

Analysis the ability of *Alphitobius diaperinus* larvae as biodegradator of potato peel waste

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ABSTRACT. The larvae of *Alphitobius diaperinus* (lesser mealworms) are often regarded as pests in livestock farms; however, they possess significant potential as waste biodegraders due to their chewing mouthparts, strong jaws, and symbiotic microbes in their digestive tracts. This study investigates their ability to biodegrade potato peel waste. A Completely Randomized Design (CRD) was employed with three treatment groups: P0 (50 grams of pollard), P1 (50 grams of pollard plus 35 grams of fresh potato peel waste), and P2 (50 grams of pollard plus 5 grams of dried potato peel waste). Third instar larvae were selected based on uniform size, color, and weight. The experiment was conducted over 10 weeks, with weekly monitoring of larval development. The results indicated that *A. diaperinus* larvae effectively biodegraded potato peel waste, with the highest waste reduction and Waste Reduction Index (WRI) observed in the P1 group. Quantitative data showed that the WRI for P1 (8.87%) was significantly higher than that of P2 (2.94%). Biomass production was analyzed using the non-parametric Kruskal-Wallis test, revealing significant differences between groups P0 and P1, while no significant differences were found between P0 and P2 or between P1 and P2. In conclusion, *A. diaperinus* larvae demonstrate considerable potential as biodegraders of potato peel waste. Moreover, the combination of potato peel and pollard as a rearing substrate positively influences larval biomass production.

Keywords: *Alphitobius diaperinus* larvae; biodegradation; biomass production; potato peel waste; Waste Reduction Index (WRI)

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INTRODUCTION

The larvae of *Alphitobius diaperinus*, commonly known as dark beetles or lesser mealworms, are frequently encountered in poultry farms, where they are often regarded as pests. Their presence poses significant challenges to livestock management, as they can act as vectors for pathogenic agents, spreading diseases through their feces and serving as intermediate hosts for parasites such as the tapeworm *Choanotaenia infundibulum* (Krinsky, 2019). The seriousness of this issue is underscored by the potential economic losses incurred by poultry farmers due to infestations, which can lead to reduced feed efficiency, increased veterinary costs, and compromised animal health. As the poultry industry continues to grow, addressing the pest status of *A. diaperinus* is crucial for maintaining the health and productivity of livestock (Tufan-Cetin & Cetin, 2025).

Although it is often considered a pest, the fact is that the *A. diaperinus* larvae contain quite high protein. Roncolini *et al* (2020) stated that *A. diaperinus* larvae used as feed contains protein as much as 58.40% even higher than that found in crickets. This high protein content has led to their inclusion in the European Union regulation 2017/893, which permits the use of certain insect species, including *A. diaperinus*, in the production of insect meal for animal feed. The existence of these regulations can change the public's perspective on these insects from a harmful pest to a potential source of nutrition. However, it is essential to note that the regulation stipulate that the substrate for feed *A. diaperinus* larvae must only contain organic products, so that *A. diaperinus* larvae can be used as a source of processed protein in feed (Rumbos *et al.*, 2018). Feed factors have a significant impact on the growth rate of *A. diaperinus* larvae, so it is important to ensure that they are fed with the right nutrients. Based on the research of van Broekhoven *et al* (2015) examples of feed used in the treatment of *A. diaperinus* larvae are organic food by-products such as grains, yeast, and crumbs of cakes or bread.

The results of the study showed that diet had an effect on the development of *A. diaperinus* larvae and feed conversion efficiency, compared to the diet used by commercial farmers.

While the nutritional benefits of *A. diaperinus* larvae are recognized, there remains a significant gap in understanding their potential as biodegradators of organic waste, particularly potato peel waste. In addition, the use of waste as feed for *A. diaperinus* larvae is one of the efforts to recycle and recover waste into a product sustainably through insects (Soetemans *et al.*, 2020). Previous studies have demonstrated the efficacy of other insect species, such as *Hermetia illucens* (Black Soldier Fly/BSF). In addition to BSF larvae, *A. diaperinus* larvae are also considered to have the potential as biodegradator of potato peel waste (*Solanum tuberosum*). This is because *A. diaperinus* larvae have a chewing mouth type, strong jaws, and symbiontal microbes in their digestive tract to help digest the cellulose contained in the feed (Chen & Ma, 2024).

To address this knowledge gap, this study aims to analyze the ability of *A. diaperinus* larvae to act as biodegradators of potato peel waste by measuring waste weight reduction and calculating the Waste Reduction Index (WRI). Additionally, the research will investigate the impact of incorporating potato peel waste into the larvae's diet on their biomass production. By utilizing organic food by-products, such as potato peel. Potato peel have the potential to be animal feed because fresh potato peel waste are rich in nutrients, including 64.82% carbohydrates, 11.42% protein, 13.76% fiber, and 1.36% fat (Cozma *et al.*, 2024). Previously, a study has been conducted by Andreadis *et al* (2022) related to the combination of *Tenebrio molitor* feed consisting of rice bran, corn cobs, potato peels, solid biogas residues, and olive oil processing residues. The results showed an increase in the total weight of *Tenebrio molitor* larvae after being given the combination of feed. The novelty of this research lies in its focus on the biodegradative capabilities of *A. diaperinus* larvae, particularly in relation to potato peel waste, which has not been extensively studied.

The novelty of this research could have significant implications for both waste management and animal nutrition, potentially transforming the perception of *A. diaperinus* from a pest to a valuable resource. By demonstrating the larvae's ability to effectively degrade organic waste while simultaneously increasing their biomass, this study could pave the way for innovative approaches to sustainable agriculture and waste recycling. Ultimately, the outcomes of this research may contribute to the development of more efficient and environmentally friendly practices in the poultry industry and beyond.

MATERIALS AND METHODS

The study was conducted at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. The research preparation and implementation were scheduled from October 2024 to January 2025. *Alphitobius diaperinus* larvae were sourced from a certified breeder in Ungaran, Semarang Regency. Third instar larvae were selected based on uniformity in color and size to ensure consistency across treatments. An experimental approach was employed using a one-factor Completely Randomized Design (CRD). The treatment design comprised three distinct feed variations, each replicated six times to ensure statistical reliability. The experimental design, including the feed formulations, is presented in Table 1.

Table 1. Research design

Treatment	Number of larvae per container (grams)	Frequency of feeding (times/week)
(P0) Control, 50 grams of pollard	5	-
(P1) Treatment of 50 grams of pollard + 35 grams of fresh potato peel waste	5	1
(P2) Treatment of 50 grams of pollard + 5 grams of dried potato peel waste	5	1

Treatment preparation. Potato peel waste was obtained from street vendors selling fried potatoes around Semarang State University. Before peeling, the potatoes were washed with running water to remove dirt and contaminants from the skin, ensuring they were clean, and then air-dried. The peeling was done manually using a knife, with the thickness of the potato skin approximately 0.03-0.05 cm. The fresh potato peels were then immediately placed in treatment containers. According to AOAC method 950.46 (AOAC, 1997) regarding the method for testing moisture content in food and beverages, the dried potato peels were obtained by drying them in an oven at 105°C for 3 hours until a constant weight was achieved, resulting in a crispy texture. Then the treatment was carried out by treating *A. diaperinus* larvae in a container in the form of a 1000 ml tube-shaped plastic jar as many as 18 jars. Each container is given a marker label according to the type of treatment and repeat number. Then in each container, 5 grams of *A. diaperinus* larvae, 50 grams of pollard, then fresh and dry potato peel waste were put in according to the treatment. All treatment containers are covered with black gauze and then incubated in the same tray and placed in a room that avoids direct sunlight. Environmental factors in the form of temperature and humidity are recorded every day in the morning and evening.

Every two days a water source is added, which is in the form of carrot pieces. The carrot pieces are placed on the surface of the garbage so as not to wet the medium as a whole so that moisture is maintained. Before treatment, a moisture content test was carried out on potato peel waste first and the moisture content was found to be around 77,6%. Then every week observations are made to see the potato peel waste degradation and the development of *A. diaperinus* larvae. After 6 weeks, it was separated between the third instar *A. diaperinus* larvae, adult beetles, and the rest of the waste. Then several weighings of *A. diaperinus* larvae were carried out until the weight of the larvae was almost constant. Then the rest of the waste is weighed dry.

Data collection. In this study, the data to be observed and collected are: (1) waste shrinkage in terms of the rate of potato peel waste degradation (recorded at the beginning and end of the treatment), (2) biomass production (larvae are harvested over a period of 4 weeks, with one harvest each week for each treatment, including 6 repetitions). The maintenance is carried out for one cycle starting from *A. diaperinus* larvae that metamorphose until obtaining third instar larvae from the first production (F1). The water source during the maintenance period uses carrot pieces. Then, in the last four weeks of maintenance, harvesting all of the third instar *A. diaperinus* larvae is conducted, and the weight of the larvae for each treatment is weighed as biomass production data. Finally, at the end of the harvest, the remaining medium and waste are weighed as medium harvest data and waste reduction data.

Data analysis. The data analysis technique is carried out as follows. Potato peel waste shrinkage data consists of waste reduction tables and waste reduction index (WRI) tables. WRI can be calculated using the formula proposed by Diener *et al* (2009), the data then analyzed descriptively:

$$WRI = \frac{D}{t} \times 100$$

$$D = \frac{W - R}{W}$$

Notes:

- W : initial amount of waste (grams)
- t : total time the larvae feed on waste (weeks)
- R : waste residue (grams)
- D : waste reduction

Biomass production data consists of tables of larval harvest data, tables of biomass production rate data, and graphs comparing total initial and final biomass. The biomass production rate data table and the graph comparing total initial and final biomass are analyzed descriptively, while the larval harvest data table is analyzed using non-parametric statistical methods with the Kruskal-Wallis test followed by post hoc test using Dunn's test. The larval harvest data will be subjected to the non-parametric test due to the non-homogeneity of the data, as evidenced by the results of Levene's test.

The Kruskal-Wallis test will assess whether there are statistically significant differences in larval harvest data among the groups. Then if significant differences are found, Dunn's test will be employed to pinpoint the specific groups that differ. This comprehensive analytical approach will explain the biomass production dynamics and elucidate the effects of varying feeding frequencies on larval harvest outcomes.

RESULTS AND DISCUSSION

The ability of *Alphitobius diaperinus* larvae as a biodegradator of potato peel waste. The larvae of *A. diaperinus* are considered to have the potential to be a biodegradator of potato peel waste judging from its ability to degrade potato peel waste. The degradation ability can be measured through the shrinkage of potato peel waste during one metamorphosis cycle. Waste shrinkage was measured at the time of larvae and medium harvesting, which is the last four weeks of treatment after the larvae reached the third instar. All of the repetitions of the potato peel waste shrinkage data can be seen in Table 2.

Table 2. Potato peel waste shrinkage data

Treatment	Potato peel waste shrinkage data every repetitions (g)						Avr
	1	2	3	4	5	6	
P1	0,78	1,69	-1,52	1,24	1,19	1,94	0,89
P2	3,49	4,71	3,86	3,48	3,37	2,26	3,53

Notes: P1 (pollard + fresh potato peel), P2 (pollard + dried potato peel)

The data has been converted based on the moisture content of potato peel waste. Based on the data in Table 2, the percentage of waste shrinkage can be calculated as shown in Table 3.

Table 3. Percentage of potato peel waste shrinkage

Treatment	Potato peel waste weight (g)		Total waste consumption (g)	Waste shrinkage (%)
	Before	After		
P1	7.85	0.89	6.96	88.66
P2	5	3.53	1.47	29.40

Based on Table 3, P1 group showed very significant results, namely waste consumption reached the highest figure of 6,96 grams and shrinkage of 88,60%. On the other hand, the P2 group actually produced data that did not meet expectations, namely waste consumption only reached the lowest figure of 1,47 grams and waste shrinkage was only 29,40%. Next, the Waste Reduction Index (WRI) was calculated. WRI can describe the ability of larvae to reduce waste in a certain period of time (Deen *et al.*, 2023). In this study, the larvae were kept for 10 weeks so that WRI results were obtained as shown in Table 4.

Table 4. Potato peel Waste Reduction Index (WRI)

Treatment	Early waste (grams)	Waste (grams)	Waste reduction (grams)	Total time larvae consume the waste (week)	WRI (100%)
P1	7.85	0.89	6.96	10	8.87
P2	5	3.53	1.47		2.94

According to Table 4, the highest WRI is found in the P1 group at 8.87%, while the lowest WRI is in the P2 group at 2.94%. The higher the WRI, the greater the larvae's ability to reduce potato peel waste. This indicates that the WRI is directly proportional to the reduction of waste. The higher the WRI value, the better the performance of the mealworms (Jucker *et al.*, 2020). Based from waste shrinkage data and WRI data, the P1 group consecutively produced the highest waste shrinkage and WRI compared to the other treatment groups. P1 is a waste substrate treatment group of fresh potato peel waste and pollards. Fresh potato peel waste is rich in nutrients, including 64.82% carbohydrates, 11.42% protein, 13.76% fiber, and 1.36% fat (Cozma *et al.*, 2024). Potato peels are a good source of

carbohydrates, particularly in the form of starch, making them an energy source for mealworms. Additionally, potato peels can enhance the protein content in the larvae, significantly contributing to their overall growth and development. Previous research has shown that *Tenebrio molitor* larvae fed with potato peels without the addition of essential oils achieved the highest protein content of up to 59.50% (Kotsou *et al.*, 2024). The addition of pollard in this study serves as a source of nutrition and substrate medium for the mealworms. Pollard, or wheat bran, is a feed ingredient derived from the milling of the outer layer of wheat grains. Pollard is recognized for its significant nutritional value as a feed source, containing approximately 16.98% crude protein, 12.88% crude fiber, and 4.0% crude fat (Utama *et al.*, 2020).

Meanwhile, the P2 group, which received treatment with pollard and the addition of dried potato peel waste, experienced the greatest reduction in waste and the smallest Waste Reduction Index (WRI) compared to the other treatments. This phenomenon is suspected to be due to the larvae's preference for consuming pollard over dried potato peels, as they tend to favor other nutritional sources when the primary substrate is less appealing to them. This is because dried potato peel waste tends to be harder and less attractive to the larvae. Research by Holmes *et al.* (2013) also indicates that overly dense substrates cannot be penetrated by BSF larvae, which affects the feed consumption process.

Based on the above results, it can be seen that the *A. diaperinus* larvae has the ability as Biodegradator of potato peel waste as reviewed from the shrinkage of potato peel waste weight and the WRI. The shrinkage of potato peel waste weight is proportional to the WRI, so the more shrinkage of the weight of waste, the greater the percentage of WRI. Thus, the larvae ability to degrade waste is also better. In this study, the ability of larvae as biodegradeator was best found in the treatment group of pollard and fresh potato peel waste, which was shown by the reduction in waste weight and the largest percentage of WRI.

Effect of potato peel waste on biomass production of *Alphitobius diaperinus* larvae. Larvae are reared for one metamorphosis cycle. Then, the harvesting of new larvae is carried out in the last four weeks. In this study, the criteria for rearing caterpillars ready for harvest are the third instar caterpillars, characterized by a brown color and relatively uniform size. The total yield of larvae can be seen in Table 5.

Table 5. Larval yield data

Treatment	Repetitions						Average
	1	2	3	4	5	6	
P0	6.33 g	5.59 g	5.15 g	5.78 g	6.20 g	5.90 g	3.50 g
P1	21.43 g	17.70 g	16.48 g	19.94 g	14.67 g	13.21 g	17.24 g
P2	11.44 g	12.86 g	13.73 g	12.65 g	10.55 g	12.09 g	12.22 g

Based on the larval harvest, the data were all distributed normally but not homogeneous, so the statistical test used was the non-parametric Kruskal-Wallis test. The results of the Kruskal-Wallis test can be seen in Table 6.

Table 6. Kruskal-Wallis test results

Test Statistics ^{a,b}	
Kruskal-Wallis H	Result
Df	14.749
Asymp.Sig.	2
	0.001

Based on Table 6, the results show that the value of Asymp.Sig < 0.05, it can be interpreted that the average biomass production between treatments differs significantly. The data was then tested (Post Hoc) with the Dunn method to compare between groups in pairs. The data from the comparison between treatment groups is presented in Table 7.

Table 7. Comparison between treatment groups

Treatment	Pairwise Comparisons of treatment		Remarks
	Sig.	Adj. Sig. ^a	
P0-P2	0.045	0.136	NS
P0-P1	<0.001	0.000	S
P2-P1	0.066	0.198	NS

Descriptions: The difference is expressed with a Sig. value of < 0.05; NS (Not significant), S (Significant)

Table 7 shows that there is a tendency for the treatment between P0-P1 to differ, while the treatments between P0-P2 and P1-P2 do not tend to differ. This indicates that treatment P1 has an effect on the biomass production of *A. diaperinus* larvae. Statistically, there is no tendency to differ between treatments P1-P2, but the biomass production data obtained shows that the biomass production of P1 is higher than that of P2. This strengthens the suspicion that treatment P1 is equivalent to or close to other best treatments. Therefore, although P1 is not the treatment with the highest absolute value, P1 is statistically better than the control and demonstrates performance comparable to the best treatment.

In the control group (P0), the biomass production was the lowest at 3.50 grams, which statistically tends to differ from P1, but does not tend to differ from P2. Similarly, P1 and P2 do not tend to differ because treatment P1 produced 17.24 grams of larvae biomass and P2 produced 12.22 grams. Group P1 used fresh potato peel waste and pollard as maintenance substrate, while P2 used dried potato peel waste and pollard. This indicates that the addition of fresh potato peel waste affects the increase in biomass production of *A. diaperinus* larvae.

The treatment with fresh potato peel waste can produce more mealworms compared to the treatment with dried potato peel waste, as the fresh potato peel waste contains a moisture content of 77.6%. The moisture content of the substrate significantly affects the growth and development of mealworms. This is supported by other research indicating that a substrate moisture content in the range of 50-80% is optimal for the development of BSF larvae, including final weight and feed conversion efficiency (Chen *et al.*, 2019). The moisture content of the substrate also influences its texture, which in turn affects the movement of the larvae, feed consumption, growth, and survival of the larvae (Palma *et al.*, 2018).

The moisture content of the substrate is suspected to also influence the gut microbiota of mealworms. This is supported by previous research that found substrate moisture content affects the diversity of gut microbiota in BSF larvae (Wang *et al.*, 2024). Microbes symbiotically interact with the larvae by providing nutrients, enhancing digestion, and regulating growth and metabolism (Yasika & Shivakumar, 2025). In this study, group P1 produced larger larvae compared to groups P0 and P2. Research by Horgan *et al.* (2023) shows a relationship between feed moisture content and larval weight, where larger BSF (Black Soldier Fly) larvae require higher moisture levels. Based on the results above, it can be concluded that the biomass production of mealworms is influenced by the combination of pollard and potato peel waste, particularly fresh potato peels that contain moisture. This is evidenced by treatment P1, which used fresh potato peel waste and produced the highest biomass of 17.24 grams. In comparison, treatment P2 with dried potato peel waste yielded 12.22 grams, while treatment P0 without the addition of potato peel waste produced 3.50 grams.

Biomass production rate. The rate of biomass production of *Alphitobius diaperinus* larvae based on data from four harvests can be seen in Table 8. The table shows the average amount of biomass production of *A. diaperinus* larvae at each harvest from four treatment groups, with the harvest time spanning four times. Group P1 demonstrated the highest biomass production rate compared to the other treatment groups. This is marked by a significant increase until the third harvest, followed by a slight decrease at the fourth harvest. Meanwhile, group P2 also showed considerable fluctuations but experienced a drastic decline at the second harvest. It then increased again at the third harvest before finally decreasing slightly at the fourth harvest.

Table 8. The rate of biomass production of *Alphitobius diaperinus* larvae

Treatment	1st harvesting (g)	2nd harvesting (g)	3rd harvesting (g)	4th harvesting (g)
P0	1.18	1.01	0.70	0.61
P1	4.21	4.53	5.32	3.19
P2	4.26	1.15	3.83	2.98

Group P0 shows a more stable biomass production rate with smaller increases compared to P1 and P2. Group P0 consistently has a lower biomass production rate than the other treatments. From these results, it can be seen that groups P1 and P2 have a more significant impact on increasing the biomass production rate of the *A. diaperinus* larvae compared to the control treatment. The fluctuations that occur show that there are other factors that affect the rate of larvae biomass production, such as in the P4 group which experienced a drastic decrease in the 2nd harvest. The decline may be due to the number of eggs that are too small or at harvest time many larvae have not reached the third instar. This can be happened because the initial treatment between groups is carried out at different times so that it affects the time of the *A. diaperinus* larvae metamorphosis. All groups exhibited characteristics of larvae metamorphosis that were influenced by ambient temperature and humidity, as well as different harvesting time factors.

Alphitobius diaperinus is a poikilothermic organism, thus its growth and reproduction are greatly influenced by environmental temperature (Zafeiriadis *et al.*, 2023). Temperature is one of the main abiotic variables that determines the metabolism and growth of animals, particularly insects (Kotsou *et al.*, 2021). An increase in temperature also enhances growth and biomass production yield, but the relationship is not linear when temperatures become too high, leading to an optimal temperature range (Björge *et al.*, 2018b). According to Ma *et al.* (2025), high temperatures create a series of negative effects on mealworms. The initial denaturation of enzymes disrupts metabolic processes, leading to problems with protein synthesis, digestion, and nutrient absorption. This ultimately disrupts growth, development, and reproduction, resulting in decreased biomass and a potential increase in mortality.

The metamorphosis period of *A. diaperinus* larvae from the egg phase to adulthood takes between 40 to 100 days with an optimal temperature of 30°C, and the larvae development time is very dependent on the ambient temperature (Sammarco *et al.*, 2023). At the time of the study, the temperature recorded in the morning ranged from 22-31°C with humidity between 55-100%, then the temperature in the afternoon ranged from 25-32°C with humidity between 51-100%. The harvesting process carried out in the last four weeks of treatment is in accordance with the time of metamorphosis of larvae. Where at the beginning of the treatment was used third instar larvae that were about to enter the pupation period. Generally, the development time between instars ranges from 10 days at 20°C to 2 days at 30°C (Sammarco *et al.*, 2023).

The results of the study indicate that the treatment group P1 produced the highest amount of larvae biomass, particularly during the third harvest. Meanwhile, group P2 experienced significant fluctuations with a drastic decline during the second harvest. Group P0 showed a more stable increase, but it was lower compared to P1 and P2. All groups exhibited characteristics of larvae metamorphosis influenced by environmental temperature and humidity, as well as different harvesting times. Thus, it can be concluded that added the potato peel waste as larvae feed contribute to the rate biomass production, although P2 experienced a decline that requires further attention. Additionally, the metamorphosis of larvae from the egg phase to adult beetles occurred as expected, and harvesting was conducted at the right time to ensure that the larvae had reached the third instar.

Total biomass production. In this study, the *A. diaperinus* larvae were maintained for one cycle of metamorphosis. After one cycle of metamorphosis, there was an increase in the total biomass of the *A. diaperinus* larvae. The comparison of total biomass before and after treatment is presented in Fig. 1.

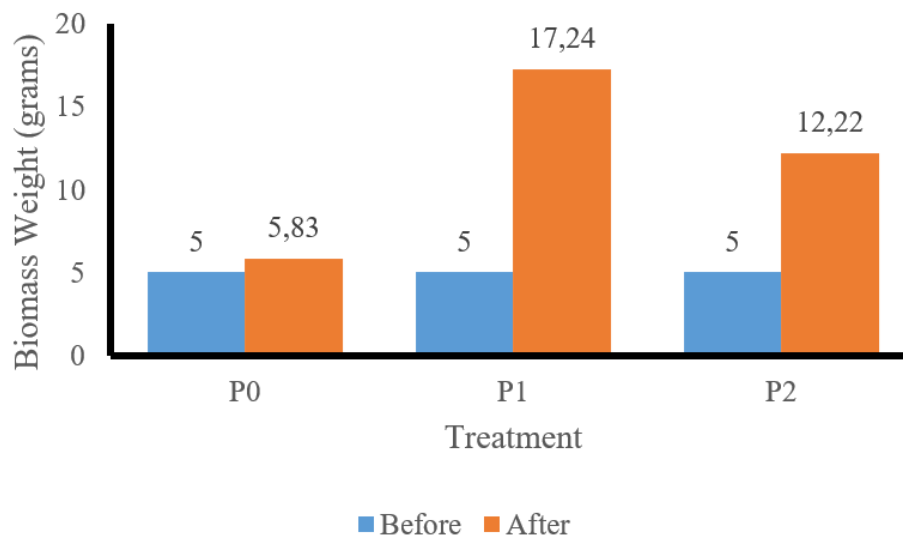


Fig. 1. Comparison of total biomass before and after treatment

Group P0 is the positive control group, where the treatment given only uses pollard as a feed source and P0 is not given potato peel waste as a supplementary nutrient source, resulting in a slight increase in total biomass production of 0.83 grams. Group P1 with fresh potato peel waste and pollard treatment shows a significant increase in total biomass production. This is suspected to be due to the combination of fresh potato peel waste and pollard meeting the nutritional needs of the mealworms. Furthermore, group P2 with dried potato peel waste and pollard treatment also shows an increase in total biomass production, although not as high as group P1. This is due to the presence of dried potato peel waste that affects the feeding preference of the mealworms, as dried potato peel waste tends to be harder and less appealing to the mealworms. Research by Holmes *et al.* (2013), also shows that a substrate that is too dense cannot be penetrated by BSF larvae, thus affecting the feed consumption process. Thus, the results of the biomass increase that occurred were not too significant.

Based on the overall data collected consecutively, group P1 showed the best results. This is due to fresh potato peel waste being rich in nutrients, including 64.82% carbohydrates, 11.42% protein, 13.76% fiber, and 1.36% fat (Cozma *et al.*, 2024). Additionally, fresh potato peel waste contains a moisture content of 77% based on the average moisture measurement at the beginning of the treatment. The combination of nutrients and moisture content in the substrate significantly influences the growth and development of *A. diaperinus* larvae (Bekker *et al.*, 2021). The growth of *A. diaperinus* larvae is significantly influenced by the availability and composition of feed nutrients, which are essential for their biological and physiological development. A balanced diet rich in proteins, carbohydrates, fats, vitamins, and minerals is crucial for optimal growth (Dobermann *et al.*, 2017).

Proteins provide essential amino acids necessary for the synthesis of new proteins and vital for tissue growth and repair. While carbohydrates serve as the primary energy source, fueling metabolic processes and supporting growth rates. Fats are important for energy storage and play a role in cellular functions and membrane integrity. The larvae possess a specialized digestive system that efficiently breaks down complex organic materials, with enzymes facilitating the digestion of proteins, carbohydrates, and lipids, thereby enhancing nutrient absorption. The metabolic rate of *A. diaperinus* larvae is closely linked to the quality and quantity of nutrients consumed; higher nutrient availability can lead to increased metabolic activity and faster growth rates. Additionally, adequate nutrient levels can stimulate the release of growth hormones, promoting cell division and development, while deficiencies may result in stunted growth. Proper nutrition also supports the immune system, enabling larvae to resist diseases and environmental stressors (Siddiqui *et al.*, 2024).

The composition of feed nutrients also contribute to the growth of symbiotic microbes in the digestive tract of *A. diaperinus* larvae. This is because symbiotic microbes greatly contribute to the

absorption of nutrients and the overall metabolism of the larvae (Yasika & Shivakumar, 2025). The digestive tract serves as a suitable habitat for the proliferation of microbes such as Proteobacteria (39.8%), followed by Firmicutes (30.8%), Actinobacteria (21.1%), Tenericutes (5.1%), Bacteroidetes (1.6%), and unclassified bacteria (1.5%) (Crippen *et al.*, 2022). *A. diaperinus* larvae symbiotically associate with these microbes because they consume potato peel that contain cellulose. However, they cannot excrete the cellulase enzyme to digest the cellulose. Therefore, symbiotic microbes function to excrete cellulase enzymes that can be used by the *A. diaperinus* larvae in digesting cellulose into polysaccharides, which are then used by the larvae as an energy source (Dvořák *et al.*, 2016). This energy source is then used by the *A. diaperinus* larvae to regulate metabolism, growth, and reproduction. Also the metabolic rate of *A. diaperinus* is influenced by temperature, with maximum growth rates observed at around 31°C, reaching up to 18.3% daily (Björge *et al.*, 2018). Additionally, factors like food availability and environmental conditions significantly affect their metabolic responses and conversion capacity.

Based on the results above, it can be concluded that the combination of fresh potato peel waste and pollard has an effect on increasing the total biomass production of *A. diaperinus* larvae. From these results, it can also be seen that there is a correlation between larvae feed consumption, digestion processes, and total biomass production in *A. diaperinus* larvae. This correlation is an important aspect of the growth and development of the larvae. The quality of the feed's nutrition will affect the larvae's digestion process. Efficient digestion is essential for breaking down complex nutrients into simpler forms that can be easily absorbed, thus maximizing energy extraction from the consumed material. This energy is then used for the growth and development of the larvae, ultimately resulting in increased total biomass production. This description is supported by the opinion of Kotsou *et al.* (2021), who state that the nutritional content of the feed greatly influences the growth and development of *A. diaperinus* larvae. In addition, the improvement in feed quality contributes to the survival of the larvae and higher growth rates. Thus, the combination of feed has a significant impact on the increase of total biomass of the *A. diaperinus* larva

These results shows the relationship between waste decomposition and biomass production efficiency in *Alphitobius diaperinus* larvae is critical for sustainable waste management and protein production. As organic waste decomposes, it releases essential nutrients that enhance the growth and development of these larvae. Increased nutrient availability from decomposed materials leads to higher feeding rates and improved biomass conversion efficiency, allowing the larvae to transform organic waste into nutrient-rich biomass effectively (Siddiqui *et al.*, 2024). This process not only maximizes biomass yield but also contributes to environmental sustainability by reducing waste accumulation.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that *Alphitobius diaperinus* larvae have the ability to act as biodegradator of potato peel waste, as assessed by the reduction in waste weight and the Waste Reduction Index (WRI). In this study, the best performance of the larvae as biodegradator was observed in the treatment group (P1) combining pollard and fresh potato peel waste, indicated by a waste weight reduction of 88,66% and the highest WRI of 8.87%. The treatment (P2) with dried potato peel waste and the control tended to be lower. The combination treatment of potato peel waste and pollard as a substrate in the maintenance of *A. diaperinus* larvae affects biomass production. The rate and total biomass production of *A. diaperinus* larvae given the combination treatment of pollard and fresh potato peel waste tend to be higher compared to the control group and the treatment with dry potato peel waste. By demonstrating the larvae's effectiveness in degrading organic waste while simultaneously enhancing their biomass, this study could contribute to innovative approaches in sustainable agriculture and waste recycling. Future research should explore the scalability of this method in larger agricultural settings and investigate the potential of other organic waste substrates to further optimize biomass production and waste reduction.

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