Use of waste polystyrene as feed for mealworms (*Tenebrio molitor*)

André Deguara[1], Simeon Deguara[2] Joseph Buhagiar[1]
[1]Department of Biology, University of Malta, Msida MSD 2080, Malta. [2]AquaBioTech Ltd., 'Central Complex', Naggar Str., Mosta MST l76l, Malta.

Introduction: 15.6 million metric tons of polystyrene (PS) were produced in 2021 (Statista Research Department, 2023). Only a few microorganisms and soil invertebrates are currently known to biodegrade PS (Ho et al., 2017; Kim et al., 2021), although the extent of biodegradation is yet unclear. *Tenebrio molitor* larvae, known as mealworm larvae (MWL), are capable of degrading PS. This research aimed to determine to what extent MWL can biodegrade PS and the best natural organic to PS feed ratio so as to obtain maximum PS consumption, growth and survivability.

Materials and methods: Four test groups were set up each with 300 MWL in three replicates were fed on 0, 50, 75 and 100% PS, with the remainder of the feed being composed of wheat bran supplemented weekly with 5g carrots. MWL mortalities, length and weight were recorded weekly. At the end of six weeks, the total PS consumed and frass produced was measured, together with the protein and lipid content of MWL for the 0% and 50% PS diets.. The frass was cultured on TSA and DNBA to detect the presence of microbes with SEM studies carried out on both microbes and frass.

Results

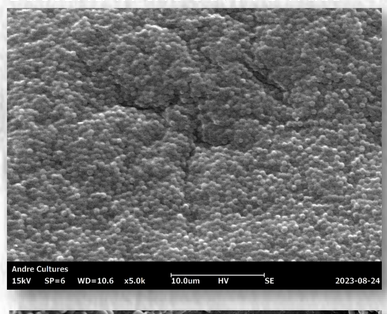
The set-up for each test group

0% PS frass

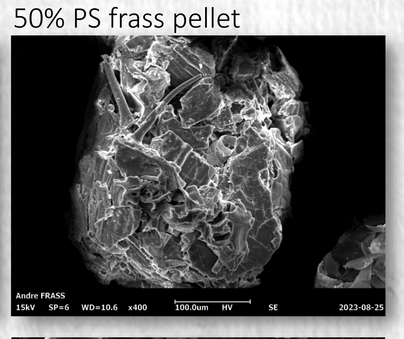
100% PS frass

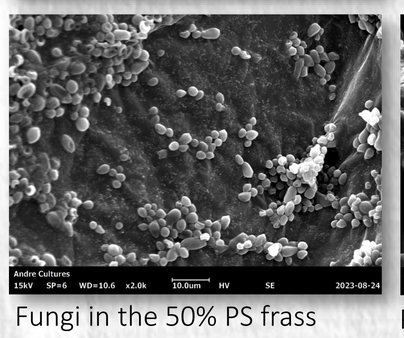
50% PS frass

Bacteria in the 50% PS frass

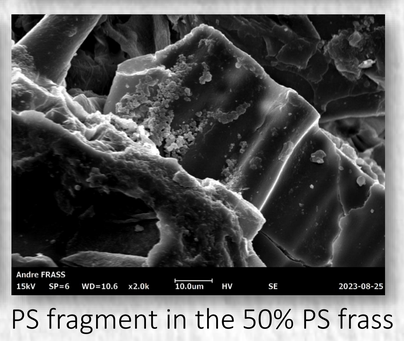


50% PS frass pellet





Fungi in the 50% PS frass



PS fragment in the 50% PS frass with microbial biofilm

- Of the PS-fed groups, MWL fed 50% PS produced the heaviest larvae at 0.11g whilst those on 100% PS-fed MWL produced the smallest at 0.09g per larvae (Table 1, Figure 1).
- Mortalities were the highest for the 100% PS group at 73.89%.
- Treatment 0% PS had the highest FCR at 5.42, and the 100% PS treatment resulted in the best FCR value at 3.40.
- The highest PS consumption was that by the 50% PS group, with 31.06% of the PS being consumed. The 100% PS test group consumed 27.39% of the PS (Figure 2).
- Nutrient analysis of dry MWL resulted in a significantly higher protein (p=0.020) and lower lipid (p=0.002) content for the 50% PS fed MWL compared to the 0% PS fed MWL.

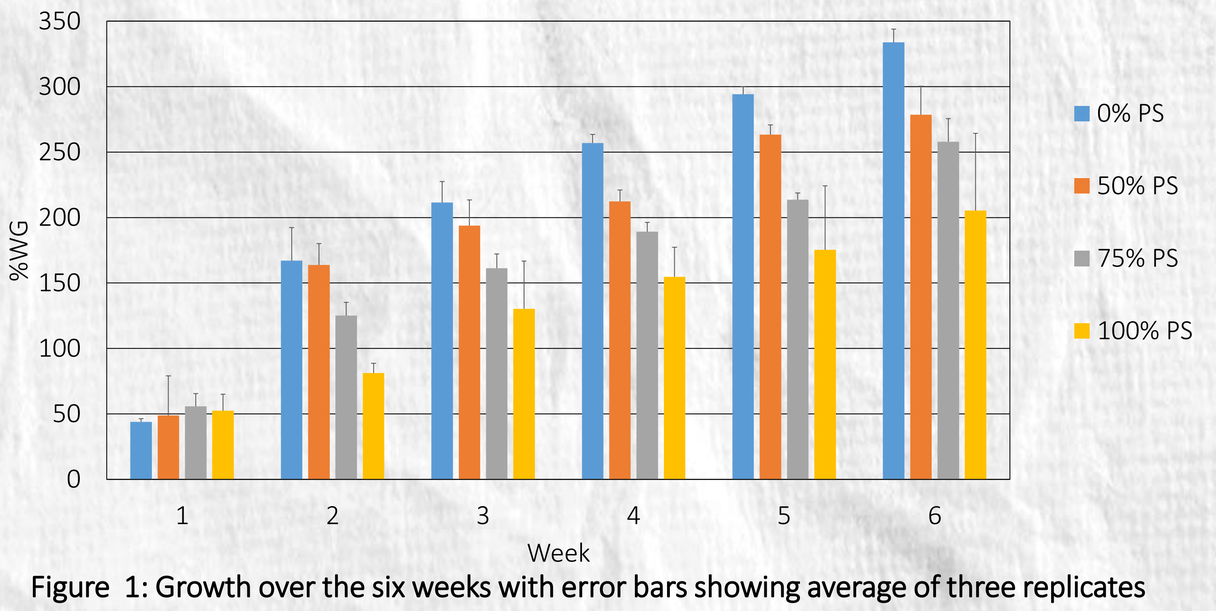


Figure 1: Growth over the six weeks with error bars showing average of three replicates

Table l: Performance parameters of the MWL. SD in brackets (n=3). Letters denote sig. difference (p=<0.05)

	0% PS	50% PS	75% PS	100% PS	p value
% PS consumed	/	**31.06 (±0.31)**	21.74 (±0.66)	27.39 (±0.84)	0.252
Total frass (g)	47.84[a] (±0.40)	28.62[b] (±0.60)	17.48[c] (±0.71)	5.28[d] (±0.59)	<0.001
Final weight (g)	0.12 (±0.01)	**0.11 (±0.01)**	0. 10 (±0.01)	0.09 (±0.02)	0.242
% Length gain	50.32 (±36.57)	47.14 (±27.67)	44.24 (±31.97)	36.57 (±15.57)	0.238
% Weight gain	333.80[a] (±0.40)	**278.60[ab] (±0.60)**	257.92[ab] (±0.71)	205.44[b] (±0.59)	0.027
% Mortalities	22.78 (±1.20)	54.67 (±2.39)	56.00 (±2.89)	73.89 (±1.85)	0.177
FCR	5.42 (±0.97)	5.34 (±1.33)	4.96 (±0.64)	3.40 (±1.41)	0.392
SGR (%/day)	3.49 (±0.06)	3.16 (±0.14)	3.03 (±0.11)	2.63 (±0.49)	0.446
% Protein content	52.02[a] (±2.66)	**56.49[b] (±0.84)**	/	/	0.020[1]
% Lipid content	28.84[a] (±0.65)	**25.51[b] (±1.10)**	/	/	0.002

[1] Mann Whitney

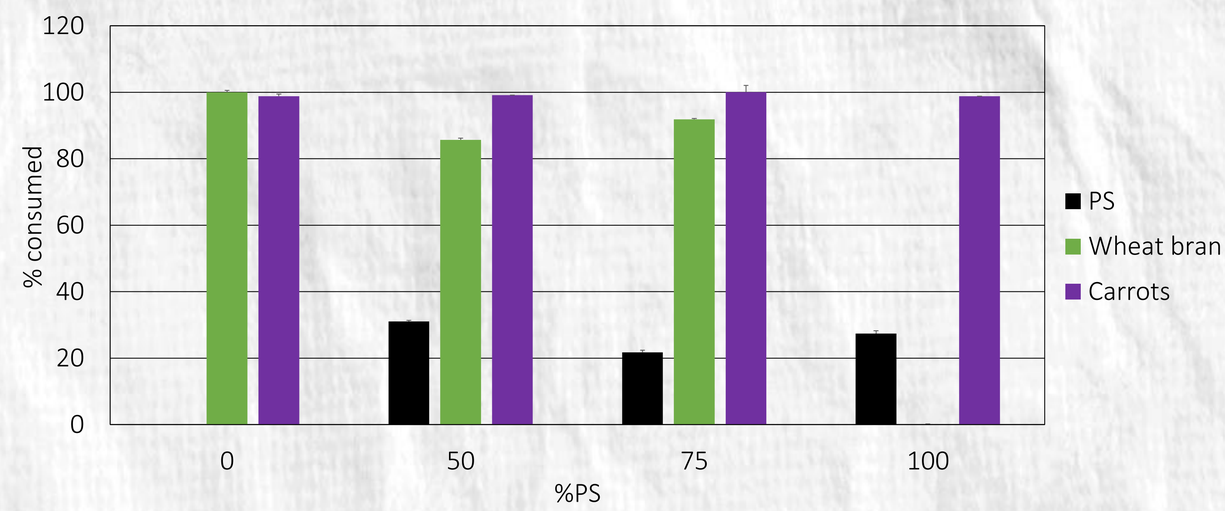


Figure 2: Percentages of the feed constituents consumed by the MWL with error bars showing average of three replicates.

Discussion & Conclusions

- MWL readily consumed the PS, although actual consumption varied between the different treatments.
- MWL started on PS at early instars are capable of growing on PS for at least 6 weeks before pupation; however, this does not guarantee long term survival.
- Results showed that a 50-50 PS and organic feed mix favoured consumption of PS.
- % mortalities was lowest for the 50 and 75% Ps when compared to control and 100%, so that optimum PS feed ratio may be intermediate between 50 & 75%.
- Carrots are beneficial components of the diet as they positively influence the MWL's gut microbiota, facilitating PS breakdown (Palmer et al., 2022).
- The % protein content, on a dry matter basis, of the 50% PS group was significantly higher than that of the 0% PS group, and % lipid content significantly lower. This difference may be of commercial relevance when the product is sold as a protein source to the industry.
- Providing additional natural feeds with the PS resulted in a better growth compared to providing a diet consisting of 100% PS and carrots only.
- The 50% PS treatment resulted in the best PS degradation growth and survivability (of the PS-fed groups).
- To best apply the findings obtained here on a commercial scale, the optimum PS-natural feed balance to achieve maximum MWL survivability and growth needs to be established.

Abbreviations

- PS: Polystyrene
- MWL: Mealworm larvae
- TSA: Tryptic soy agar
- DNBA: Dilute nutrient broth agar
- SEM: Scanning electron microscope
- FCR: Feed conversion ratio
- SGR: Specific growth rate
- %WG: Percentage weight gain

References

- Ho, B., Roberts, T., and Lucas, S. (20l7). An overview on biodegradation of polystyrene and modified polystyrene: the microbial approach. Critical Reviews In Biotechnology, 38(2), 308-320. doi: l0.l080/0738855l.20l7.l355293
- Kim, H. W., Jo, J. H., Kim, Y. B., Le, T. K., Cho, C. W., Yun, C. H., Yeom, S. J. (202l). Biodegradation of polystyrene by bacteria from the soil in common environments. Journal of Hazardous Materials, 4l6, l26239. https://doi.org/l0.l0l6/j.jhazmat.202l.l26239
- Palmer, K., Lauder, K., Christopher, K., Guerra, F., Welch, R., and Bertuccio, A. (2022). Biodegradation of Expanded Polystyrene by Larval and Adult Stages of Tenebrio molitor with Varying Substrates and Beddings. Environmental Processes, 9(1). doi: 10.1007/s40710-021-00556-6
- Statista. (2023, March 24). *Global production capacity of polystyrene 202l &026*. https://www.statista.com/statistics/l065889/global-polystyrene-production-capacity/#:~:text=The%20global%20production%20capacity%20of,million%20metric%20tons%20that%20year.