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COMMENT

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Comment on "Expanded polystyrene is not chemically degraded by mealworms" by Z. M. Tahroudi, G. Flematti, J. Joshi, G. Fritz and R. Atkin, *RSC Sustainability*, 2025, 3, 383

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Biodegradation of commercial expanded polystyrene foam (EPS) and pure EPS foams was investigated by Tahroudi *et al.* (2025) with a single source of mealworms (larvae of *Tenebrio molitor*) from Australia. They claimed that EPS is not chemically degraded by yellow mealworms because degradation of the additive was solely responsible for the molecular weight reduction of commercial EPS, and pure EPS was essentially unaffected by passage through the digestive tract. They found that both pure and commercial EPS diets failed to sustain mealworm growth, and survival rates decreased, which has been documented by other researchers. Our comments are that the conclusions of Tahroudi *et al. i.e.* "expanded polystyrene is not chemically degraded by mealworms" were not fully supported by their data and key evidence was overlooked due to methodological limitations and other weaknesses, including an incomplete mass balance, misinterpretation of GPC and FTIR data, and underutilization of analytical tools established for assessment of plastic degradation. Published results, including our own, demonstrated polystyrene biodegradation of both commercial foams and high-purity PS products by mealworms from various sources. Degradation capabilities varied by mealworm strain, larval age, physical and chemical properties of PS products, nutrients, and environmental factors, making broad generalizations problematic. We also call for microbiome, transcriptome and metabolome analyses to better understand enzymatic contributions to plastic biodegradation. Given the growing body of evidence supporting mealworm-mediated plastic degradation, we highly recommend a more comprehensive approach to assessing plastic biodegradation, incorporating long-term studies, CO_2 release, advanced analytical techniques (^{1}H NMR, GC-MS, py-GC/MS, δ^{13}C, XPS *etc.*) with mass balance calculations associated with gut microbiome, transcriptome and metabolome. Comparison of mealworms from different sources, nutrition history and feeding conditions, and instar stage would provide new insights into the mealworm-mediated plastic degradation.

Sustainability spotlight

Biodegradation of plastics by insects, especially mealworms (*Tenebrio molitor* larvae), has been confirmed widely. Tahroudi *et al.* (2025) published their paper and concluded that mealworms do not chemically degrade expanded polystyrene (EPS). We argue their conclusions are not fully supported by the data and overlook key evidence, and highlight methodological limitations and weaknesses, including incomplete mass balance analysis, the negative impacts of individual housing, and the underutilization of analytical tools for assessing degradation. We urge a more comprehensive approach to assessing plastic biodegradation. Our work emphasizes the importance of the following UN sustainable development goals: clean water and sanitation (SDG 6), industry, innovation, and infrastructure (SDG 9), ensure sustainable consumption and production (SDG 12).

Introduction

Biodegradation of polystyrene (PS) by yellow mealworms (larvae of *Tenebrio molitor* Linnaeus 1758) as well as other insects has been investigated around the world for a decade[1–10] since Yang *et al.* (2015) confirmed PS biodegradation by yellow mealworms from a source in Beijing, China by feeding both commercial EPS and α-^{13}C and β-^{13}C labeled PS powders.[1] Tahroudi *et al.* (2025) recently published a study in *RSC Sustainability* concluding that expanded polystyrene is not chemically degraded by mealworms using the larvae from a source in Australia because molecular weight reduction of commercial EPS was solely due to additive biodegradation, and pure EPS was essentially unaffected by passage through the mealworm digestive tract, which

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provides clear chemical evidence that neither mealworms nor their gut microbiota possess enzymes capable of breaking down EPS for energy.[11] Their investigation included feeding of pure polystyrene (PEPS) foam (M_w 280 kDa) and commercial EPS (CEPS) foam (M_w 227 kDa, M_n 106 kDa, and M_z 390 kDa) containing 4489 ppm (or 0.45%, w/w) additives by switching diet from wheat bran to PS only at intervals of 10 days, over 200 days to compare average larval weight and survival rates. In this comment article, we discuss whether their conclusions are generally correct based on solid evidence/or are not fully supported due methodological weakness using only one mealworm source.

The authors tested the ingestion of commercial EPS *versus* pure EPS to examine EPS degradation. This is technically sound. We believe that a pure, additive-free version of the same polymer should be used to characterize biodegradation of specific plastics.[9,12] To date, however, many researchers have used commercial plastic products to conduct biodegradation tests in order to address feasibility of solutions to environmental pollutants. The same approaches have been widely used for PS biodegradation by *T. molitor* larvae from various sources around world, *e.g.*, China, Hong Kong, India, Indonesia, Japan, Republic of Korea, Poland, Singapore, Spain, and the USA, and other insects.[1–7,13–16] More than 160 000 chemicals are reported in plastics with more than 4200 chemicals of concern, which are persistent, bioaccumulative, mobile or toxic. PS products contain 823 chemicals that have been detected with 307 of these chemicals of concern.[17,18] The investigation of degradation and toxicity of the additives during insect biodegradation has been proposed[19] but rarely investigated, *e.g.*, Brandon *et al.* (2020) investigated the effect and fate of HBCD in EPS foam after ingestion by mealworms.[20] Tahroudi *et al*. (2025) addressed the impact of additives on PS biodegradation, which was rarely emphasized previously. and provided valuable insights into the effects of feeding PS alone for larval growth and rate of survival, confirming that both pure and commercial EPS diets failed to sustain mealworm growth and decreased rates of survival.[11] However, their conclusions, that mealworms do not chemically degrade PS, challenge prior studies that have presented strong evidence for PS biodegradation by yellow mealworms, mainly based on the so-called "**unaffected**" M_n and M_w of residual polymers extracted from frass fed pure PS foam and FTIR spectra of frass sample fed on pure EPS. Based on Fig. 5 of ref. 11, both molecular weights and FTIR spectra are **less changed** but not **unaffected**. The study of Tahroudi *et al.* (2025) contributes to the ongoing discussion regarding plastic degradation, but their conclusions are not fully supported by the data presented.

Discussion

Evidence of PS biodegradation

Tahroudi *et al.* (2025) reported significant depolymerization of commercial EPS by mealworms but attributed this change to additive degradation alone.[11] We concur that plastics free of additives or pure plastics need to be used to verify biodegradation of specific plastic polymers[12] because degradation of additives could result in changes in the molecular weight distribution of polymers. The first report on PS biodegradation by mealworms was investigated by using both α-^{13}C and β-^{13}C PS and commercial EPS foam by Yang *et al.* (2015).[1,2] During the past ten years, researchers have conducted PS biodegradation studies using not only commercial PS foams but also various high purity PS products and other high purity plastics including PE,[13,15] PP,[21] PVC,[22,23] and PET.[21] All of these tests demonstrated that yellow mealworms from sources in China, the USA and UK can biodegrade high purity PS and other plastics.[9] A number of studies using both commercial PS foams and high-purity PS powders demonstrated that mealworms from various sources can depolymerize and reduce PS mass significantly, by more than 50%, not only for commercial PS foams but also for high purity PS without additives. Table 1 shows the results reported by our research team and collaborators. As is well known, EPS foams contain blowing agents, flame retardants, stabilizers, *etc.*, and these additives constitute a relatively small percentage of the EPS product's weight, *e.g.* only 0.45%, w/w including monoglycerides, alkyl amine *N*-oxides, and siloxanes in commercial EPS foams as Tahroudi *et al.* (2025) reported.[11] For flame retardant HBCD, only ~0.25% (w/w) was detected in commercial insulation EPS foam while $\sim 8.0 \times 10^{-5}$% (w/w) in commercial packing EPS foam by Brandon *et al.* (2020).[20] In Table 1, the PS foam mass reduced by >50% could not be attributed to the removal of additives.

Because Tahroudi *et al.* (2025) tested EPS degradation using the mealworms from only one source, it is not sound to draw a general conclusion that EPS is not chemically degraded by mealworms even if their evidence were strong.

Absence of mass balance analysis

A crucial aspect of evaluating biodegradation is tracking the complete fate of ingested EPS, including mass balance analysis of polymer loss, metabolic intermediates, and residual PS in excretion. The primary weakness of Tahroudi *et al.*'s work is that the authors only reported PS consumption rate, *i.e.*, the mass of PS ingested by the mealworms but did not provide a full mass balance assessment for both commercial and pure EPS after passage through the mealworm digestive tract, making it difficult to confirm no EPS degradation. In contrast, most prior studies reported significant mass reduction calculated based on the mass of PS ingested by mealworms, residual PS in the incubator and PS extracted from frass (Table 1) and/or specific PS removal rates, *i.e.*, the mass of PS removed per 100 larva per day,[5,6,9,10] reinforcing evidence of biodegradation. Even under antibiotic suppression, Wang *et al.* (2024) observed that antibiotics negatively impacted reduction of M_n, M_w, and M_z of commercial PS foam, yet significant PS mass removal (>45%) still occurred (Table 1).[28]

Alternatively, Tahroudi *et al.* (2025) could have also determined CO_2 production from mealworms fed with pure EPS, commercial EPS *versus* unfed controls. Yang *et al.* (2015) assessed CO_2 generation from mealworm metabolism and carbon balance, indicating that the carbon of ingested PS converted to CO_2 increased from 20.7% on day 4 to 47.7% on

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Table 1 Changes in molecular weights after biodegradation of PS plastics and mass reduction of ingested polymers by *Tenebrio molitor* larvae (mealworms) reported in the literature (detention time in intestinal tract 12 to 20 h)[a]

Type	Pristine GPC results		Co-diet/additive	Residual GPC results		Plastic mass reduction %	Reference
	M_w (kDa)	M_n (kDa)		M_w (kDa)	M_n (kDa)		
PS foam	124.2	40.43	None	98.33	32.26	50.8	Yang *et al.*, 2015 (ref. 1)
MPs, HP	6.7	6.47	None	6.01	4.23	74.1	Peng *et al.*, 2022 (ref. 24)
	29.17	27.81	None	26.57	24.43	64.1	
	88.63	84.32	None	80.49	68.13	64.4	
	192.9	182.4	None	155.6	124.8	73.5	
	612.2	561.4	None	566.3	427.11	60.6	
	1346	1268	None	1870	1637	39.7	
MPs, HP	240.8	93.7	Agar	225.5	79.6	48.7	Ding *et al.*, 2024 (ref. 21)
MPs, HP, UV	236.1	92.2	Agar	212.9	63.8	49.6	
MPs, HP	194.7	78.8	None	125.2	40.5	67.7	Peng *et al.*, 2023 (ref. 25)
PS foam	338.5	106.3	None	234.9	58.14	78.2	Peng *et al.*, 2023 (ref. 26)
PS foam	193.06	74.62	None	174.6	81.2	Nd	Wang *et al.*, 2024 (ref. 27)
PS foam aged	208.18	78.24	None	197.0	109.98	Nd	
PS foam	181.176	86.381	None	124.29	76.03	57.6	Wang *et al.*, 2024 (ref. 28)
	181.176	86.381	GMS	161.69	59.42	57.8	
	181.176	86.381	AMP	173.43	65.15	45.8	
	181.176	86.381	NS	170.26	79.88	56.7	

[a] Agar = Agar added as adhesive for plastic powders to feed mealworms; AMP = ampicillin suppression; GMS = gentamicin suppression; HP = high purity; NS = nystatin suppression; UV = UV treated prior to biodegradation. All data of molecular weights determined using GPC analyses.

day 16.[1] Shahzad *et al.* (2025) mealsured oxygen consumption by mealworms fed expanded PS foam (M_w 204.1 kDa, M_n 77.1 kDa) and polypropylene (PP) (M_w 484.4 kDa, M_n 87.2 kDa) using sealed biological respirometers linked to an oxygen cylinder and estimated respective degradation efficiencies of 86.28% and 84.61% on the basis of CO_2 released over 28 days.[16] But they did not show this activity.

PS depolymerization/degradation using GPC analysis

Tahroudi *et al.* used GPC analysis as a tool to characterize PS degradation. GPC is a powerful tool but is not the sole approach to verify PS biodegradation. Previous studies have provided strong evidences of depolymerization and mass reduction of high purity PS by mealworms from various sources using GPC analyses as shown in Table 1. For instance, Peng *et al.* (2022) evaluated six high purity PS powders across a range of molecular weights (6.7, 29.17, 88.63, 192.9, 612.2 and 1346 kDa), observing significant mass removal or degradation in the groups fed PS with lower molecular weights, while the higher molecular weight PS (1346 kDa) group showed increased M_n and M_w with relatively lower mass reduction (Table 1).[24] In general, significant decreases or increases in molecular weight (M_n and M_w as well M_z) *i.e.*, changes in molecular weights during biodegradation indicate a change in the molecular weight distribution (MWD) of plastic polymers.[9,10,27,28] In these studies, counterintuitive outcomes may occur due to smaller chain degradation and small variations.[12] An increase in M_n and M_w of residual PS foam was also reported during biodegradation of aged and commercial EPS foams by yellow mealworms.[29] Similar trends *i.e.*, increases and decreases in molecular weights during plastic degradation have been reported for polyurethane degradation by landfill microbes[30] and UV degradation of low-density polyethylene (LDPE) gauze,[31] suggesting an intermediate degradation phase or apparent unchanged molecular weights could occur under conditions that Tahroudi *et al.* (2025) did not consider.

Gel permeation chromatography (GPC) data revealed significant differences in residual PS before and after intestinal passage for commercial EPS (Fig. 5a, $p < 0.05$), whereas purified EPS showed insignificant differences (Fig. 5b).[11] GPC accuracy depends on calibration standards, detector precision, and instrument conditions. Typically, relative accuracy within the same system is around 2%, while absolute accuracy across different systems or methods varies by 5% or more due to calibration, solvent effects, and column performance. Notably, Fig. 5b does show changes in M_n, M_w, and M_z, though with $p > 0.05$, raising the question of whether these changes fall within GPC measurement error margins. In Fig. 5b of Tahroudi *et al.* (2025),[11] a minor increase in M_n and minor decrease in M_w and M_z do not necessarily indicate an absence of degradation, as initial oxidation or crosslinking can maintain or even increase M_w before further breakdown. The fact that the molecular weight of pure EPS did change but was not unaffected as the authors described, even slightly, means that the microbes in the mealworm gut did, in fact, have some effect on the pure polymer backbone. In this case of insignificant change in GPC results, more analytical methods must be performed to verify whether degradation of polymers occurs or does not.

Critique of FTIR analysis

Tahroudi *et al.* (2025) claimed that in the absence of plasticizers, the chemical structure of pure EPS is unaffected by

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passage through the mealworm. In general, comparison of spectra of pristine PS *versus* residual PS in frass can provide chemical evidence whether PS is oxidized or degraded. In Fig. 5c,[11] the FTIR spectra presented show only one marked as "polystyrene" but it is not explained whether the spectrum is pure EPS or pristine commercial EPS foam. They should have presented the spectra of both pure- and commercial-EPS foams for comparison. The spectra of both commercial-EPS frass and pure PS frass show a C=O peak at 1735 cm^{-1} although the former is more pronounced (Fig. 5c). The strong C=O peak in the commercial EPS suggests significant oxidative degradation, likely catalyzed or initiated by the additives. The weak C=O peak in the pure EPS confirms that some oxidative degradation of the polymer backbone also occurred, albeit to a lesser extent. This reinforces the conclusion that the mealworms are capable of degrading the pure polymer, but the process is much slower or less efficient without the help of additives. This contradicts the claim that the mealworms cannot degrade PS, as changes in functional groups provide qualitative evidence of polymer oxidation.

In addition, no analysis was performed for the carbonyl index (CI), a critical parameter for detecting oxidative degradation,[32] which can be calculated using the spectra with wavenumber ranging from 4000 cm^{-1} to 400 cm^{-1}. Tahroudi *et al.* should also have calculated the CI of pure and commercial EPS before and after biotreatment to determine whether pure EPS is oxidized or not.

Summarizing the above two sections, based on GPC data and FTIR spectra (Fig. 5),[11] the results of pure EPS (or PEPS) should be "**less changed**" but not "**unaffected**". This distinction is crucial. "**Unaffected**" would mean zero change, which would confirm that the mealworms only consume additives. "**Less changed**" means that the presence of additives likely accelerates the degradation process. The presence of additives might make the polymer more accessible to enzymes, or the degradation of the additives might produce byproducts (like free radicals) that help initiate the breakdown of the polymer backbone.

Variability in mealworm biodegradation capabilities

Another critical weakness of Tahroudi *et al.*'s conclusions is that they use the results of the mealworms from one source to draw a general conclusion. Since Yang *et al.* (2015) reported that mealworms from a source in Beijing, China biodegraded PS foam with mass reduction up to 50%,[1,2] significant mass reduction of plastics by mealworms have been reported around the world.[3–7,9,23] The plastic-degrading ability of mealworms varies by geographical source,[5,33] larval age,[34] physical properties of polymers tested,[9,34] and incubation conditions such as temperature,[5] water or moisture[35] *etc.* It is well known that mealworms from different sources behavior differently in their physiological characteristics *e.g.*, digestive ability, growth rates, tolerance or response to temperature, life cycle span *etc.* Previously studies indicated that yellow mealworms from different sources showed different specific PS consumption rates and depolymerization extents, *e.g.*, Yang *et al.* (2018) reported that the mealworms from 12 sources (USA, China, UK) exhibited different PS consumption rates (mg per 100 larvae per day) and various depolymerization extents based on the reduction in M_n and M_w.[6] Tahroudi *et al.* (2025) tested only a single Australian yellow mealworm strain from a Petbarn shop in Perth, Australia and generalized their findings to all mealworms. This overlooks substantial evidence that different mealworm populations exhibit varying plastic consumption and degradation abilities, and their study should not be used to dismiss PS biodegradation in other mealworm populations.

Impact of incubation method

Tahroudi *et al.* used individual housing (*i.e.*, one larva per house) to eliminate cannibalism-related survival artifacts. This method has been used by investigators, farmers, and students to prevent cannibalism of superworms (*Zophobas atratus*) and dark mealworms (*Tenebrio obscurus*), both species having higher cannibal rates than yellow mealworms prior to pupariation.[36,37] It was proper to use this method to eliminate cannibalism. However, it is well known that growth density significantly affects mealworm growth rate, individual size, and survival rate. Mealworms are social insects, and an appropriate density promotes mutual stimulation, increasing feeding activity and movement. Most investigators use a group rearing method to test biodegradation of PS and other plastics by yellow mealworms because low cannibalism is observed during short to middle term (4–6 weeks). We usually use 150–250 larvae per incubator with 2 larvae per cm^2 because the lack of group interaction could negatively impact PS consumption and degradation.[5,6,13] The authors should discuss the impact of the individual housing method on PS ingestion and degradation compared to a group rearing. Comparison of these two methods should be considered in future studies.

Density of EPS foam diets

Mealworms prefer chewing and ingesting PS foam with lower density. In this study, pure EPS had a density of 0.034 ± 0.004 g cm^{-3}, which was much higher than commercial EPS at 0.021 ± 0.003 g cm^{-3} by 61%, contradicting the authors' claim that the two foams had similar densities. Density differences affect the PS consumption rate, as reported by Yang *et al.* (2018) that the PS removal rate decreased by 56.6% when foam density increased from 0.021 g cm^{-3} to 0.042 g cm^{-3}.[5] The authors discussed that the lower density of commercial EPS could make it easier for mealworms to mechanically process and ingest. We should also indicate that the commercial EPS is much less dense than the pure EPS, which means it has a much higher surface area-to-volume ratio. Biodegradation, especially in solid materials, is a surface phenomenon. A less dense foam has a more open, porous structure with a greater internal and external surface area. This makes the polymer chains much more accessible to microbes, enzymes, and water. Thus, the difference in degradation rates and the magnitude of the observed changes in M_n, M_w, M_z, and the FTIR spectra could also be a direct result of the difference in physical structure and accessibility, not necessarily the presence of additives alone.

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The pure EPS, being a denser material, would simply be harder for the mealworms and their gut microbes to degrade.

To isolate the effect of additives from the effect of physical structure, the authors should have attempted to prepare the pure EPS and commercial EPS to have the same density and surface area (*e.g.*, by re-preparing EPS foam using the commercial EPS as raw material as pure EPS foam).

PS as sole diet and toxicity

The authors report that mealworms fed solely on PS exhibited reduced growth and survival, using this as evidence against biodegradation. We basically agree with the statement of the authors that "compared to starvation, both pure and commercial expanded polystyrene (EPS) diets failed to sustain mealworm growth, and survival rates decreased, indicating that EPS consumption is toxic to mealworms." According to the results of the authors over 200 days and our previous studies *e.g.*, by Yang *et al.* (2018),[5,6] mealworms cannot develop and grow on either pure EPS or commercial EPS without added co-diet *e.g.*, bran over the long term. It is well documented that PS alone lacks essential nutrients,[5,6,9,35] In reports by Bożek *et al.* (2017)[3] and Urbanek *et al.* (2020),[38] the larvae fed with PS foams lost weight even more than the starvation control. Matyja *et al.* (2020) doubted about the use of mealworms as an effective technology for utilizing PS in plastic waste management based on laboratory data of mealworm incubation and dynamic energy budget (DEB) model analysis.[39]

During PS degradation, the elevation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) is a known response to plastic ingestion and potential toxicity.[25,40] Tahroudi *et al.* should further monitor ROS and RNS levels to show if ROS and RNS elevated to imbalanced level (which causes toxicity) due to breaking down PS, lacking of nutrients, or toxic additives in comparison with bran-fed larvae in which ROS and RNS remain at a balanced level.[40]

Need for comparative transcriptome and microbiome analysis

To better assess whether biodegradation occurs, future studies should compare the transcriptome and microbiome of gut microbes and host mealworms before and after feeding on pure and commercial EPS foams as other researchers did during investigation of plastic degradation previously.[13,29,38,41–47] The rearing methods, *i.e.*, group rearing and individual housing, should be compared. Additionally, mealworms from different sources should be analyzed to determine variability in their plastic degradation capabilities. These analyses would provide molecular-level insights into enzymatic and microbial contributions to PS breakdown.

Additional analytical tools for residual PS

Comprehensive polymer degradation assessments require robust analytical techniques.[9,10,12,17] To date, analytical methods for the characterization of plastic polymers and additives have been well established.[9,10,12,17] The authors relied primarily on GPC to compare PS before and after passage through the intestine, but complementary methods such as ^{1}H NMR, X-ray photoelectron spectroscopy (XPS), X-ray diffraction (XRD), thermogravimetric analysis (TGA), elemental analysis (EA), and pyrolysis-GC/MS (py-GC/MS) could provide more definitive evidence of PS degradation patterns. GC-MS analysis can be used to identify intermediates generated during PS degradation test as Tsochatzis *et al.* (2020) reported.[8] The authors used ^{1}H NMR to analyze the extracted materials from commercial EPS but they did not use ^{1}H NMR to characterize the oxidation of both CEPS *versus* PEPS in order to verify whether pure and commercial EPS are oxidized or not.

To verify biodegradation by mealworms, δ^{13}C isotopic analysis of the residual polymer in frass *versus* pristine polymer can provide a powerful tool.[9] Because organisms often preferentially metabolize the lighter isotope (^{12}C) over the heavier isotope (^{13}C), this selective degradation can lead to residual plastic becoming enriched in ^{13}C. This method has been successfully used to confirm biodegradation of PS, LDPE, PVC, PLA and PET by mealworms,[9,26,40,48] Measurement of δ^{13}C shift in the commercial EPS compared to the pure EPS would further evaluate the biodegradation process in the presence and absence of additives, while a measurable shift in the pure EPS would provide independent evidence of backbone cleavage.

Evidence from other high purity polymer biodegradation studies

Additional studies have reported biodegradation of high-purity plastic polymers by yellow mealworms from various sources *e.g.*, polyethylene (LLDPE, LDPE, and HDPE),[15] polypropylene (PP),[21] polyvinyl chloride (PVC),[22,40] and polyethylene terephthalate (PET).[21] These studies examined the degradation of polymers with different molecular weights and branching patterns, and found depolymerization trends similar to those reported for PS by Peng *et al.* (2020).[22] This supports the argument that the yellow mealworms studied can indeed degrade synthetic polymers, contradicting the conclusions of Tahroudi *et al.* (2025).[11]

Conclusion

Tahroudi *et al.* (2025)[11] claim that yellow mealworms do not degrade polystyrene chemically and raise important considerations in plastic biodegradation research. They determined additives in commercial EPS and provided strong evidence that both pure and commercial EPS diets fail to sustain mealworm growth and result in decreased survival rates but their conclusions, *i.e.*, EPS is not chemically degraded by mealworms, overgeneralize findings from a single source of mealworms and dismiss substantial prior evidence strongly supporting PS biodegradation. Based on their data, the degradation of pure EPS by mealworms cannot be ruled out, and the observed differences in degradation rates between commercial and pure EPS could be due to a combination of factors, including the presence of additives and the significant difference in physical structure (density/surface area), with more analytical evidence (especially mass balance of ingested EPS) needed to disentangle these effects. We recommend future studies incorporating mass balance analysis, multiple mealworm strains, and multiple

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analyses, not only GPC and FTIR but also additional ^{1}H NMR, XPS, δ^{13}C isotope, GC-MS, py-GC/MS, CO_2 release *etc.* to characterize PS consumption and degradation. A more comprehensive understanding of microbial contributions and impact of PS ingestion on larval transcriptome and physiology is also essential for accurate assessment of plastic degradation by yellow mealworms.

Conflicts of interest

There are no conflicts to declare.

Data availability

All data used for this study is available upon reasonable request.

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