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AGRICULTURAL RESIDUES FOR ORGANIC COMPOST FERTILIZER CATALYZED BY SELECTED MICROBIAL STRAINS

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ABSTRACT

Agricultural wastes become potential sources of greenhouse gas emissions, water eutrophication, soil contaminantion, and pathogen transmittance if it is not treated appropriately. This study sought to evaluate organic fertilizers produced from composting of crop residues and livestock manure catalyzed by selected microbial inoculants. Field surveys on agricultural waste generation were conducted in four northern provinces: Hoa Binh, Ha Noi, Hung Yen and Ha Nam. The pilot experiments for composting of rice straw and pig manure were conducted for 30 days. The calculated results from 4 provinces showed that crop residues generated weighed a total of 3.34 million tons per year, of which rice straw accounts for 551.7 $\pm$ 388.5 thousand tons/year. Manure from pig and poultry in Hanoi were 1,321.2 and 2,107.8 thousand tons/year, respectively. AT-YTB, Bo-Bio 386 containing *Trichoderma spp, Bacillus megaterium, Azotobacter* are optimal for rice straw composting; Bio-MT, Emina and Trichoderma containing *Trichoderma spp., Streptomyces spp., Bacillus spp., Rhodobacter spp., Lactobacillus spp.* are optimal for pig manure composting. Application of these inoculants contributes to an increase in digestible nitrogen content of 32.5-56.6% from rice straw composting and 21.7% from pig manure composting. Further studies on utilization of compost fertilizers from these sources for soil improvement and crop production should be conducted.

Key words: pig manure, microbial inoculants, compost fertilizer, sustainable agriculture

INTRODUCTION

The agricultural sector has contributed a significant generation of wastes including field crop wastes and livestock manure (Kim and Dale 2004, Ottmar et al. 2011). The crop residues are defined as above ground straw or stalks or the remain parts of plant after harvesting (Daioglou et al. 2016, Vo et al. 2018). It was reported that about 140 billion metric tons of biomass are annually generated from agriculture (UNEP 2009). These wastes have been used for animal feed, food, bioenergy, but a significant amount of agricultural biomass discharged or burned freely causing greenhouse gas emissions (Yagi and Minami 1990, Nasaer et al. 2007), environmental pollution (Kaushal and Prashar 2020) and disease dispersion (Kerdraon et al. 2019). In Vietnam, the total amount of agricultural waste is relatively high, reaching 49.83 million tons of dry matter per year, of which rice straw accounts for 85.49%, corresponding to 42.6 million tons of dry matter per year. Meanwhile, large amounts of livestock manures in rural areas are not utilized effectively and discharged into anaerobic digester which remains high concentration of COD effluent (Nguyen et al. 2021).

The nutrient content in agricultural residues is very high. The nutrient concentrations (dry weight) of corn (N 9.2%, P 1.5%, K 6.2%), peanut (N 18.2%, P 1.6%, K 5.8%), rice (N 9.1%, P 1.3%, K 10%) are high (Jia et al. 2018). The content of protein, glucose and cellulose in maize, peanut, and weed in Hoa Binh province was in the range of 26.5% to 36.2% (Vo et al. 2018a). Cellulose is the major component of crop residues followed by protein and lignin. The residues contain a potential carbon source for soil amendment via organic matter supplement. Therefore, reuse of crop residues toward organic fertilizers is essential not only for cleaning and protecting the environment but also returning organic matter for the crops, solving the shortage of organic fertilizer. Using organic fertilizer could contribute to reducing chemical fertilizer use thus enabling the conversion of conventional agriculture toward organic farming. High cellulosic content is difficult to compost and requires long-term degradation. The ideal conditions for organic fertilizer composting require the C:N ratio in the range between 12-20 using effective microorganisms. The current approach is to use microorganisms to shorten composting time, improve quality of compost products, and enrichment of nutrients. Microorganisms in bio-catalytic products accelerate the decomposition of cellulose, lignin, starch, organic phosphorus, pathogenic microorganisms, to shorten the time of incubation, reduce odor, and destroy harmful microorganisms (Abe et al. 2021, Chen et al. 2020).

The application of organic fertilizer often increases soil organic matter and nutrient content such as nitrogen (Mahmood et al. 2017). Organic matter in the soil affects plant growth and productivity through nutrient supply. The changes in soil physical properties contribute to improving root and stimulatory environment for crop development (Liebig and Doran 1999). Crop production based on the use of organic fertilizer is considered to be more sustainable than chemical-based agriculture. Therefore, using organic fertilizers has received the attention of environmentalists, agricultural researchers and consumers in recent years. This research sought to estimate the generation of crop residues and livestock waste in rural areas in northern Vietnam, compost crop residues with livestock manure and different microbial inoculants, and evaluate the quality of composted fertilizer.

MATERIALS AND METHODS

Material and experimental design. The composting experiments of rice straw employed 8 commercial inoculants including AT-YTB, Bo-bio 386, CNX-ABI, Emina, Emic, Fito -Biomix RR, Sagi-Bio, Saccharomyces- Bacillus Trichoderma. The selected inoculants contain microorganisms, *Trichoderma spp, Bacillus megaterium, Azotobacter,* which degrade cellulose, starch, protein, and phosphate and contribute to nitrogen fixation. The density of microorganisms, between 10^6-10^9 CFU/g, was indicated on the label of the commercial inoculant products (Table 1). The field experiment used rice straw at 2000 kg per pile and was designed as randomly complete block design (RCBD) with 3 replicates. The experiments were conducted in Yen Cuong commune, Y Yen district, Nam Dinh province.

Table 1. Treatment of rice straw with bio-catalytic products

No.	Name of Product	Microorganisms	Density *(CFU/g)*	Activity
1	AT-YTB	*Trichoderma spp, Bacillus megaterium, Azotobacter*	$>10^7$	Microorganism for degradation of cellulose, starch, protein and phosphate; nitrogen fixation.
2	Bo-Bio 386	*Trichoderma spp.*	$>5.10^7$	Microorganism for degradation of cellulose, starch and protein.
3	CNX-ABI	*Trichoderma spp.*	$>2.10^9$	Microorganism for degradation of cellulose, starch and protein.
4	EMIC	*Bacillus lacto, Streptomyces,*	$>10^6$	Microoganisms for fermentation; deodorization;

No.	Name of Product	Microorganisms	Density (*CFU/g*)	Activity
		Saccharomyces		degradation of carbohydrate; polysaccharide formation; inhibitor of toxicity.
5	EMINA	*Bacillus lactose, Bacillus subtilis, Bacillus megaterium*	$>10^8$	Microorganism for fermentation and deodorization, degradation for carbohydrate, phosphate and protein; inhibitor of toxicity.
6	Fito-Biomix RR	*Bacillus polyfermenticus, Trichoderma virens, Streptomyces*	$>10^8$	Microorganism for fermentation; degradation of cellulose, starch, protein and Phosphate; inhibitor of toxicity.
7	Sagi-Bio	*Bacillus, Streptomyces*	$>10^8$	Microorganism for fermentation; degradation of cellulose, starch, protein and phosphate; inhibitor of toxicity.
8	S-Trichoderma	*Saccharomyces, Bacillus, Trichoderma spp*	$>10^9$	Microorganism for fermentation; degradation of cellulose, starch, protein and phosphate; inhibitor of toxicity.

Note: the microbial strains and density are provided by the producers as indicated on the label.

The composting experiments of pig manure employed 8 commercial inoculants including Balasa N01, Bio-Mt, Comfort maker, Emina-E, Emuniv, Fito-Bio RR, Saccharomyces-Trichoderma, and Trichoderma- Bacillus (Table 2). The selected inoculants contain microorganisms, *Bacillus subtilis, Saccharomyces cerevisiae, Streptococcus lactis, Thiobacillus spp*., respond to fermentation and deodorization; degradation of cellulose, starch, protein and inhibitor of toxicity. The density of microorganisms in the inoculants was in the range of 10^6-10^9 CFU/g. Composting of manure was conducted on tarpaulins and covered by black plastic. The inoculant rate varies from 1-2% depending on the type of product.

Table 2. Treatment of pig manure with bio-catalytic products

No.	Product	Microorganisms	Density (*CFU/g*)	Activity
1	BALASA N01	- *Bacillus subtilis; Saccharomyces cerevisiae* - *Streptococcus lactis; Thiobacillus spp.*	$>5,8.10^6$ $>3,7.10^6$	Microorganism for fermentation and deodorization; degradation of cellulose, starch, protein and inhibitor of toxicity
2	BIO-MT	- Aerobic microorganism - Protein degradation microorganism - Cellulose degradation microorganism - Starch degradation microorganism	$>10^7$ $>10^6$ $>10^6$ $>10^6$	Microorganism for fermentation; degradation of cellulose, starch, protein and phosphate
3	Compost maker	Cellulose, phosphate, protein degradation microorganisms, fermentation mico-	$>10^8$	Microorganism for fermentation and deodorization; degradation of cellulose, starch, protein and phosphate

No.	Product	Microorganisms	Density (*CFU/g*)	Activity
		organism and deodorize mico-organism		
4	EMINA-E	- *Trichoderma spp.* - *Streptomyces spp.; Bacillus spp* - *Rhodobacter spp*; *Lactobacillus spp*	$>10^7$ $>10^8$ $>10^6$	Microorganism for fermentation and deodorization; degradation of cellulose, starch, protein
5	EMUNIV	Cellulose, starch, protein, lipid, pectin degradation microorganisms	$>10^9$	Microorganism for deodorization; degradation of cellulose, starch, pectin and protein
6	FITO-BIOMIX RR	*Bacillus polyfermenticus*; *Streptomyces thermocoprophilus*; *Trichoderma virens*	$>10^8$ $>10^8$	Microorganism for fermentation; degradation of cellulose, starch, protein and phosphate; inhibitor of toxicity
7	S-Trichoderma (Saccharomyces-Bacillus)	Saccharomyces, Bacillus, Lactobacillus, Nitrosomonas, Nitrobacter, Trichoderma	$>10^9$	Microorganism for fermentation and deodorization; degradation of cellulose, lipit, protein and phosphate; ammonization, inhibitor of toxicity
8	Trichoderma – Bacillus.sp	Calcium phosphate (20%), and Trichoderma-Bacillus	$>10^9$	Microorganism for degradation for cellulo, phosphate and protein; inhibitor of toxicity

Note: The microbial strains and density were provided as indicated on the label.

Data collection and analysis. Structured questionnaires interviews were conducted with producers, enterprises and local authorities in intensive growing areas of four northern provinces in 2017 (Hoa Binh, Ha Noi, Hung Yen and Ha Nam provinces). In each province, 9 communes in three districts were selected to collect data on the crop residue and animal manure. In each commune, 15 farm households including 10 farms with mainly crop production and 5 other ones with livestock were interviewed to investigate the sources of raw materials from agricultural activities. The statistical data on production and trading of agricultural products enterprises, pesticides and bio-catalyze products were collected from the Department of Agriculture and Rural Development.

Treatment condition. Rice straw and pig manure were treated separately. The temperature and humidity were measured in each treatment of straw or pig manure 3 days until 30 days after incubation. The thermometer was inserted into the pile with a depth of 30 cm and measured in triplicate.

Composting effectiveness. At 14 days and 30 days after incubation, the straw and pig's manure were randomly sampled for measurement and analysis of physical and biochemical parameters. In each formula, the sample was taken at 3 points and then mixed into one laboratory sample to analyze pH, moisture, organic matter (OM), total nitrogen (N), digestible phosphorus (P) and digestible potassium (K), C/N ratio and microorganism degrade cellulose. Moisture was measured by drying method, pH was measured using a portable pH meter (ISO 10390:2005), organic matter (OM) by Walkley-Black method (TCVN 9294 : 2012), total nitrogen content (%) by Kjeldahl method (TCVN 8557:2010), digestible phosphorus (mg P_2O_5/100g) by Olsen method (TCVN 8559:2010), digestible potassium (mg K_2O/100g) by Mátlova, flame spectrometer (TCVN 8560:2010). Microorganisms including cellulose degradation, *Salmonella* and *E.coli* were analyzed by direct generation on agar and counting the number of micro cells after 48-72 hours.

RESULTS AND DISCUSSION

Crop residues. In this research, we focused on four provinces experiencing high rates of agriculture production in Hoa Binh, Ha Noi, Hung Yen and Ha Nam. The total amount of crops residues (rice, beans, peanut, cassava, sugarcane, and vegetable) were approximately 3.34 million tons per year. The largest amount of residues was generated from agricultural activities in Hanoi with 1.3 million tons per year. Hoa Binh, Hung Yen and Ha Nam accounted for 917 ton/year, 603.8 ton/year and 469 ton/year, respectively (Table 3). On average, rice residues accounted for 551.7±388.5 thousand tons/year, occupied highest yield compared to other crops. Cassava and vegetables accounted for an average of 146.7 and 72.3 thousand tons/year respectively. Hoa Binh province contributed 578.2 thousand tons of cassava per year. These results indicated that residues from agriculture contain high value of biomass having high potential for re-utilization for succeeding seasons. This is a significant contribution of carbon sources if the residues are used in the composting process. To produce organic fertilizer, other sources of nitrogen should also be considered.

Table 3. Residues from major crops in selected provinces in Vietnam.

Province	Rice	Beans	Peanut	Cassava	Sugar cane	Vegetable	Total residues amount
Hoa Binh	215.8	3.4	19.0	578.2	61.1	39.4	916.9
Ha Noi	1,109.5	49.3	19.4	7.9	0.2	167.5	1,353.8
Ha Nam	395.5	0.7	3.1	0.4	34.7	34.7	469.1
Hung Yen	485.9	15.2	7.6	0.1	47.5	47.5	603.8
Average	551.7	17.2	12.3	146.7	35.9	72.3	835.9
SD	*388.5*	*22.3*	*8.2*	*287.7*	*26.1*	*63.7*	*392.9*

Unit: thousand tons/year Sources: field survey, 2018

On the household level, the farmers recognized and classified the main crop residues into rice straws and vegetables. Surveyed households produced a large amount of rice straw in Hanoi, which accounted for 18 tons/year whereas other provinces generated 2.6-3.3 tons/year (Table 4). Farmers in suburban districts invest in planting high yielding varieties and use harvesting machines, therefore, rice straw was not used for any purpose. Recently, burning of rice straw in open spaces in Hanoi posed serious air pollution (Pham et al. 2021) that an alternative treatment of the straw should be initiated.

Table 4. Volume of main crops residues in households in north Vietnam.

Residue source	Hoa Binh	Ha Noi	Ha Nam	Hung Yen
Rice straw	2.6	18.0	3.3	2.7
Vegetables	10.1	7.3	6.4	8.9
Total	**12.7**	**9.1**	**9.7**	**11.6**

Unit: ton/household/year Sources: field survey, 2018

Livestock residues. Livestock is characterized as buffalo, cows, pigs, and poultry raising at household or farm scale in the Red River Delta. Livestock raising in the Red River Delta consisted of 120 thousand buffaloes, 490.7 thousand cows, 7085.5 thousand pigs, and 99.123 thousand poultries (GSO 2018). While the household owned about a few to several hundred heads of pigs or animals, farms raised up to thousand heads. The low treatment technologies applied in livestock production resulted in a large amount of manure. It was reported that effluent from pig production caused a severe impact on water quality, such as increased TSS, nitrate, phosphorus, and coliform (Vo et al. 2018b). The total manure generation in Hoa Binh, Ha Noi, Ha Nam and Hung Yen provinces are shown in Table 5. The highest amount of manure from pig and poultry in Hanoi corresponded to 1,321.2 and 2,107.8 thousand tons/year, respectively.

Table 5. Manure produced from main livestock in some provinces.

Province	Buffalo	Cow	Pig	Poultry
Hoa Binh	591.3	227.4	344.4	340.1
Ha Noi	131.2	495.2	1,321.2	2,107.8
Ha Nam	18.5	101.5	525.0	469.5
Hung Yen	16.9	149.7	459.9	657.0
Total	757.9	973.8	2650.5	3574.4

Unit: thousand tons/year Sources: Field survey, 2018

Residue generation from livestock production generally consisted of feeding materials and manure. The water discharged from cow farming consisted of 8.18-10.49 liters urine/head.day and 84.87-87.53 liters wastewater/head.day, whereas it produced 7,457 kg manure/head for whole life cycle (405 days) (Cao et al. 2018). This indicates a potential for reuse of manure to reduce the load on the environment. Table 6 shows the general types of livestock wastes at household farms in Hung Yen, Hoa Binh, Ha Noi, Ha Nam provinces. For pig production, the solid waste was higher than the amount of liquid wastes, and the highest levels were found in Hanoi and Hung Yen provinces, 4.9 tons and 4.7 tons per household a year, respectively. The waste generated depended on raising density and type of feeding stuff.

Table 6. Livestock waste from the household

Type of waste	Hung Yen	Hoa Binh	Ha Noi	Ha Nam
Pig manure	4.7	4.1	4.9	4.4
Pig urine	4.0	3.5	4.2	3.7
Buffalo/ cattle manure	16.1	9.8	1.4	1.0
Poultry manure	3.8	4.1	4.9	3.9
Total	**28.8**	**21.6**	**15.6**	**13.1**

Unit: ton/household/year Source: field survey, 2018.

It is important to know how much crop residues and livestock waste can be used for composting because crop residues provide sources of carbon whereas livestock manure provides sources of nitrogen and carbon. The ratio C/N impact on the consumption rate of microorganism activities, therefore, impact on composting efficiency. It was reported that pig waste can be used to feed the earthworms (Nguyen et al. 2018, Vo and Tran 2018). In addition, there is the possibility to combine rice straw and pig manure for earthworms in waste treatment and organic fertilization (Nguyen 2018). Table 8 indicates the rate of residue generation on some main crops and solid manure generation from livestock production. For rice production, the residue was generally 50% of total biomass production. Soybean and peanut accounted for the highest rate (70%) while sugarcane, cassava and vegetable produced only 10-20%.

For livestock production, cattle including buffalo and cattle produced 10-15 kg/capita/day, much higher than that of pig and poultry 2.0 and 0.2 kg/capita/day, respectively.

Rice straw compost. The composition of rice straw consisted mainly of 19.64% lignin, 32.15% cellulose, 28.0% hemicellulose, 11.33% ash and others 8.88% (Shawky et al. 2011). Rice straw contained C, 36.88–44.75%; O, 45.99–46.52%; K, 1.43–2.67%; Si, 4.78–13.92% and others (Dinh et al. 2017). Straw are poorly digested by ruminants because of their high cell-wall content. In this research, targeted inoculants of *Trichoderma spp, Bacillus spp,* and *Azotobacter spp* strains were employed to decompose the rice straw. Table 7 shows the pH, OM, N, digestible P and digestible K analysis at 14 and 30 days after incubation and finished treatment of 8 inoculant conditions and control experiment (without presence of microbial). There was no significant difference in total organic matter between treatments and control with an average of 21.17% compared to 22.39%, respectively. For nitrogen content, there were significant difference for AT-YTB and Bo-Bio inoculants at 30 days after treatment compared with the control, 1.10% and 1.30%, respectively. These nitrogen levels contributed to an increase of 32.5-56.6%.

AT-YTB used *Trichoderma spp, Bacillus megaterium, Azotobacter* as main strains and Bo-bio (*Trichoderma spp.*) showed the highest performance of rice straw composting in terms of enhancing organic matter (OM%), total nitrogen (N%), digestible phosphorus (P%) and digestible potassium (K%). It was reported that *Trichoderma spp*. plays a key role for cellulose decomposition, *Azotobacter* for nitrogen fixing, and *Bacillus megaterium* for releasing phosphorus. Azotobacter species play an important role in maintaining soil N status. Azotobacter species were also found to improve their P solubilizing through mutagenesis starting from soil isolates, therefore, the application of these inoculants shows high composting performance (Kumar et al. 2001; Aasfar et al. 2021). Recently, the reduction of lignin, hemicellulose, and cellulose percentage in rice straw was associated with highest observed cellulase activity at 1.5 U/mL by *Trichoderma spp* (Nurul et al. 2018). This finding is consistent with the treatment performance of AT-YTB and Bo-Bio with *Trichoderma spp*. as main strains.

Table 7. Physical and nutrient characteristics in composting samples after 14 days and 30 days

Inoculants	pH		OM (%)		N (%)		Digestible P(%)		Digestible K(%)	
	14	30	14	30	14	30	14	30	14	30
AT-YTB (CT1)	6.40	6.73	21.03	22.91	0.73	1.10*	0.038	0.048	0.16	0.12
Bo-Bio (CT2)	6.59	6.28	21.32	21.69	0.85	1.30*	0.045	0.052	0.14	0.39
CNX-ABI (CT3)	7.11	6.76	22.29	20.20	0.84	0.80	0.047	0.033	0.25	0.13
Emic (CT4)	6.22	6.47	21.17	20.12	0.84	0.98	0.037	0.038	0.05	0.14
EMINA (CT5)	6.31	7.09	20.63	20.84	1.19*	0.95	0.057*	0.039	0.19	0.15
Fito-Biomix (CT6)	6.84	7.42	22.02	20.36	0.81	0.93	0.075	0.059	0.29	0.18
Sagi Bio (CT7)	6.43	6.19	19.69	22.88	0.89*	0.92	0.039*	0.041	0.14	0.07
S-Trichoderma (CT8)	7.27	6.31	21.75	20.31	1.18*	0.75	0.039	0.041	0.20	0.23
Average	6.65	6.66	21.24	21.17	0.89	1.00	0.051	0.048	0.21	0.17
Control (no microbial)	6.42	6.45	21.87	22.39	0.70	0.83	0.029	0.030	0.16	0.13

Note: *: Significant difference at 0.05 by LSD

Livestock manure compost. Physico-chemical composition (%) of pig manure is characterized by pH, moisture (%), total nitrogen (TN%), organic matter (OM%), C:N ratio, total phosphorus (TP%), total potassium (TK%). There were no significant differences in total organic matter between treatments and control with an average of 33.32% compared to 35.20% after 30 days of treatment (Table 8). For nitrogen, there were significant differences for most treatments and higher than the control (without inoculants) after 14 days of treatment, however, the treatment with Trichoderma showed a significant difference with an increase of 21.7% compared to control. Meanwhile, phosphorus and potassium were highest with Bacillus and Trichoderma inoculants. The manure characteristics were affected by the feed diets with 12-14% crude protein in combination with either 2.5 or 8.7% cellulose. Therefore, the biological inoculants such as Balasa, Bio-MT, Compost maker, Emina-E, EMUNIV, FITO-BioRR, Saccharomyces-Trichoderma and Trichoderma-Bacillus containing various effective microbial strains were applied.

The most effective biochemical inoculants for livestock regardless of substitution of inorganic compositions were Bio-MT, Emina and Trichoderma. The advantages of these inoculants include strains of *Trichoderma spp.*, *Streptomyces spp.*, *Bacillus spp.*, *Rhodobacter spp.*, *Lactobacillus spp*. *Trichoderma spp.* is not only suitable for rice straw composting but also good for conversion of solid manure (Islam et al. 2014). The presence of *Streptomyces spp* is considered as biofertilizer to increase plant growth and yield (Buzón-Durán et al. 2020). *Rhodobacter spp.* was reported as most effective for hydrogen sulfide (H_2S) and ammonia (NH_3) removal, contributing to odor reduction (Chen et al. 2018). Inoculation with *Bacillus subtilis* promoted the maturation of compost, enhanced total organic carbon and humic substance and fermentation of the manure (Duan et al. 2020). It was also confirmed that the starch-degrading microorganism was *Bacillus licheniformis* S3, and its highest enzyme activity was estimated at the C/N ratio 0.8% (Wang and Liang 2021).

The coliforms, especially *E. coli* and *Salmonella*, should be removed in the treated manure. *Cellulomonas* bacteria reduced 88.7% in the treatment with Bio-MT (Table 9). In addition, *E. coli* and *Salmonella* bacteria in all the treatments were reduced significantly by 52.2%-88.9% after 30 days of treatment compared to control. There was no significant difference in concentration of Cd and Pb between treatments and control, after 14 days and 30 days. The most effective biochemical inoculants for producing compost fertilizer from animal waste were Emina-E, BioMt and EMUNIV.

CONCLUSION

The agricultural residues were classified into crop residues and livestock manure. The total crop residues in four provinces in Vietnam was estimated at 3.34 million ton/year, with rice residues being the major source. The conventional agriculture practice was burning or freely discharging the crop residues in the field. The livestock manure was sourced from buffalo, cows, pigs and poultry, with pig and poultry as the largest source. Special microorganisms of commercial inoculants revealed good conversion of cellulose, hemicellulose, lignin and starch from rice straw and pig manure. The optimal conversion was obtained from inoculants with *Trichoderma* spp. for rice straw compost. The most effective microbial inoculants for composting pig waste were combined strains within inoculants which enhanced manure composting efficiency by increasing N, P and K content.

Based on the achieved nutrient composition of the compost products, it is recommended for application in vegetables and other crops and compared with the conventional fertilizers.

Table 8. Physical, nutrient characteristics in composting samples from pig manure after 14 and 30 days.

Inoculants	**pH_{KCl}**		**OM (%)**		**N (%)**		**Digestible P (%)**		**Digestible K (%)**	
	14	**30**	**14**	**30**	**14**	**30**	**14**	**30**	**14**	**30**
Balasa	8.0	7.0	26.78	35.02	0.83	0.66	0.14	0.24	0.33	0.33
Bio-MT	7.9	6.9	38.54	32.00	0.88*	0.60	0.21*	0.28*	0.36*	0.21
Compost marker	7.9	6.9	34.03	33.51	0.92*	0.62	0.15	0.25	0.37*	0.34
Emina-E	8.0	7.0	35.02	33.08	0.99*	0.64	0.21*	0.29*	0.24	0.30
EMUNIV	8.2	7.2	34.63	32.00	0.97*	0.61	0.22*	0.31*	0.36*	0.39
FITO-Biomix RR	7.8	6.8	28.97	34.87	0.96*	0.67	0.17	0.27	0.24	0.32
S- Bacillus Trichoderma	7.9	6.9	32.78	30.75	0.88	0.73*	0.14	0.33*	0.30	0.36
Tricoderma-Bacillus.sp	8.0	7.0	34.68	33.08	0.95*	0.66	0.12	0.24	0.39*	0.45*
Average	8.0	7.0	32.28	33.32	0.90	0.65	0.17	0.28	0.32	0.34
Control	8.0	8.2	25. 08	35.20	0.82	0.60	0.14	0.23	0.23	0.34

Note: *: Significant difference at 0.05 by LSD

Table 9. Heavy metal and microorganism content in pig manure after biological treatment after 14 and 30 days.

Inoculants	**Cd (%)**		**Pb (%)**		***Cellulomonas microbes*** **(CFU.10^4/ml)**		***E.coli*** **(CFU.10^3/ml)**		***Salmonella*** **(CFU.10^3/ml)**	
	14	**30**	**14**	**30**	**14**	**30**	**14**	**30**	**14**	**30**
Balasa	0.00027	0.00016	0.00028	0.00026	6.17	6.08	7.24	0.87	2.00	0.44
Bio-MT	0.00023	0.00021	0.00019	0.00020	4.81	0.79*	3.83	2.22	1.16	0.63
Compost Marker	0.00013	0.00023	0.00008	0.00019	7.76	1.16	7.66	1.79	0.91	0.31
Emina-E	0.00015	0.00014	0.00011	0.00021	3.44	0.81*	2.74	1.00	0.97	0.41
EMUNIV	0.00022	0.00017	0.00013	0.00016	4.90	1.86	3.32	1.22	0.49	0.62
FITO-Biomix RR	0.00018	0.00020	0.00016	0.00018	7.04	2.07	4.29	1.57	1.23	0.88
S-Trichoderma	0.00020	0.00018	0.00019	0.00018	6.39	3.18	8.55	2.16	1.35	0.81
Tricoderma- Bacillus.sp	0.00015	0.00017	0.00017	0.00019	7.87	2.48	7.85	3.74	1.37	0.58
Average	0.00019	0.00018	0.00020	0.00019	6.05	2.30	5.68	1.57	1.19	0.62
Control	0.00019	0.00017	0.00022	0.00011	5.38	7.01	9.35	7.84	3.34	7.35

*: Significant difference at 0.05 by LSD

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