The Efficacy of a Compost Accelerator in Straw Composting and Subsequent Agricultural Effects

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A comprehensive, system-level evaluation was carried out for a liquid microbial compost accelerator—inoculated with *Saccharomyces cerevisiae* and *Bacillus subtilis*—on straw composting and subsequent rice production. Composting experiments demonstrated that the accelerator significantly enhanced the process by achieving a peak temperature of 63 °C and sustaining a thermophilic phase (>55 °C), which accelerated straw decomposition, as evidenced by a rapid color transition to dark black within 30 days, a reduction in shear force to 35.6% of the initial value, and an increase in the weight loss rate to 13.6% at 60 days. Field trials confirmed the agricultural benefits: the accelerator safely promoted straw degradation in situ, with extents reaching up to 61.5%, and significantly increased rice yield by up to 4.4% in a dose-dependent manner. These findings distinguish themselves by establishing a complete causal pathway from microbial inoculation through efficient composting to tangible field outcomes, thereby offering a validated technological solution for enhancing straw resource utilization and promoting sustainable agricultural productivity.

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Keywords: Straw compost accelerator; Composting; Straw decomposition; Soil fertility; Rice yield

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INTRODUCTION

Rice straw, which is generated in large quantities during crop cultivation, represents a valuable resource for agricultural production (Li *et al.* 2023). China, as a major agricultural country, produces over 800 million tons of straw annually. However, the utilization rate remains low (Aghaei *et al.* 2022), with approximately 60% of straw being burned or discarded, leading to resource waste and environmental problems such as air pollution, soil degradation, and ecological imbalance (Singh *et al.* 2021). Additionally, the long-term excessive use of chemical fertilizers and pesticides has resulted in declining soil fertility, increased production costs, and aggravated environmental pollution, thus creating an urgent need for efficient straw utilization technologies to address these challenges (Liu *et al.* 2021).

Organic material ripening agents, as novel types of microbial preparations, offer a potential solution by accelerating the decomposition of straw and other organic materials into beneficial organic matter for soil improvement (Wu *et al.* 2022). This is typically achieved through inoculation—the introduction of specific functional microorganisms into the composting matrix to enhance the microbial community and enzymatic activity. This process enhances soil structure, increases soil fertility, and promotes crop growth, aligning with the goals of sustainable agriculture (Kilic 2023).

Previous research and practices have shown that organic material ripening agents, often based on specialized microbial consortia, can effectively promote the decomposition of organic matter *via* such inoculation strategies. The efficacy of these accelerators hinges on the functional metabolites produced by the inoculated microorganisms, which include a suite of hydrolytic and oxidative enzymes such as cellulases, hemicellulases (*e.g.*, xylanases), and lignin-modifying enzymes (*e.g.*, laccases and peroxidases). These enzymes act synergistically to depolymerize the complex lignocellulosic structure of straw (Andlar *et al.* 2018). Furthermore, microbial activity generates organic acids, biosurfactants, and plant growth-promoting factors, which collectively enhance the solubilization of organic compounds, improve nutrient availability, and stimulate crop growth. However, studies focusing on the application of specifically formulated accelerators in integrated straw treatment and their subsequent impacts on agricultural production systems are still limited. There is a need for systematic research to evaluate their efficacy in different agricultural settings.

The ultimate goal of composting is not merely decomposition but the production of mature compost, a stable and sanitized product that is beneficial for agricultural use. Compost maturation is characterized by the stabilization of organic matter, a reduction in the carbon-to-nitrogen (C/N) ratio, the absence of phytotoxic substances (such as organic acids and ammonia), and the elimination of weed seeds and pathogens through sustained thermophilic temperatures (Onwosi *et al.* 2017). The application of immature compost can be highly detrimental, as it may introduce phytotoxins that inhibit seed germination and plant growth, cause nitrogen immobilization in the soil which competes with crops for nutrients, and lead to putrefaction and foul odors (Bernal *et al.* 2009). Therefore, assessing the efficacy of a compost accelerator must extend beyond the rate of decomposition to include its ability to facilitate the production of mature, high-quality compost that is safe for crops and enhances soil health.

However, a systematic evaluation of its efficacy, linking the accelerated composting process directly to quantifiable improvements in soil fertility and crop yield in a field setting, remains a critical knowledge gap. Therefore, this study aimed to fill this gap by providing, to the best of our knowledge, the first comprehensive demonstration of the entire pathway−from microbial-driven straw decomposition to enhanced soil fertility and, ultimately, to a significant rice yield increase−for this specific microbial consortium in a single, cohesive field study.

EXPERIMENTAL

Materials

The organic material compost accelerator used in this study was a liquid product supplied by Jilin New Outlook Fertilizer Co., Ltd. Its main components included *Saccharomyces cerevisiae* and *Bacillus subtilis*, with an effective live bacterial count of ≥200 million per mL ($\geq 2 \times 10^8$ CFU/mL). The urea product was prilled urea (46% N) procured from Shandong Hualu Hengsheng Group Co., Ltd. Rice variety: Dahuaxiang No. 4.

Composting Experimental

The composting test included two treatments: a treatment with the addition of an organic material compost accelerator and a control without the accelerator. The moisture content was maintained at 60 to 75%, and the carbon-to-nitrogen (C/N) ratio was adjusted to approximately 30:1 by adding agricultural-grade urea (46% N, Shandong Hualu Hengsheng Group Co., Ltd.).

The liquid microbial accelerator was applied at a dosage of 0.5% (w/w). The required volume of the accelerator was first diluted with an appropriate amount of tap water to ensure uniform distribution. This solution was then evenly sprayed onto the composting materials while they were being thoroughly mixed. For the control treatment, an equal volume of tap water without the accelerator was applied in an identical manner to maintain consistent moisture conditions across both groups. The compost pile, with dimensions of 1.5 m × 1.2 m × 1.5 m, was turned every 5 to 7 days as the primary method to ensure aerobic conditions by thoroughly mixing the materials and introducing fresh air. In between turnings, to facilitate daily gas exchange and prevent the accumulation of anaerobic gases, the covering plastic film was opened twice daily for passive aeration. This combined strategy effectively maintained aerobic conditions while minimizing moisture and heat loss.

Temperature was measured by inserting a thermometer vertically into the top and sides to a depth of 20 to 35 cm, with the average value recorded. Ambient temperature was also measured. The measurement period was 30 to 40 days. Straw color changes were visually observed during the composting process.

Weight Loss Experiment

Rice straw segments of similar thickness and length (3 to 5 cm) were weighed (50 g) and placed into nylon mesh bags (40 mesh, 25 cm × 35 cm). Twenty bags were prepared for each treatment, totaling 40 bags, which were numbered. The straw in Treatment 1 was moistened with the compost accelerator diluted 50 times with water, while the straw in Treatment 2 was moistened with an equal amount of water. The 20 bags for each treatment were divided into five groups of four bags each, tied together with thin ropes, and buried in the soil at a depth of 7 cm in a five-point plum blossom pattern. The moisture content was actively maintained at 60 to 80% throughout the process by spraying with water. In contrast, the carbon-to-nitrogen (C/N) ratio was adjusted to an initial value of approximately 30:1 and was expected to decrease naturally as composting progressed.

After 10, 20, 30, 40, 50, and 60 days, five bags from each treatment were randomly retrieved for testing. Additionally, five bags (50 g/bag) were rinsed with tap water until the dripping water was colorless, dried at 85 °C for 12 h, and reweighed to calculate the weight loss rate based on the weight change before and after the experiment.

Straw Degradation Experiment

Rice seeds were sown in a dedicated seedbed to raise seedlings. At the 4 to 5 leaf stage (approximately 25 to 30 days after sowing), the seedlings were transplanted into the experimental paddy field. The transplanting followed a fixed density with a planting specification of 30 cm between rows and 12 cm within rows, with 4 to 6 seedlings per hill.

The experiment used a plot comparison method with each plot measuring 110 square meters. Four treatments were set: T1 was conventional fertilization without the compost accelerator (control), applying N45kg/hectare (urea with 46% N), P_2O_5 45kg/hectare (superphosphate with 44% P_2O_5), and K_2O_5 37.5kg/hectare (potassium chloride with 60% K_2O); T2, which received the conventional base fertilizer supplemented with the solid powder formulation of the straw-composting accelerator at 30 kg/ha; T3, which received the base fertilizer plus the accelerator at 60 kg/ha; and T4, which received the base fertilizer plus the accelerator at 90 kg/ha. The accelerator was applied during land preparation for paddy fields, mixed with the base fertilizer. The tiller fertilizer was urea with N34kg/hectare, and the panicle fertilizer was urea with N34kg/hectare and potassium chloride with K_2O_5 37.5kg/hectare. The planting specification was 30 × 12 cm, with 4 to 6 plants per hole. Soil fertility and yield were measured.

Rice straw was cut to about 10 cm, weighed (30 g), and placed into 10 mesh (27 cm × 32 cm) nylon mesh bags. The bags were buried in the mud before transplanting at a depth of 10 to 20 cm. The experiment included four treatments with compost accelerator addition rates of 30kg/hectare, 60 kg/hectare, 90 kg/hectare, and a normal planting control. To quantify the straw degradation rate at each key growth stage (transplanting, tillering, jointing, heading, and maturity), a destructive sampling method was employed. At each of these stages, three randomly selected nylon mesh bags per treatment were carefully retrieved from the soil. The retrieved straw was gently rinsed with tap water to remove adhering soil particles, oven-dried at 85 °C to a constant weight, and then reweighed. The degradation rate was calculated based on the percentage of dry weight loss compared to the initial dry weight.

RESULTS AND DISCUSSION

During composting, the temperature of both the compost accelerator treatment and control gradually increased, but the accelerator treatment showed a significantly higher rate of increase. After the first turning on day 7, the temperature dropped on day 8 and began to rise again on day 9. The accelerator treatment quickly entered the high-temperature fermentation phase, peaking at 63 °C on day 17 (Fig. 1).

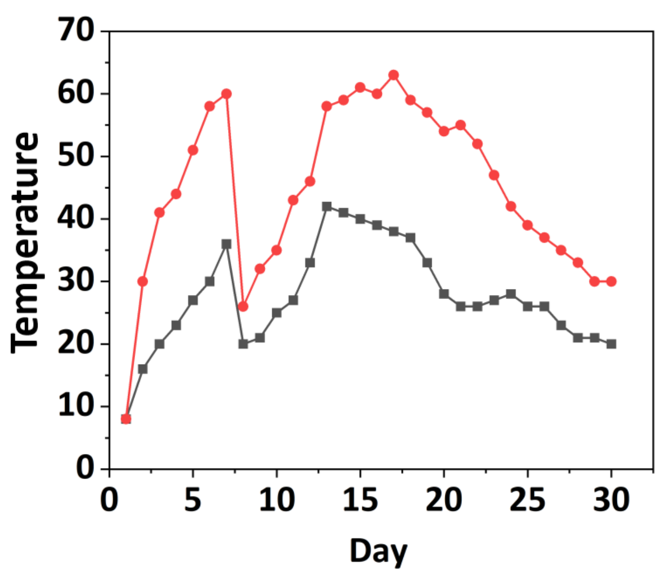

Fig. 1. Temperature dynamics in compost piles treated with organic material ripening agent (red) *versus* control (black)

Furthermore, the accelerator treatment maintained a substantially longer and more effective thermophilic period (*e.g*., above 55 °C) overall compared to control. In contrast, the maximum temperature of control only reached 42 °C (Fig. 1), which is below the typical threshold for effective thermophilic composting. This indicates that the accelerator treatment markedly enhanced the composting process by achieving a higher peak temperature and a more robust thermophilic phase, thereby promoting organic matter degradation and potentially shortening the overall composting time.

Initially, the straw in both treatments was yellow. However, the straw in the accelerator treatment changed color much faster than that in the control group. By day 10, it turned yellowish-brown; by day 20, brown; by day 25, dark brown; and by day 30, dark black. In contrast, the control group remained yellow until day 10, turned light yellow by day 15, yellowish-brown by day 20, and brown by day 30. This demonstrates that the accelerator accelerated the decomposition and transformation of organic matter in the straw, leading to faster color changes.

Over time, the shear force of straw decreased in both conditions, but the decrease was more rapid in the accelerator treatment. However, the shear force in the accelerator treatment decreased more rapidly. By day 15, the decrease accelerated, and by day 30, the shear force in the accelerator treatment had dropped to 35.6% of the initial value, indicating that the straw had reached a composted state. In contrast, the shear force in the control group decreased to only 68.9% of the initial value, and the straw had not yet become fully composted. The difference between the two was significant ($P<0.05$), indicating that the accelerator significantly reduced straw shear force and promoted composting.

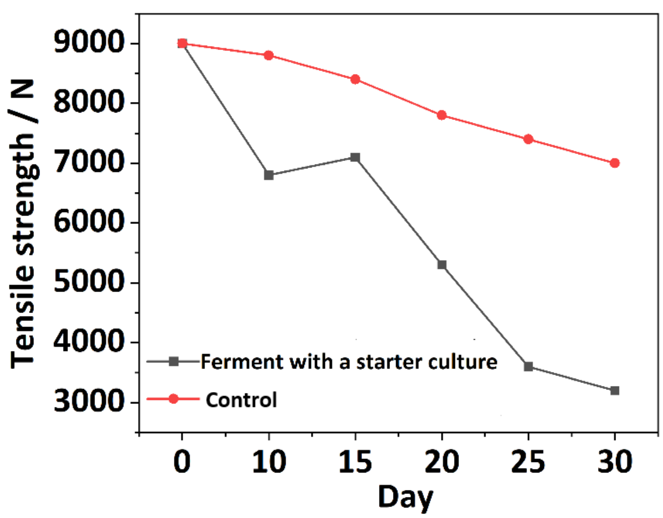

Fig. 2. Comparative effects of organic material ripening agent and control on shear resistance in composted straw

The weight loss rate of straw was consistently higher in the accelerator treatment than in the control throughout the 60-day decomposition period. The differences were 4.41%, 5.43%, 7.37%, 10.57%, 10.99%, and 13.55% on days 10, 20, 30, 40, 50, and 60, respectively. The gap between the two treatments widened over time, and the difference in weight loss rate became highly significant by day 60. These results confirm that the accelerator effectively promotes straw decomposition and increases the weight loss rate.

In the pot experiment, rice plants grew normally during both the seedling and panicle stages in all treatments, with no signs of yellowing or wilting. Notably, the plant height in the accelerator treatment was greater than that in the control. These observations indicate that the accelerator is not only safe for rice growth, causing no adverse effects, but may even have a promoting effect.

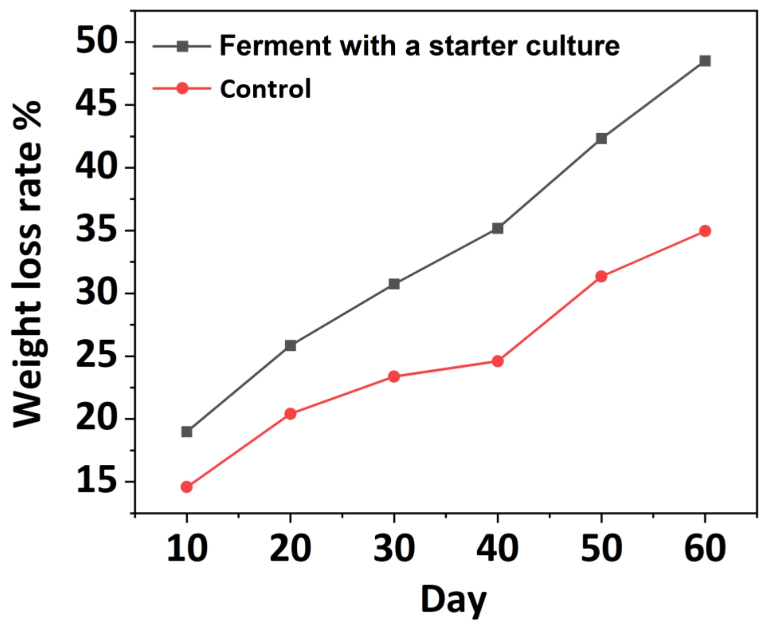

Fig. 3. Dynamic changes in straw weight loss rate under organic material ripening agent treatment *versus* control

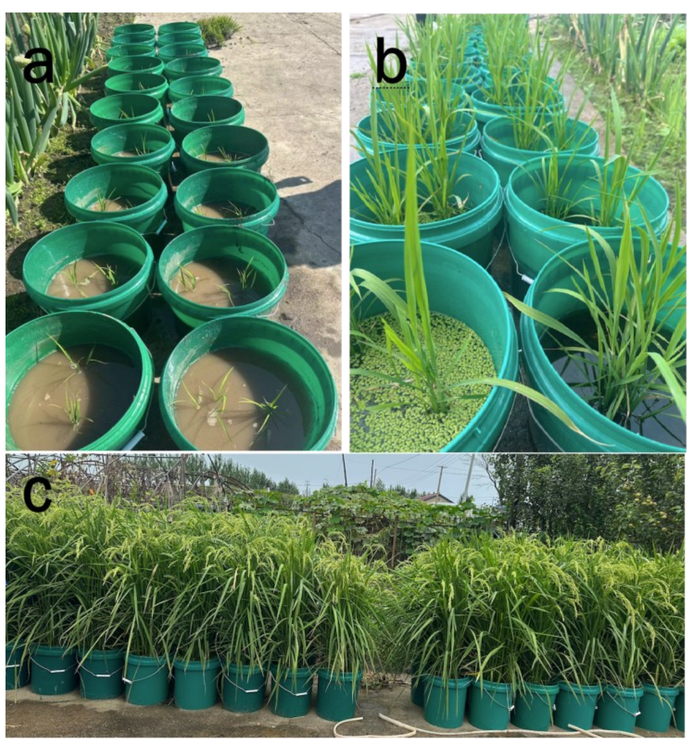

Fig. 4. Rice growth responses to ripening agent application: (a, b) seedling stage and (c) heading stage

The straw degradation rate increased over the rice growth period and was positively correlated with the accelerator application rate. At maturity, the degradation rates reached 55.71%, 57.01%, and 61.53% for the application dosages of 30, 60, and 90 kg ha^{-1}, respectively. These results clearly demonstrate that a higher application rate of the accelerator led to a higher straw degradation rate.

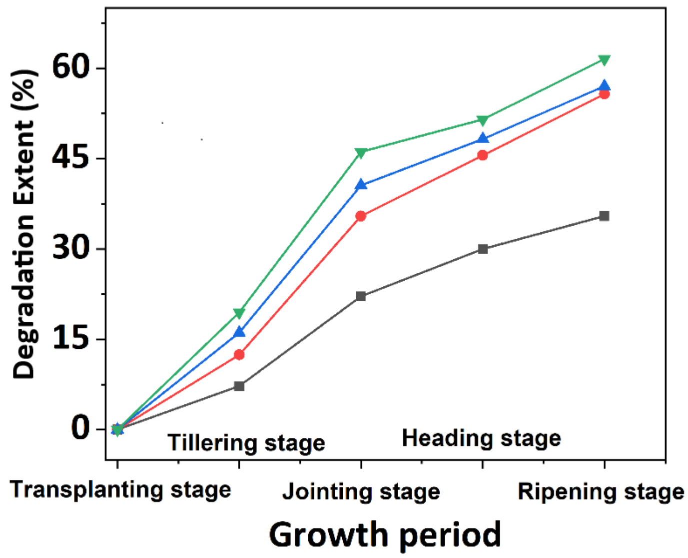

Fig. 5. Dose-dependent effects of organic material ripening agent on straw degradation rate

The application of the accelerator also positively affected rice yield. Compared to the control, yields increased by 3.16%, 3.92%, and 4.35% for the 30, 60, and 90 kg ha^{-1} treatments, respectively, and this yield-promoting effect became more pronounced with increasing application dosages. This positive correlation is likely attributable to the role of the accelerator in enhancing straw decomposition and improving soil fertility, which in turn supplied more nutrients for rice growth and consequently increased grain yield.

Table 1. Effects of Organic Material Ripening Agent on Rice Yield Parameters

Treatment	Plant Height (cm)	Panicles per m²	Grains per Panicle	Seed Setting (%)	1000-Grain Weight (g)	Yield (kg/ha)	Yield Increase (%)
1	114 ± 3.2	515 ± 12.5	68.4 ± 2.1	89.48 ± 1.85	25.98 ± 0.45	9156 ± 206	–
2	119 ± 2.8	517 ± 11.8	70.1 ± 1.9	89.94 ± 1.92	26.05 ± 0.41	9446 ± 198	3.16%
3	119.5 ± 3.1	520 ± 10.9	70.1 ± 1.7	90.25 ± 1.65	26.09 ± 0.38	9515 ± 216	3.92%
4	120.5 ± 2.9	521 ± 13.2	70.2 ± 2.0	91.04 ± 1.73	26.11 ± 0.42	9554 ± 189	4.35%
p-value	0.015*	0.245	0.087	0.032*	0.110	0.008* *	

Notes: Values are presented as mean ± standard deviation (n = 3). p-values were obtained from one-way ANOVA followed by Duncan's test. * indicates significant differences at $p < 0.05$.

The findings of this study are consistent with, yet extend beyond, the existing literature on microbial-assisted composting. For instance, while the role of microbial consortia and their enzymes in lignocellulose degradation is well-established (Andlar *et al.* 2018), previous studies on straw treatment, such as that by Wu *et al.* (2022), have often focused on solid organic fertilizers rather than specialized microbial accelerants. In contrast, the present study utilized a defined liquid microbial accelerator containing *Saccharomyces cerevisiae* and *Bacillus subtilis*, which not only achieved a higher peak temperature (63 °C) and a more sustained thermophilic phase—a key criterion for efficient composting and sanitation (Onwosi *et al.* 2017; Bernal *et al.* 2009)—but also demonstrated a clear dose-dependent improvement in both straw degradation (up to 61.5%) and rice yield (up to 4.4%).

Moreover, while systems-level approaches such as combined straw and organic fertilizer application can enhance crop growth (Wu *et al.* 2022; Kilic 2023), and straw incorporation itself can benefit soil properties and yield (Liu *et al.* 2021), few studies have provided a holistic evaluation spanning from microbial inoculation through in-situ straw decomposition to field-scale agronomic outcomes. The present work bridges this gap by establishing a direct causal pathway: from enhanced microbial activity during composting to improved soil nutrient availability and, ultimately, to measurable yield gains. This systems-level validation, which addresses the pressing need for alternatives to straw burning (Singh *et al.* 2021) and low utilization rates (Aghaei *et al.* 2022), represents a significant advance over earlier compartmentalized approaches.

It should be noted that this study primarily relied on physical and biological indicators to assess composting efficiency; future work incorporating detailed chemical analyses of the compost product (*e.g.*, C/N ratio, lignin-cellulose degradation, and germination index) would provide deeper insight into the maturation process and final product quality.

CONCLUSIONS

1. This study confirmed that the organic material compost accelerator—a liquid microbial inoculant containing *Saccharomyces cerevisiae* and *Bacillus subtilis*—showed significant advantages in straw treatment. By accelerating high-temperature composting, reducing the mechanical strength of straw, and increasing the weight loss rate, it achieved rapid and harmless decomposition of straw.
2. In field applications, the accelerator safely promoted rice growth and significantly enhanced *in-situ* straw degradation in a dose-dependent manner, which ultimately translated into a significant increase in rice yield. The promotion effects on straw degradation and yield increase became more pronounced with increasing application rates.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

Data availability

Data will be made available on request.

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