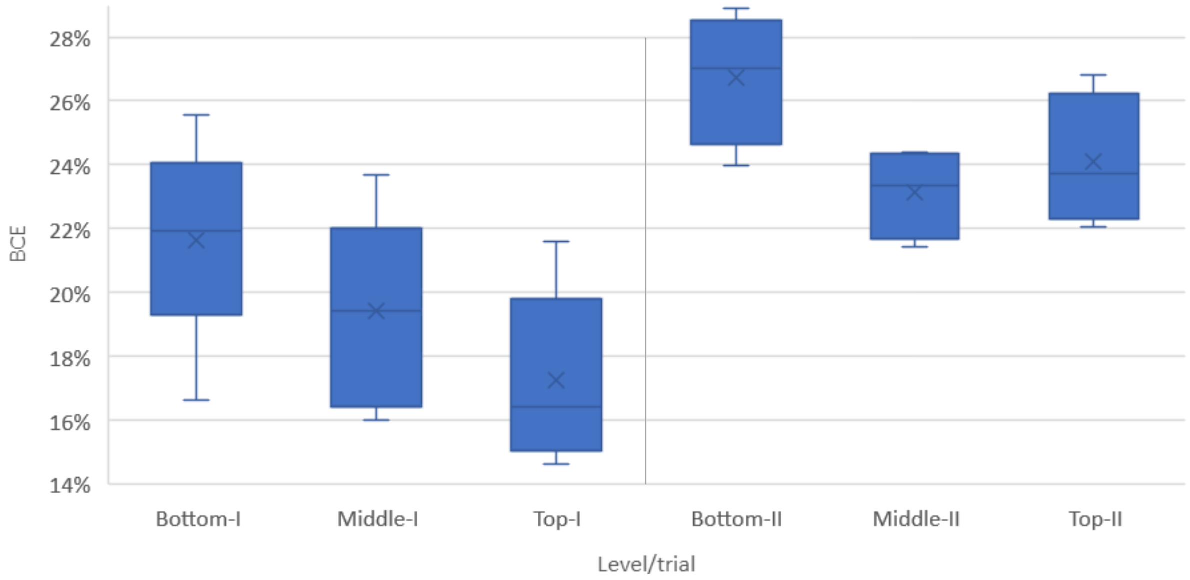

Figure 6. A schematic representation of the bioconversion efficiency based on volatile solids (with trial I and trial II).

The average bioconversion efficiency based on volatile solids could be increased by changing the feeding from 19,4±3,2 % to 24,7±2,2 % (table 4). The bioconversion efficiencies on total solid based are 0,1 – 0,2 % higher than if based on volatile solids.

Table 6: The different average temperature values and humidity of the different levels (ANOVA with Tukey method done within the columns).

	Average temperature [°C]	Average humidity [%]
Bottom	$25{,}3^{A}$±0,6	$51{,}0^{A}$±3,6
Middle	$27{,}0^{B}$±0,5	$47{,}5^{B}$±2,5
Top	$26{,}2^{C}$±0,3	$46{,}0^{B}$±2,4

Table 6 shows the average temperature of the different levels and the average humidity including the standard deviations.

The average temperature differs significantly between all levels. The average humidity differs only between the bottom level and middle respectively top level.

5. Discussion

This study was done to investigate the Black soldier fly composting efficiency by using a mobile treatment facility. The main parameters of interest were temperature, bioconversion efficiency and the influence of the position of the treatment boxes (bottom, middle, and top).

5.1. Accuracy of the data

Evaluating the actual input in comparison to the calculated feed load brought to light the high variance of the input. On average, the real input was around 13 % lower than assumed based on samples and calculations (see table 2). This can be explained with different factors. The feeding material is not entirely homogenous after the pre-treatment of milling, thus causing variation. Depending on the person feeding the boxes the feeding was also done in a different way. Especially the way of using the scoop, that was the reference for the amount to add to the treatment, varied. The samples to define the exact weight per scoop were taken with freshly milled loose bread. The bread dried out over time and was compacting. The feeding order also differed. Usually, the bread was added first and then the vegetables followed, but in a few boxes the bread was added after the vegetables.

The hatchlings that were added in the beginning of the treatment did not always have the same size. Depending on the age of the hatchlings, the weight varies entailing a variation in starting points for the boxes. For most results, the variation was lower in trial II. An explanation could be that the larvae for all in trial II started boxes were added at the same time and the larvae came from the same counting. This might have lowered the variation caused by counting errors.

One more factor that could have led to less variation of the output in trial II is that all boxes for analysis were running at the same time and therefore the feeding substrate might have had a smaller variation and the feeding was done by the same person. Even external impacts such as ventilation failures and the opening of the entrance of the container might have affected the treatment boxes in a similar way.

5.2. External influences on the temperature and microclimate

The stacks with the analysed boxes did not stand at the same place in the container at each time. Looking at the temperature data (raw data table 32), it is visible that depending on the position in the container, the temperature was not always the same but within the levels the variation is not very high (table 6). The position of the stacks was noted but not further considered in the calculations. It was not possible to eliminate this source of variation either as several stacks for analysis were running at the same time.

The ventilation system was also not running continuously during the monitored treatments. There was a failure during an uncertain time in trial I. To improve the airflow, ventilators were placed in the container and might have affected the treatment in some boxes more than in others as the airflow was probably not very homogenous throughout the container. From time to time, the door to the container was opened for work insight. The temperature might have decreased because of these activities due to inflow of cold air from outside.

As visible in figure 4 b) the top boxes were not covered by the next box. This could eventually have led to faster drying out because of higher airflow or less individual microclimate in the treatment. Usually, the larvae create a microclimate with higher humidity and higher temperatures because of evaporation and metabolic activities of the larvae. This individual climate was probably higher marked with a box on top allowing less airflow. In this report, the top boxes were still compared with the boxes from the other levels. The middle boxes had, unlike expected, in average the highest temperature and not the top boxes. Still, the average temperatures of the different levels were significantly different from each other. Even between the middle and the top temperature was a significant difference even though the values were very close to each other.

The average temperature of the different levels was very close to the aimed temperature (27 °C). This shows that the heating system and distribution in the container worked properly. However, the average humidity was on all levels higher than targeted (<40 %). This might be because of the earlier mentioned microclimate in the boxes or due to an inaccurate working ventilation system.

5.3. Duration of the treatment

Further improvement could be done by running all treatment boxes for the same number of days. As the range for the described experiments was between 9 and 14 days, this might have caused some variation as well. Once the residue was dry enough for harvesting with the sieve, the analysis of the boxes was executed. And as not all the boxes were dry at the same number of days the treatment duration is varying but not within the stacks.

Feeding

The change in feeding composition influenced parameters such as water content. According to Sarpong et al., the ideal water content is between 40 % and 60 %. The water content for the treatment in the container rose with the change in the feeding between the trials from 63 % to almost 68 %, which is not the ideal range (Sarpong et al. 2019). On the other hand, another study stated that the optimal water content might be close to 70 % (Lopes et al. 2020). Above 60 %, there is a higher risk for environmental odours (Sarpong et al. 2019). In the container trial it was possible to improve the process efficiency by increasing the water content. Therefore, for the container trial the ideal moisture content is not correlating with the suggested one of Sarpong et al. However, it correlates with the suggestion of Lopes et al. This could be because of different interactions of materials with water. Bread might absorb and hold the water better than other materials.

By changing the feed for trial II, the input was lowered except for the water. At the same time, the output of biomass in form of larvae rose and the residue was reduced after being the roughly the same regarding wet weight. Both changes could be considered as being positive. The larvae biomass is the valuable part, and a high output should be targeted. A reduced residue might be less energy demanding to process further (e. g. fertilizer or composting).

5.4. Bioconversion efficiency

Lalander 2020 proposed a bioconversion efficiency of 25 % based on an input of 1,000 kg food waste and an output of 250 kg of larvae biomass. In trial II, the average bioconversion efficiency of the in this report presented experiments reached a similar value of 24.7 %. Some boxes even reached a higher value up to 28.9 %. This shows that there is still potential of improving the treatment.

The improvement of the bioconversion efficiency between trial I and trial II has been checked for significance as well. A positive test was expected and proven.

A study from 2019 achieved a bioconversion efficiency on total solids basis of 24±8 % by using food waste as a feed (Ermolaev et al. 2019). This value correlates very closely with the here described experiments. An evaluation of different feedings and the impact on the bioconversion efficiency achieved maximum values of approximately 15 % (Lalander et al. 2019). This shows how the values can differ between different papers and studies.

5.5. Statistical analysis

The ANOVA test with Tukey method showed that there was only a significant difference between the bottom and the top boxes. No difference could be found nor between the bottom and the middle boxes, neither between the middle and the top boxes. The difference in average temperature between the bottom and the middle boxes was the biggest; however, there was no significant difference in output of larvae biomass between those two levels.

The temperature in between the levels is significantly different but not between all the levels regarding larvae biomass output. The bioconversion efficiency is representing partly the efficiency of the Black soldier fly treatment. One of the main purposes of this report was to investigate the influence of temperature on the treatment. There was no correlation between the bioconversion efficiency and the temperature. This might be surprising as the temperature and the biomass output had some significant differences in between the levels. But other factors then the temperature are also influencing the output such as earlier discussed variation and of course the change in feeding between trial I and trial II.

The described experiments did not have many replicates, and this might be affecting the validity of the report. In trial I, there were 6 boxes analysed per level and in trial II only 4. In further going experiments the number could be improved to reach higher validity.

6. Conclusion

This report displays the process efficiency of a running production and allows insight into process parameters that are often used to describe the productivity of Black soldier fly treatments. The collected data sets allow to investigate the explained container trial. Initial concerns about huge differences in between the levels in example could not be reinforced.

The analysis showed the impact of a change in feeding composition. By improving the input into the treatment, the bioconversion efficiency could be augmented significantly.

In many cases, the bottom boxes showed the highest output of larvae biomass as well as the highest bioconversion efficiency. To improve the overall treatment, it should be considered to aim for those conditions even on the other levels. This would mean lowering the temperature for the whole container. But other factors, such as the drying of the residue, could become a problem. This should be further investigated.

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Appendix

Table 7: Feeding of the different stacks with amount in scoops and date.

STACK	FEEDING	BREAD [SCOOPS]	VEGETABLES [SCOOPS]	DATE
R3	1	12	3	24. Feb
	2	6	3	01. Mar
	3	6	0	04. Mar
R5	1	12	3	24. Feb
	2	6	3	01. Mar
	3	3	0	03. Mar
	4	3	0	04. Mar
R1	1	12	3	25. Feb
	2	6	1,5	03. Mar
	3	6	1,5	08. Mar
R2	1	12	3	25. Feb
	2	6	1,5	03. Mar
	3	6	1,5	08. Mar
L2	1	12	3	01. Mar
	2	6	1,5	09. Mar
	3	6	1,5	11. Mar
R1	1	8	4	11. Mar
	2	6	1,5	16. Mar
	3	6	1,5	18. Mar
L0	1	8	4	16. Mar
	2	6	1,5	22. Mar
	3	6	1,5	25. Mar
L1	1	8	4	16. Mar
	2	6	1,5	22. Mar
	3	6	1,5	25. Mar
L3	1	8	4	17. Mar
	2	6	1,5	22. Mar
	3	6	1,5	25. Mar
L4	1	8	4	17. Mar
	2	6	1,5	22. Mar
	3	6	1,5	25. Mar

Table 8: Scoop sampling bread and vegetables with STDEV for standard deviation.

WEIGHT PER SCOOP	SAMPLE	[G]	STDEV	[KG]
VEGETABLES	1	1064		
VEGETABLES	2	1118		
VEGETABLES	3	1035		
AVERAGE VEGETABLES		1072	34	1,072
BREAD	1	266		
BREAD	2	270		
BREAD	3	258		
AVERAGE BREAD		265	5	0,265

Table 9: Calculated feed load per treatment box

FEED	BREAD [KG]	VEGETABLES [KG]
TRIAL I	6,35	6,43
TRIAL II	5,29	7,51

Table 10: Finding out of real feed load.

WEIGHT STARTING BOXES	FEED LOAD [KG]	BREAD [SCOOPS]	VEGETABLES [SCOOPS]
1	5,605	8	4
2	5,01	8	4
3	5,255	8	4
4	5,96	8	4
5	6,14	8	4
6	5,415	8	4
7	5,815	8	4
8	5,635	8	4
9	5,985	8	4
10	5,365	8	4
11	5,3	8	4
12	5,425	8	4
13	5,435	8	4
14	5,685	8	4
15	5,73	8	4
16	5,31	8	4
17	4,975	8	4
18	5,355	8	4
19	5,7	8	4
20	5,545	8	4
21	5,88	8	4
22	6,825	8	4
23	6,345	8	4
24	5,74	8	4
25	4,995	8	4
26	5,305	8	4
27	5,025	8	4
28	5,35	8	4
29	5,385	8	4
30	5,715	8	4
AVERAGE	5,57366667		
STANDARD DEVIATION	0,41238151		

Table 11: Boxes with position, Tiny Tag, fraction weight, and start and end date.

BOX	POSITION	TINYTAG	TOTAL OUT [KG]	RESIDUE [KG]	LARVAE BIOMASS [KG]	START DATE	END DATE	RUNNING TIME [DAYS]
1	R3a	7	4,76	2,39	2,34	24. Feb	05. Mar	9
2	R3b	8	5,08	2,60	2,50	24. Feb	05. Mar	9
3	R3c	9	3,90	2,23	1,66	24. Feb	05. Mar	9
4	R5a	1	4,75	1,90	2,84	24. Feb	08. Mar	12
5	R5b	2	3,81	1,49	2,32	24. Feb	08. Mar	12
6	R5d	3	3,31	1,19	2,12	24. Feb	08. Mar	12
7	R1a	13	3,96	1,62	2,32	25. Feb	10. Mar	13
8	R1b	14	4,00	2,14	1,85	25. Feb	10. Mar	13
9	R1c	15	3,72	2,15	1,55	25. Feb	10. Mar	13
10	R2a	10	3,49	1,50	1,95	25. Feb	11. Mar	14
11	R2b	11	3,28	1,50	1,77	25. Feb	11. Mar	14
12	R2c	12	3,93	2,29	1,64	25. Feb	11. Mar	14
13	L2a	4	4,09	1,51	2,58	01. Mar	15. Mar	14
14	L2b	5	4,05	2,15	1,89	01. Mar	15. Mar	14
15	L2c	6	3,91	2,17	1,74	01. Mar	15. Mar	14
16	R1a	1	6,06	3,24	2,83	11. Mar	24. Mar	13
17	R1b	2	3,87	1,23	2,70	11. Mar	24. Mar	13
18	R1c	3	3,62	1,09	2,43	11. Mar	24. Mar	13
19	L0a	7	4,28	1,63	2,60	16. Mar	29. Mar	13
20	L0b	8	3,97	1,86	2,11	16. Mar	29. Mar	13
21	L0c	9	4,32	2,08	2,24	16. Mar	29. Mar	13
22	L1a	13	3,99	1,43	2,54	16. Mar	29. Mar	13
23	L1b	14	4,00	1,89	2,10	16. Mar	29. Mar	13
24	L1c	15	3,67	1,59	2,07	16. Mar	29. Mar	13
25	L3a	4	3,80	1,17	2,63	16. Mar	30. Mar	14
26	L3b	5	3,37	1,13	2,24	16. Mar	30. Mar	14
27	L3c	6	3,77	1,34	2,43	16. Mar	30. Mar	14
28	L4a	10	4,33	1,42	2,90	17. Mar	31. Mar	14
29	L4b	11	3,66	1,35	2,31	17. Mar	31. Mar	14
30	L4c	12	3,85	1,38	2,47	17. Mar	31. Mar	14

Table 12: Sampling of larvae including total solids and ash analysis with ts for total

9	8	7	6	5	4	3	2	1	BOX
7,11	6,15	14,99	9,72	11,51	10,06	17,95	21,77	38,27	**SAMPLE 1 [G]**
47	34	97	75	82	66	154	121	235	**LARVAE [#]**
0,12	0,58	1,2	1,47	0,66	0,26	0,74	1,98	2,27	**CONTAMINATION [G]**
5,25	13,72	6,04	8,89	8,09	11,08	17,97	22,44	24,48	**SAMPLE 2 [G]**
36	71	39	83	53	70	149	136	142	**LARVAE [#]**
0,04	1,63	0,4	1,07	0,84	0,63	0,61	2,46	0,62	**CONTAMINATION [G]**
6,99	9,3	5,89	8,7	11,14	15,03	16,66	15,75	19,51	**SAMPLE 3 [G]**
47	55	38	69	74	96	158	97	115	**LARVAE [#]**
0,1	0,39	0,49	1,07	0,85	0,6	0,71	1,46	0,95	**CONTAMINATION [G]**
1,75	1,74	1,74	1,74	1,74	1,73	1,72	1,76	1,73	**CUP**
16,49	16,46	15,49	9,36	12,02	11,48	18,89	18,00	16,08	**WW+CUP**
7,47	7,46	7,07	4,94	5,86	5,51	8,39	8,02	7,16	**TS+CUP**
1,98	1,97	1,97	1,87	1,89	1,89	1,99	2	1,96	**ASH+CUP**

19	18	17	16	15	14	13	12	11	10	BOX
10,83	8,85	12,21	12,73	8,75	7,79	7,91	6,08	12,88	10,15	**SAMPLE 1 [G]**
59	55	68	62	69	59	48	44	82	40	**LARVAE [#]**
0,27	0,18	0,215	0	0,083	0,154	0,161	0,49	0,72	0,65	**CONTAMINATION [G]**
15,73	13,63	15,94	12,4	4,65	12,1	8,61	6,56	13	10,06	**SAMPLE 2 [G]**
86	86	85	60	36	93	60	48	78	39	**LARVAE [#]**
0,25	0,26	0,315	0	0,148	0,265	0,17	0,4	0,79	0,64	**CONTAMINATION [G]**
10,39	12,95	11,79	12,02	4,35	5,25	13,69	6,36	10,45	10,21	**SAMPLE 3 [G]**
59	83	62	63	35	42	84	48	67	42	**LARVAE [#]**
0,35	0,2	0,004	0	0,037	0,079	0,24	0,57	1,01	0,38	**CONTAMINATION [G]**
1,75	1,74	1,74	1,75	1,73	1,75	1,76	1,74	1,73	1,73	**CUP**
15,37	13,94	17,37	15,51	14,09	15,36	18,43	13,49	13,85	15,89	**WW+CUP**
7,01	6,28	7,49	6,29	6,56	7,12	8,15	6,54	6,74	7,03	**TS+CUP**
1,98	1,94	2	1,95	1,94	1,97	2,02	1,94	1,95	1,97	**ASH+CUP**

29	28	27	26	25	24	23	22	21	20	BOX
8,09	15,06	12,16	11,35	11,52	13,75	11,68	7,5	8,26	10,26	**SAMPLE 1 [G]**
52	88	70	74	50	95	72	43	56	67	**LARVAE [#]**
0,06	0,23	1	0,14	0,86	0,14	0,43	0,19	0,25	0,41	**CONTAMINATION [G]**
10,87	11,24	13,43	14,87	16,21	12,73	11,61	15,09	11,44	13,92	**SAMPLE 2 [G]**
67	71	73	91	61	84	66	82	71	98	**LARVAE [#]**
0,01	0,14	0,44	0,11	1,95	0,43	0,57	0,63	0,4	0,48	**CONTAMINATION [G]**
17,93	7,97	9,28	9,09	11,31	8,92	12,52	12,89	9,25	9,07	**SAMPLE 3 [G]**
99	48	54	56	44	58	77	71	54	63	**LARVAE [#]**
0,12	0,19	0,02	0,1	1,48	0,41	0,29	0,45	0,17	0,59	**CONTAMINATION [G]**
1,72	1,73	1,76	1,73	1,74	1,75	1,73	1,77	1,73	1,74	**CUP**
12,3	13,99	14,15	13,44	14,03	14,39	15,07	16,44	15,9	15,58	**WW+CUP**
5,71	6,18	6,46	6,36	6,21	6,65	6,75	7,51	7,08	7,2	**TS+CUP**
1,9	1,93	1,98	1,95	1,94	1,95	1,93	2,03	1,95	1,97	**ASH+CUP**

BOX	SAMPLE 1 [G]	LARVAE [#]	CONTAMINATION [G]	SAMPLE 2 [G]	LARVAE [#]	CONTAMINATION [G]	SAMPLE 3 [G]	LARVAE [#]	CONTAMINATION [G]	CUP	WW+CUP	TS+CUP	ASH+CUP
30	13,27	92	0,61	14,4	112	0	11,58	88	0,23	1,73	13,08	6,18	1,91

Table 13: Sampling of residue including total solids and ash analysis with ts for total solids.

BOX	SAMPLE [G]	CONTAMINATION [G]	CUP	WW+CUP	TS+CUP	ASH+CUP
1	51,31	2,35	1,73	23,93	15,95	3,31
2	90,69	1,67	1,74	26,49	18,32	3,53
3	47,73	3,35	1,74	20,94	16,6	2,99
4	86,78	0,5	1,76	23,52	16,59	3,75
5	103,2	1,19	1,73	30,6	24,09	4,84
6	56,16	2,46	1,74	22,28	18,37	4,1
7	165,58	2,14	1,75	24,16	18,73	4,67
8	175,27	1,77	1,73	27,81	22,54	4,58
9	143,55	1,99	1,75	20,04	17,16	3,04
10	152,76	0,91	1,77	31,69	23	5,77
11	188,05	2,53	1,75	23,93	19,42	5,25
12	123,27	1,46	1,73	23,51	19,83	3,82
13	158,5	1,19	1,75	28,42	23,42	4,82
14	186,84	2,03	1,75	33,64	27,37	4,84
15	132,58	2,2	1,74	22,96	19,03	3,52
16	-	-	1,73	39,54	13,79	3,73
17	156,66	1,63	1,74	30,33	22,41	6,51
18	136,47	2,52	1,74	28,95	23,79	6,3
19	116,72	1	1,75	22,68	15,72	3,73
20	155,23	2,61	1,74	28,56	21,76	4,01
21	172,43	1,07	1,73	30,18	23,31	4,08
22	141,35	1,01	1,72	26,67	20,57	5,14
23	168,23	1,98	1,77	25,1	21,03	3,65
24	127,47	2,25	1,72	24,63	19,83	4,03
25	130,44	3,73	1,74	24,49	16,69	4,08
26	113,45	1,7	1,76	28,29	22,64	5,61
27	130,89	0,37	1,75	23,89	19,54	4,65
28	119,9	1,83	1,75	27,45	21,22	5,73
29	128,97	1,76	1,73	26,65	22,32	4,81
30	194,09	5,7	1,76	28,66	24,41	5,22

Table 14: Output by fractions by considering the contamination of the different fractions.

BOX	TOTAL OUT [KG]	FINAL RESIDUE [KG]	FINAL LARVAE BIOMASS [KG]
1	4,76	2,39	2,34
2	5,08	2,79	2,30
3	3,90	2,13	1,75
4	4,75	2,00	2,73
5	3,81	1,65	2,16
6	3,31	1,41	1,89
7	3,96	1,78	2,16
8	4,00	2,28	1,70
9	3,72	2,14	1,56
10	3,49	1,60	1,85
11	3,28	1,60	1,66
12	3,93	2,38	1,54
13	4,09	1,55	2,54
14	4,05	2,16	1,88
15	3,91	2,16	1,74
16	6,06	3,24	2,83
17	3,87	1,25	2,67
18	3,62	1,11	2,41
19	4,28	1,68	2,55
20	3,97	1,92	2,04
21	4,32	2,13	2,18
22	3,99	1,51	2,45
23	4,00	1,94	2,04
24	3,67	1,61	2,04
25	3,80	1,43	2,37
26	3,37	1,13	2,23
27	3,77	1,44	2,33
28	4,33	1,45	2,87
29	3,66	1,34	2,32
30	3,85	1,39	2,45

Table 15: Output in wet weight, total solids, volatile solids, ash, and water of the different fractions: residue and larvae. All values are in g.

BOX	RESIDUE WW	LARVAE WW	RESIDUE TS	LARVAE TS	RESIDUE VS	LARVAE VS	RESIDUE ASH	LARVAE ASH	ASH TOTAL	RESIDUE WATER	LARVAE WATER

12	11	10	9	8	7	6	5	4	3	2	1
2302,29	1511,60	1569,20	2183,59	2158,54	1554,73	1250,70	1640,83	2126,18	2259,00	2747,88	2385,00
1536,43	1662,75	1847,16	1558,98	1702,11	2160,82	1891,67	2155,20	2729,13	1746,32	2297,28	2340,00
1913,29	1204,24	1113,44	1839,76	1722,36	1178,01	1012,62	1270,83	1449,04	1748,37	1840,80	1527,69
627,65	687,33	691,38	604,98	661,42	837,61	794,40	863,76	1058,06	678,39	885,53	885,45
1692,36	965,71	903,66	1685,75	1486,48	975,43	868,92	1094,07	1254,60	1601,30	1642,07	1357,95
601,49	657,14	660,07	580,65	634,82	801,47	762,13	832,31	1013,28	650,93	851,58	847,94
220,93	238,53	209,79	154,01	235,88	202,58	143,70	176,76	194,44	147,07	198,74	169,74
26,15	30,18	31,31	24,33	26,60	36,14	32,27	31,45	44,79	27,46	33,95	37,51
247,08	268,71	241,09	178,34	262,48	238,72	175,98	208,20	239,23	174,53	232,69	207,25
389,00	307,36	455,76	343,84	436,18	376,71	238,08	370,00	677,13	510,63	907,08	857,31
908,78	975,43	1155,78	954,00	1040,69	1323,21	1097,27	1291,45	1671,07	1067,93	1411,75	1454,55

24	23	22	21	20	19	18	17	16	15	14	13
1614,33	1943,22	1505,56	2125,43	1917,51	1677,14	1092,23	1225,00	3556,52	2322,20	2142,61	1689,67
2040,67	2041,78	2454,44	2184,57	2042,49	2547,86	2406,14	2671,71	2825,00	1744,73	1875,92	2537,67
1276,10	1604,22	1137,47	1612,19	1431,34	1119,43	885,10	885,65	1134,40	1892,12	1721,34	1372,90
791,08	768,34	960,36	824,80	805,78	983,98	895,40	982,88	932,09	681,80	740,17	972,75
1113,33	1447,63	931,09	1436,63	1269,04	960,77	702,06	681,27	946,27	1697,33	1513,74	1178,40
758,79	737,73	916,86	790,89	771,84	940,95	855,95	938,43	891,02	652,16	709,84	933,17
162,77	156,59	206,37	175,56	162,29	158,66	183,04	204,38	188,13	194,79	207,61	194,50
32,29	30,61	43,50	33,92	33,94	43,03	39,44	44,44	41,06	29,64	30,32	39,58
195,06	187,20	249,87	209,48	196,24	201,68	222,49	248,82	229,19	224,44	237,93	234,08
338,23	339,00	368,09	513,24	486,17	557,71	207,13	339,35	2422,12	430,08	421,27	316,77
1249,59	1273,43	1494,08	1359,77	1236,71	1563,89	1510,74	1688,84	1892,91	1062,93	1135,75	1564,92

1392,23	1338,54	1445,63	1437,75	1130,30	1425,55
2452,77	2316,46	2869,37	2327,25	2229,70	2374,45
1172,27	1105,96	1095,19	1155,26	889,58	936,79
961,66	873,60	1041,49	882,82	881,60	863,61
993,19	940,53	871,32	966,94	725,55	790,16
922,76	834,19	994,68	841,49	839,71	824,97
179,07	165,44	223,88	188,32	164,03	146,63
38,90	39,41	46,81	41,32	41,89	38,64
217,97	204,85	270,68	229,65	205,92	185,27
219,96	232,58	350,44	282,48	240,72	488,76
1491,11	1442,86	1827,88	1444,44	1348,10	1510,84

Table 16: Output in wet weight, total solids, volatile solids, ash, and water of the different fractions: residue and larvae.

BOX	RESIDUE TS	LARVAE TS	RESIDUE VS	LARVAE VS	RESIDUE ASH	LARVAE ASH	RESIDUE WATER	LARVAE WATER
1	64,05%	37,84%	88,89%	95,76%	11,11%	4,24%	35,95%	62,16%
2	66,99%	38,55%	89,20%	96,17%	10,80%	3,83%	33,01%	61,45%
3	77,40%	38,85%	91,59%	95,95%	8,41%	4,05%	22,60%	61,15%
4	68,15%	38,77%	86,58%	95,77%	13,42%	4,23%	31,85%	61,23%
5	77,45%	40,08%	86,09%	96,36%	13,91%	3,64%	22,55%	59,92%
6	80,96%	41,99%	85,81%	95,94%	14,19%	4,06%	19,04%	58,01%
7	75,77%	38,76%	82,80%	95,68%	17,20%	4,32%	24,23%	61,24%
8	79,79%	38,86%	86,30%	95,98%	13,70%	4,02%	20,21%	61,14%
9	84,25%	38,81%	91,63%	95,98%	8,37%	4,02%	15,75%	61,19%
10	70,96%	37,43%	81,16%	95,47%	18,84%	4,53%	29,04%	62,57%
11	79,67%	41,34%	80,19%	95,61%	19,81%	4,39%	20,33%	58,66%
12	83,10%	40,85%	88,45%	95,83%	11,55%	4,17%	16,90%	59,15%
13	81,25%	38,33%	85,83%	95,93%	14,17%	4,07%	18,75%	61,67%
14	80,34%	39,46%	87,94%	95,90%	12,06%	4,10%	19,66%	60,54%
15	81,48%	39,08%	89,71%	95,65%	10,29%	4,35%	18,52%	60,92%
16	31,90%	32,99%	83,42%	95,59%	16,58%	4,41%	68,10%	67,01%
17	72,30%	36,79%	76,92%	95,48%	23,08%	4,52%	27,70%	63,21%
18	81,04%	37,21%	79,32%	95,59%	20,68%	4,41%	18,96%	62,79%
19	66,75%	38,62%	85,83%	95,63%	14,17%	4,37%	33,25%	61,38%
20	74,65%	39,45%	88,66%	95,79%	11,34%	4,21%	25,35%	60,55%

21	75,85%	37,76%	89,11%	95,89%	10,89%	4,11%	24,15%	62,24%
22	75,55%	39,13%	81,86%	95,47%	18,14%	4,53%	24,45%	60,87%
23	82,55%	37,63%	90,24%	96,02%	9,76%	3,98%	17,45%	62,37%
24	79,05%	38,77%	87,24%	95,92%	12,76%	4,08%	20,95%	61,23%
25	65,71%	36,37%	84,35%	95,53%	15,65%	4,47%	34,29%	63,63%
26	78,70%	39,54%	81,56%	95,25%	18,44%	4,75%	21,30%	60,46%
27	80,35%	37,93%	83,70%	95,32%	16,30%	4,68%	19,65%	62,07%
28	75,76%	36,30%	79,56%	95,51%	20,44%	4,49%	24,24%	63,70%
29	82,62%	37,71%	85,04%	95,49%	14,96%	4,51%	17,38%	62,29%
30	84,20%	39,21%	84,72%	95,96%	15,28%	4,04%	15,80%	60,79%

Table 17: Mass balance based on volatile solids with STDEV for standard deviation.

BOX	**BREAD [G]**	**VEGETABLES [G]**	**TOTAL INPUT [G]**	**LARVAE [G]**	**RESIDUE [G]**	**TOTAL OUTPUT [G]**
1	3557,42	407,66	3965,07	847,94	1357,95	2205,89
2	3557,42	407,66	3965,07	851,58	1668,86	2520,44
3	3557,42	407,66	3965,07	650,93	1512,46	2163,40
4	3557,42	407,66	3965,07	1013,28	1180,66	2193,94
5	3557,42	407,66	3965,07	832,31	1100,05	1932,37
6	3557,42	407,66	3965,07	762,13	981,90	1744,03
7	3557,42	407,66	3965,07	801,47	1116,26	1917,72
8	3557,42	407,66	3965,07	634,82	1568,67	2203,49
9	3557,42	407,66	3965,07	580,65	1652,88	2233,53
10	3557,42	407,66	3965,07	660,07	920,15	1580,22
11	3557,42	407,66	3965,07	657,14	1023,62	1680,76
12	3557,42	407,66	3965,07	601,49	1752,11	2353,61
13	3557,42	407,66	3965,07	933,17	1079,13	2012,30
14	3557,42	407,66	3965,07	709,84	1528,90	2238,75
15	3557,42	407,66	3965,07	652,16	1575,32	2227,47
16	3557,42	407,66	3965,07	891,02	860,73	1751,75
17	3557,42	407,66	3965,07	938,43	694,22	1632,65
18	3557,42	407,66	3965,07	855,95	712,75	1568,71
AVERAGE TRIAL I	3557,42	407,66	3965,07	770,80	1238,15	2008,95
STDEV	0	0	0	127,56	334,03	283,20
19	2964,51	475,60	3440,11	940,95	960,77	1901,72
20	2964,51	475,60	3440,11	771,84	1269,04	2040,88
21	2964,51	475,60	3440,11	790,89	1436,63	2227,51
22	2964,51	475,60	3440,11	916,86	931,09	1847,95
23	2964,51	475,60	3440,11	737,73	1447,63	2185,36
24	2964,51	475,60	3440,11	758,79	1113,33	1872,12
25	2964,51	475,60	3440,11	824,97	790,16	1615,13
26	2964,51	475,60	3440,11	839,71	725,55	1565,26
27	2964,51	475,60	3440,11	841,49	966,94	1808,43
28	2964,51	475,60	3440,11	994,68	871,32	1866,00
29	2964,51	475,60	3440,11	834,19	940,53	1774,71
30	2964,51	475,60	3440,11	922,76	993,19	1915,95
AVERAGE	2964,51	475,60	3440,11	847,91	1037,18	1885,09

TRIAL II						
STDEV	0	0	0	76,65	224,82	188,87

Table 18: Bioconversion efficiency on WW (wet weight), TS (total solids) and VS (volatile solids) basis

BOX	BCE WW	BCE TS	BCE VS
1	21,04%	21,54%	21,39%
2	20,65%	21,54%	21,48%
3	15,70%	16,50%	16,42%
4	24,54%	25,73%	25,56%
5	19,38%	21,01%	20,99%
6	17,01%	19,32%	19,22%
7	19,43%	20,37%	20,21%
8	15,30%	16,09%	16,01%
9	14,02%	14,71%	14,64%
10	16,61%	16,82%	16,65%
11	14,95%	16,72%	16,57%
12	13,81%	15,27%	15,17%
13	22,81%	23,66%	23,53%
14	16,87%	18,00%	17,90%
15	15,69%	16,58%	16,45%
16	25,40%	22,67%	22,47%
17	24,02%	23,91%	23,67%
18	21,63%	21,78%	21,59%
19	22,88%	27,49%	27,35%
20	18,34%	22,51%	22,44%
21	19,62%	23,04%	22,99%
22	22,04%	26,83%	26,65%
23	18,34%	21,47%	21,45%
24	18,33%	22,10%	22,06%
25	21,32%	24,13%	23,98%
26	20,02%	24,63%	24,41%
27	20,90%	24,66%	24,46%
28	25,77%	29,10%	28,91%
29	20,80%	24,41%	24,25%
30	22,03%	26,87%	26,82%

Table 19: Material reduction rate on WW, TS and VS basis

BOX	MTR WW	MTR TS	MTR VS
1	78,56%	62,84%	65,75%
2	74,89%	54,50%	57,91%
3	80,82%	59,83%	61,86%
4	82,01%	66,83%	70,22%
5	85,17%	68,92%	72,26%
6	87,29%	72,17%	75,24%
7	84,00%	67,21%	71,85%
8	79,52%	55,79%	60,44%

9	80,75%	56,13%	58,31%
10	85,63%	72,42%	76,79%
11	85,60%	68,95%	74,18%
12	78,57%	51,82%	55,81%
13	86,09%	69,42%	72,78%
14	80,54%	57,71%	61,44%
15	80,62%	57,29%	60,27%
16	70,92%	74,90%	78,29%
17	88,78%	78,05%	82,49%
18	90,03%	78,14%	82,02%
19	84,94%	68,73%	72,07%
20	82,78%	60,01%	63,11%
21	80,91%	54,96%	58,24%
22	86,48%	68,22%	72,93%
23	82,55%	55,18%	57,92%
24	85,50%	64,35%	67,64%
25	87,20%	73,83%	77,03%
26	89,85%	75,15%	78,91%
27	87,09%	67,73%	71,89%
28	87,02%	69,40%	74,67%
29	87,98%	69,10%	72,66%
30	87,50%	67,25%	71,13%

Table 20: Temperature and humidity data with standard deviation

BOX	AVERAGE TEMPERATURE [°C]	HUMIDITY [%]	STANDARD DEVIATION TEMPERATUR	STANDARD DEVIATION HUMIDITY
1	25,18	52,63	1,56	4,83
2	26,80	51,43	2,39	5,60
3	26,25	48,91	1,51	6,64
4	24,98	56,04	2,23	4,70
5	27,60	51,94	1,96	7,11
6	26,15	46,34	1,36	6,79
7	25,47	52,16	2,83	6,12
8	25,97	46,36	2,28	6,47
9	25,95	41,49	1,56	6,08
10	25,48	52,73	2,86	5,12
11	26,38	49,17	2,57	7,11
12	26,14	48,12	1,87	6,55
13	25,63	49,92	3,33	6,46
14	27,78	44,42	2,61	6,53
15	26,78	42,10	1,53	7,10
16	24,97	53,92	1,85	8,31
17	26,92	44,86	0,98	7,07
18	26,43	46,49	1,11	6,85
19	25,77	48,86	1,87	6,22
20	26,51	45,58	1,33	7,46

21	25,49	47,67	0,89	6,66
22	26,07	50,61	2,20	6,62
23	27,13	46,27	1,86	6,23

24	26,06	48,00	1,19	6,79
25	23,92	41,79	2,22	6,94
26	27,49	47,14	2,00	6,90
27	26,29	45,38	0,85	6,11
28	25,23	51,01	1,88	6,12
29	27,12	47,83	1,58	7,55
30	26,49	45,79	1,02	7,60

Table 21: Survival of larvae

BOX	INITIAL NUMBER (#)	LARVAE WEIGHT END TOTAL (G)	WEIGHT PER LARVAE (G)	END NUMBER (#)	SURVIVAL
1	15000	2340,00	0,16	14680,94	0,9787
2	15000	2297,28	0,15	15043,23	1,0029
3	15000	1746,32	0,11	15935,39	1,0624
4	15000	2729,13	0,15	18257,17	1,2171
5	15000	2155,20	0,14	15866,07	1,0577
6	15000	1891,67	0,10	18118,55	1,2079
7	15000	2160,82	0,14	15142,26	1,0095
8	15000	1702,11	0,17	10249,82	0,6833
9	15000	1558,98	0,15	10616,40	0,7078
10	15000	1847,16	0,24	7774,13	0,5183
11	15000	1662,75	0,15	11163,71	0,7442
12	15000	1536,43	0,13	12263,38	0,8176
13	15000	2537,67	0,15	16438,88	1,0959
14	15000	1875,92	0,13	14768,63	0,9846
15	15000	1744,73	0,12	13972,21	0,9315
16	15000	2825,00	0,20	14067,97	0,9379
17	15000	2671,71	0,18	14576,93	0,9718
18	15000	2406,14	0,16	15492,25	1,0328
19	15000	2547,86	0,18	14405,89	0,9604
20	15000	2042,49	0,14	14658,12	0,9772
21	15000	2184,57	0,16	14056,43	0,9371
22	15000	2454,44	0,17	14062,28	0,9375
23	15000	2041,78	0,16	12716,74	0,8478
24	15000	2040,67	0,15	14051,11	0,9367
25	15000	2374,45	0,22	10591,09	0,7061
26	15000	2229,70	0,16	14095,10	0,9397
27	15000	2327,25	0,17	13722,51	0,9148
28	15000	2869,37	0,16	17619,66	1,1746
29	15000	2316,46	0,17	13759,88	0,9173
30	15000	2452,77	0,13	18646,44	1,2431