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Моделирование процессов биоконверсии с использованием личинок черной мухи-солдатки при утилизации пищевых отходов в больницах

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Аннотация. *Пищевые отходы - это социальная проблема, поскольку они уменьшают количество безопасных и питательных продуктов, увеличивают риск заражения из-за неправильной утилизации, привлекают вредителей, способствуют росту вредных бактерий и обостряют экологические проблемы, угрожающие продуктивности сельского хозяйства. Цели исследования: выяснить, как больничные пищевые отходы можно превратить в богатые питательными веществами корма и удобрения для животных, установив стандарты на основе количества пищевых отходов, поступающих от стационарных пациентов; проанализировать, как различные методы обработки отходов влияют на рост и поглощение питательных веществ личинками. Данное исследование актуально тем, что в нем рассматривается применение личинок черной мухи-солдатки Hermetia illucens (H.Illucens) в качестве агента биоконверсии в больничных условиях. Это относительно неизученный подход, который обещает производство высококачественной биомассы для корма животных и органических веществ. Эффективная модель поможет оптимизировать процесс биоконверсии, тем самым повысить эффективность и результативность переработки пищевых отходов. Таким образом, данное исследование может улучшить наше понимание управления пищевыми отходами в больницах, особенно в ранее неизученных областях.*

Ключевые слова: производство кормов для животных, производство удобрений, моделирование структурных уравнений, пищевые отходы, утилизация органических отходов, личинки черной мухи-солдатки

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Research article

Simulation of bioconversion processes using larvae of the black soldier fly in the disposal of food waste in hospitals

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Abstract. *Food waste is a social problem because it reduces the amount of safe and nutritious foods, increases the risk of infection due to improper disposal, attracts pests, promotes the growth of harmful bacteria and exacerbates environmental problems that threaten agricultural productivity. Research objectives: to find out how hospital food waste can be converted into nutrient-rich animal feed and fertilizers by setting standards based on the amount of food waste coming from inpatient patients; to analyze how various waste treatment methods affect the growth and absorption of nutrients by larvae. This study is relevant because it examines the use of larvae of the black soldier fly Hermetia illucens (H.Illucens) as a bioconversion agent in hospital settings. This is a relatively unexplored approach that promises the production of high-quality biomass for animal feed and organic matter. An effective model will help optimize the bioconversion process, thereby increasing the efficiency and effectiveness of food waste processing. Thus, this study may improve our understanding of food waste management in hospitals, especially in previously unexplored areas.*

Keywords: animal feed production, fertilizer production, structural equation modeling, food waste, organic waste disposal, larvae of the black soldier fly

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Introduction. In the quest to make hospitals environmentally friendly, waste management is a key aspect to consider. This is in line with sustainable design concepts of green hospitals, which emphasize the need to reduce, reuse, recycle and compost waste. Hospitals, being one of the significant producers of organic waste, have the potential to manage the food waste generated every day.

According to the study, the generation of rice waste in hospitals is 36.25%, and it is obvious that food waste management in hospitals requires further attention for sustainable development [1, 2,3].

Food waste is used in hospitals through bioconversion, a process that involves the use of living organisms such as insects to process waste. The use of insect larvae in this not only helps in the utilization of waste but also allows for the simultaneous production of energy, making it an effective alternative solution [4, 5].

Materials and research methods. Use of Hermetia larvae illucens (H. illucens) or black soldier fly larvae offer a sustainable solution for converting organic waste into high- value products such as animal feed and organic fertilizers [6,7,8]. These larvae effectively reduce the volume of waste and convert it into protein-rich biomass, providing significant additional nutritional value [9, 10].

This study is relevant because it examines the use of black soldier fly larvae as a bioconversion agent in a hospital setting, a relatively unexplored approach that holds promise for the production of high-quality biomass for animal feed and organic matter [11,12,13]. An effective model could help optimize the bioconversion process, thereby improving the efficiency and effectiveness of food waste management [14,15]. Thus, this study may improve our understanding of food waste management in hospitals, especially in previously unexplored areas.

The study used:

1. A literature review to understand the flow and characteristics of food waste in hospitals.

Observations were then carried out by counting food waste for eight days, starting with sorting, packing and collection by a nurse assistant under the supervision of a senior nurse, and with the assistance of cleaners in sorting and collecting waste.

2. The food waste collected in the morning and evening is mixed and homogenized depending on its characteristics (rice and non-rice waste) and then subjected to several types of treatment before being used as a food source for H. illucens. This treatment includes:

a. Onggok - residual fermentation of rice waste
b. Unfermented rice waste
c. Rice waste without fermentation
d. Rice waste without probiotic fermentation
e. Non-rice waste and rice without probiotic fermentation
f. Probiotic fermentation of non-rice waste and rice waste
g. Probiotic fermentation of non-rice and ongok wastes
h. Non-rice waste and ongok without probiotic fermentation

Table 1 – Calculation quantities forage waste for 1770 g /12 days / Table 1 – Calculation of the amount of feed waste for 1770 g/12 days

D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	Units of measurement
30	40	50	60	70	80	100	200	300	310	320	330	gram
1.59	2.12	2.65	3.17	3.7	4.23	5.29	10.58	15.87	16.4	16.93	17.46	%

Table 2 – Calculation quantities forage waste for 1890 g /12 days / Table 2 – Calculation of the amount of feed waste for 1890 g/12 days

D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	Units of measurement
40	50	60	70	80	90	110	210	310	320	330	340	gram
1.99	2.49	2.99	3.48	3.98	4.48	5.47	10.45	15.42	15.92	15.92	16.92	%

Table 3 – Calculation quantities forage waste for 2010/12 days / Table 3 – Calculation of the amount of feed waste for 2010/12 days

D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	Units of measurement
50	60	70	80	90	100	120	220	320	330	340	350	gram
2.35	2.82	3.29	3.76	4.23	4.69	5.63	10.33	15.02	15.49	15.96	16.43	%

Research results and their discussion. The eight treatments consist of consuming H. illucens larvae, which are given in three size ranges: 1770 g/12 days, 1890 g/12 days, and 2010 g/12 days, as shown in Table 1, Table 2, and Table 3.

The recovery of rice waste by fermentation and the processing of rice waste by fermentation and distillation can produce ongok and bioethanol with 80% content. The whole process can produce larvae as raw material for animal feed and raw material for fertilizer by decomposing food waste.

The study included the following tests: homogeneity test, normality test, dispersion test.

The homogeneity test is performed in a multivariate mode due to the simultaneous participation of the dependent variable. To test homogeneity, the Box M-test is used with a significance level of α = 0.05. The decision criteria are defined as follows: if the obtained significance value is greater than 0.05, the variance-covariance matrix in both classes is homogeneous or identical. The homogeneity of variance test is used to test the homogeneity of the samples that were collected. The dependent variable was subjected to the homogeneity test. Levene SPSS 26 for Windows was used to conduct the homogeneity test. The decision criterion shows that the variance of the data group is homogeneous if the significance is greater than 0.05.

The purpose of this normality test is to determine whether the data is normally distributed. The Kolmogorov-Smirnov test is used to determine whether the data is normal, and a significance value (p) of 0.05 or higher is considered to indicate a normal distribution. In addition, the data will be considered normally distributed if the skew and kurtosis values are between -2 and +2. In other words, the population under study can be represented by normally distributed data.

We used ANOVA to determine the simultaneous effect of independent variables on the dependent variable. Establishing a significant relationship implies that it applies to the entire population. Depending on the researcher's preference, we used different significance levels, including 0.01 (1%), 0.05 (5%), and 0.10 (10%). This test assessed the effect of each treatment on black soldier fly larval count, protein, fat, and carbohydrate content.

We plotted the distribution of H. illucens decay weight and physical residue measurements at 12 days post-consumption for the eight types of food waste. We then tested the data for normality using the one-sample Kolmogorov-Smirnov test, and the results are presented in Tables 4–6.

Table 4 – Normality test / Table 4 – Normality test

	Kolmogorov-Smirnov statistical test	Assumption	Description
Number of live larvae	0.168	0.076 ^{s}	Fine
Weight of 1 larva	0.157	0.130 ^{s}	Fine
Weight of all larvae	0.133	0.200 $^{s,\,d}$	Fine
Total weight of the remainder	0.090	0.200 $^{s,\,d}$	Fine

According to Table 4, the number of live larvae in Asympia is high. Sig 0.076>0.05 indicates the data is normally distributed. Then comes the weight of one larva of Asympia. Sig 0.130>0.05 , which means the data is normally distributed, and then the weight of all larvae is asymptote. Sig. 0.200>0.05 means the data is normally distributed. So all three data are normally distributed.

Homogeneity test is done as a prerequisite for testing hypotheses. Table 5 below shows the results of homogeneity test. All tested data showed homogeneous results.

Table 5 – Homogeneity test / Table 5 – Uniformity test

	Leuven statistics	Meaning	Description
Number of live larvae	0.321	0.933	Homogeneous
Weight of 1 larva	1.464	0.249	Homogeneous
Weight of all larvae	2.211	0.090	Homogeneous
Total weight of the remainder	0.063	0.999	Homogeneous

A one-way ANOVA test was conducted to determine the existence of potential for live larval count, single larval weight, and total larval weight as an alternative source of animal feed raw material. The results of the one-way ANOVA test are presented in Table 6 below.

Table 6 – Test on dispersive analysis / Table 6 – Test for analysis of variance

	Actual value	Errors
Number of live larvae	35.738	<0.001
Average weight of 1 larva	90.903	<0.001
Weight of all larvae	45.048	<0.001

Based on the data in Table 6, it was found that the one-way ANOVA test value of the number of live larvae, the average weight of 1 larva, and the weight of all larvae had a value of <0.001, so this parameter was significant. This means that there is a potential for larvae.

Conclusion. The use of black soldier fly larvae, Hermetia illucens, in the bioconversion of hospital food waste into valuable by-products such as animal feed and organic fertiliser illustrates an innovative approach to the sustainable disposal of organic waste. The efficiency of black soldier fly larvae in converting waste while providing high nutritional quality makes this method particularly attractive for both waste reduction and resource recovery.

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