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Recycling Sprout-Growing Mediums in Urban Areas as Compost and New Growing Mediums

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Used sprout-growing mediums (SGMs) are nutrient-rich biomass characterised by high lignocellulosic content and low levels of natural biodegradability, producing waste, commonly in urban areas. Accumulation of used SGMs has caused severe environmental pollution in sprout production areas. To reduce waste volume at the source, this study proposed several methods for effectively reusing SGMs in urban areas: producing compost (M1), creating new mediums for growing sprouts (M2), and creating new mediums for growing hydroponic vegetables (M3). First M1, a mixture of used SGM, peanut stalks, urea fertiliser and BIMA microbial product (C: N ratio of 30: 1) was thermophilically composted for 63 d. Then, its chemical and biological properties were analysed. For M2, a mixture of sun-dried used SGM and mung bean sprout husks was crushed and then incubated with the BIMA microbial product for 21 d. For M3, the used SGM was mixed with lime powder and incubated for 7 d before being dried. The products obtained after treating the used SGM demonstrated almost neutral pH reactions (6.37 for M1; 6.31 for M2; 7.52 for M3 - a weakly alkaline reaction). The nutrient content of M1 demonstrated the most organic matter content (OM, 58.44 %), total nitrogen (T-N, 1.77 %), total phosphorus (T-P_2O_5, 1.62 %), and total potassium (T-K_2O, 4.01 %) with a C: N ratio of 15. The M2 medium contained 58.70 % OM, 1.16 % T-N, 0.86 % T-P_2O_5, and 0.98 % T-K_2O, with a C: N ratio of 23. The M3 medium included 72.07 % OM, 0.54 % T-N, 0.55 % T-P_2O_5, and 0.58 % T-K_2O, with a C: N ratio of 63. The heavy metal content (Cu, Zn, Pb, Cd, As) for all products was within the permitted limits. There were no pathogenic microorganisms such as *E. coli, Salmonella* spp. found in any of the products. Based on the phytotoxicity test, M1 was confirmed to be mature, and M2 could be used to grow sprouts. Lettuce planted in M3 according to the hydroponic method was safe and of good quality. The SGM treatment methods evaluated are accessible and could be applied widely in sprout production locations, especially in urban areas.

1. Introduction

Sprouts have recently become a clean food trend in various Eastern and Western cuisines (Steve, 1999). In Vietnam, sprout cultivation has only really appeared in the last twenty years but has developed substantially in urban areas. Most used sprout-growing mediums (SGMs) can only be used once before discarding. Without processing, an SGM cannot grow sprouts a second time because the sprouts will grow poorly (low production, yellow leaves, rot-prone stems, disease susceptibility, and mass death). The disposal of used SGMs is a weakness for greenhouse crop production and a consequently large environmental burden (Diara et al., 2012). Sprout-growing mediums contain abundant organic matter, including nutrients and minerals. Recycling represents a useful solution for the environmental management of used SGMs and should be encouraged. Composting, for example, can convert such organic waste into organic fertilisers (Sanadi et al., 2018). Creating new SGMs is another approach which makes complete use of the used SGM (Nguyen and Nguyen, 2019). In several parts of Vietnam, used SGMs were mixed with lime powder before being used to grow fruit trees or flowers (Bui, 2011). Abd-Elmoniem and El-Behairy (2004) investigated crop responses to cultivation in recycled SGMs compared with a virgin growing medium, finding reduced crop yield and product quality from the recycled mediums; however, other studies have found no significant differences between virgin and reused substrates (Fernandes et al., 2007). There has not enough research to completely evaluate the

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possibility of substrate reuse. Most of the previous studies only focused on evaluating the effect of using untreated used SGMs on the yield of crops. Still, they did not provide method detail to process this waste and evaluate the quality and safety of the treated products for vegetables. To the best of the author‘s knowledge, the contents implemented in this study such as using the co-composting method of used SGM with legumes by-products and additives (urea fertiliser and microbial product BIMA) to produce compost; incubating used SGM with microbial product BIMA or lime to create new growing mediums being clean and safe for vegetables have not been researched to date in Vietnam. This research was aimed to propose detailed methods for recycling of used SGM to create useful products being suitable for urban areas and minimise waste volume, causing environmental pollution. Data collected in this study from analysis of chemical, biological parameters, and testing phytotoxicity will be critical in assessing the quality and safety of treatment products and the suitability of the used methods. Created products in this study need to be environmentally friendly and meet Vietnam's quality standards of organic growing mediums and fertilisers.

2. Materials and methods

2.1 Materials

Used SGMs included the used medium, as well as discarded sprout stems and roots. These were collected in Hanoi, Vietnam, in addition to several other types of agricultural residues – peanut stalks and leaves and dry mung bean sprout husks – used to co-compost or to create new organic mediums for growing sprouts and hydroponic lettuce. The total organic carbon (T-C), total nitrogen (T-N), and moisture content of these dry materials were measured before using them for experimental purposes. The microbial product BIMA – containing fungal strains of the *Trichoderma* genera measuring 5 x 10^6 spores/g – was produced by Biotechnology Centre (Ho Chi Minh City, Vietnam). Additives such as urea fertiliser $(NH_2)_2CO$ and lime powder were produced at the Soils and Fertilizers Research Institute, Vietnam.

2.2 Experimental design for treating used sprout-growing mediums

First, thermophilic composting was used to create compost M1. The material mixture containing 15 kg of used SGM, 15 kg of peanut stalks and leaves was mixed with additives (2.72 g of urea fertiliser, 300 g of BIMA) and then incubated in a 100 L plastic container with a lid. To ensure the incubation system was aerated, 20 holes were drilled around the sides of the container, eight holes were drilled into the bottom, and four holes were drilled into the lid; all of the holes were 1 cm in diameter. A tray was placed under the plastic container to collect leachate; this was sprayed on the compost pile. The mixture’s initial C: N ratio was 30: 1, and its humidity was adjusted with water to reach about 60 %. This produced optimal conditions for the compound’s organic decomposition of microorganisms. The material mixture was turned once a week to homogenise the mixture and provide oxygen for the composting process. Second, the medium M2 was created to grow sprouts. A mixture comprising 15 kg of sun-dried used SGM and 15 kg of crushed mung bean sprout husks was incubated with 300 g of BIMA. Next, the mixture was sprayed to reach a moisture content of 55-60 %, before being incubated for 21 d in a 100 L plastic container drilled for aeration in the same manner as M1. Finally, the medium M3 was created to grow hydroponic lettuce. A mixture comprising 15 kg of used SGM and 1.5 kg of lime powder was incubated for 7 d and then dried in the sun for 7 d (drying time of 6-7 h/d). Figure 1 describes diagram of the incubation system, and Table 1 lists used-SGM treatment methods.

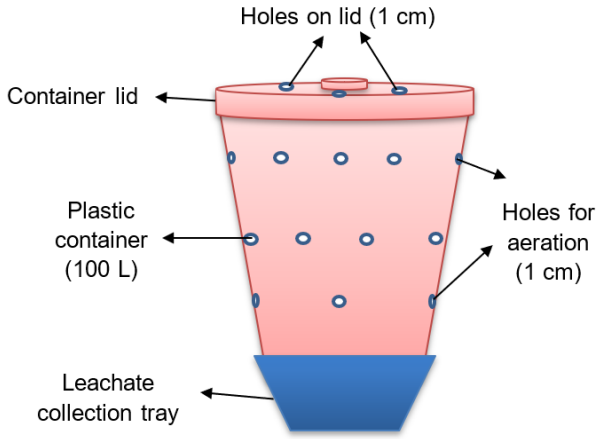

Figure 1: Diagram of the incubation system

Table 1: Methods for treating used sprout-growing medium

Treatments	Materials	Microbial product
Compost M1	15 kg used SGM + 15 kg peanut stalks and leaves + 2.72 g $(NH_2)_2CO$	BIMA (300 g)
Medium M2	15 kg used SGM + 15 kg mung bean sprout husks	BIMA (300 g)
Medium M3	15 kg used SGM + 1.5 kg lime powder	-

2.3 Physical, chemical and biological analysis of used sprout-growing mediums and treatment products

The lignocellulosic composition of the SGMs was determined using acetone, sodium hydroxide (NaOH – 0.5 mol/L), sulphuric acid (98 %) and barium chloride solution according to the procedure described by Mansor et al. (2019). Moisture content was determined using the gravimetric method (TCVN 9297:2012), and pH in H_2O was measured using a glass electrode in a 1: 5 suspension of the sample in water (TCVN 5979:2007 – ISO 10390:2005). Organic matter content (OM) was determined using the Walkley–Black method (TCVN 9294:2012), while T-N was determined according to the Kjeldahl method (TCVN 8557:2010), total phosphorus (T-P_2O_5) by colourimetry using a spectrophotometer (TCVN 8563:2010), and total potassium (T-K_2O) by a flame photometer (TCVN 8562:2010). Plant nitrate content (NO_3^-) was determined by colourimetric method (TCVN 8742:2011).

Additionally, M1, M2 and M3 were tested for limiting factors such as the content of heavy metals (Cu, Zn, Pb, Cd, As) and pathogenic bacteria (*E.coli* and *Salmonella* spp.). Flame absorption spectrometric methods (TCVN 6496: 2009 - ISO 11047: 1998) were used to determine the Cu, Zn, Pb, and Cd content in aqua regia extracts, while atomic absorption spectrometry (TCVN 8467: 2010 - ISO 20280: 2007) was used to determine the As content. Pathogenic bacteria (*E. coli* and *Salmonella* spp*.)* were determined at the Center of Industrial Microbiology at the Food Industry Institute in Vietnam (TCVN 6846:2007 – ISO 7251:2005; TCVN 4829:2005 – ISO 6579:2002).

2.4 Quality assessment of the compost and new mediums

Evaluations of M1's maturity and M2's quality were conducted using the phytotoxicity test described in TMECC: Method 05.05-B (Thompson, 2002). A sample of each was mixed with distilled water (1: 3 w/v ratio) and shaken for 2 h. Then, the mixture was filtered through filter paper to obtain a filtrate. A 10-fold diluted solution was made by mixing 10 mL of filtrate and 90 mL of distilled water. Then, 10 mL of each test solution – full-strength extract, 10-fold diluted extract and distilled water was added to a filter paper (7.5-cm diameter) in a Petri dish (9-cm diameter). Ten *Brassica integrifolia* cress seeds were placed evenly into each Petri dish, which was then sealed with Parafilm. Petri dishes were then incubated in the dark for 72 h at 23 °C. Each experiment was repeated three times. Following incubation, the number of germinated seeds and the root lengths were used to calculate a germination index (GI), as represented by Eq(1):

$$GI = \frac{Mean\ seed\ germination\ for\ treatment}{Mean\ seed\ germination\ \ for\ control} \times \frac{Mean\ root\ length\ for\ treatment}{Mean\ root\ length\ for\ control} \times 100\ \% \quad (1)$$

The quality of M3 was evaluated by planting hydroponic lettuce in a nutrient solution, as proposed by Howard (2013). The nutrient solution included N-NH_4^+ (15 ppm), N-NO_3^- (165 ppm), P (50 ppm), K (210 ppm), Ca (180 ppm), Mg (40 ppm), Fe (3 ppm), Mn (0.5 ppm), Cu (0.1 ppm), Zn (0.1 ppm), B (0.5 ppm), and Mo (0.05 ppm). The nutrient solution's pH was 5.8, and the EC was 1.9 mS. The lettuce seedlings were transplanted into the nutrient solution when they reached the three-leaf stage. The lettuce was allowed to mature for 50 d. The quality of M3 was evaluated by lettuce yield and analysis of heavy metals, nitrates, and pathogenic bacteria (*E.coli, Salmonella* spp.) in lettuce products, which followed the same procedure described in the previous section.

3. Results and discussion

3.1 Properties of used sprout-growing mediums

Determining the properties of used SGMs is necessary to select appropriate treatment methods. The used SGM in this study demonstrated a weakly alkaline pH level (7.45) with high lignocellulosic content (32.42 % cellulose, 6.19 % hemicellulose, 26.54 % lignin). It featured 36.53 % moisture content, 76.36 % OM, 0.51 % T-N, 0.52 % T-P_2O_5 and 0.56 % T-K_2O. The C: N ratio of the used SGM was 68: 1.

3.2 Chemical and biological properties of the produce of compost and new mediums

Table 2 lists the parameters used to evaluate the chemical and biological properties of compost and new mediums following used-SGM treatment.

Table 2: Chemical and biological properties of products after treatment of used sprout-growing medium

Parameters	Products		
	Compost M1	Medium M2	Medium M3
pH	6.37 ± 0.22	6.31 ± 0.15	7.52 ± 0.04
OM (%)	58.44 ± 1.03	58.70 ± 1.0	72.07 ± 1.07
T-N (%)	1.77 ± 0.03	1.16 ± 0.11	0.54 ± 0.06
T-P_2O_5 (%)	1.62 ± 0.06	0.86 ± 0.03	0.55 ± 0.03
T-K_2O (%)	4.01 ± 0.25	0.98 ± 0.18	0.58 ± 0.19
C: N	15: 1	23: 1	63: 1
Cu (ppm)	20.13 ± 1.21	17.7 ± 1.19	18.1 ± 1.08
Zn (ppm)	80.14 ± 2.03	33.2 ± 2.05	22.9 ± 1.17
Pb (ppm)	9.41 ± 1.11	0.86 ± 0.23	1.5 ± 0.29
Cd (ppm)	0.22 ± 0.02	0.05 ± 0.01	0.6 ± 0.17
As (ppm)	0.38 ± 0.02	0.03	0.07 ± 0.01
E.coli (MPN/g)	Negative	Negative	Negative
Salmonella spp. (MPN per 25 g)	Negative	Negative	Negative

The chemical and biological analysis results of the products of M1, M2 and M3 after used-SGM treatment showed high levels of OM (58.44 - 72.07 %), meeting the requirements of organic fertiliser and medium quality for plants according to Vietnam's Decree on fertiliser management (№ 108/2017/ ND-CP), according to which the OM of composts and growing mediums must be higher than 20 %. The T-N was higher than that of the original material, increasing from M3 (0.54 %) to M2 (1.16 %), with the highest content found in M1 (1.77 %). This trend was also observed for T-P_2O_5 and T-K_2O. The incubation process increased the mineralisation of the organic compounds in the materials, leading to the release of nitrogen and other nutritional elements (Lee et al., 2002). It indicated that in contrast to the increase in nutrient content, there was less OM in M1, M2 and M3 than in the original used SGM material. The higher concentrations of T-N, T-P_2O_5 and T-K_2O in M1 was due to the longer incubation time and the combination of materials being chosen to create compost that would meet the decree on fertiliser management's organic-fertiliser-quality requirements. M2's nutrient content was lower due to a shorter incubation time; this medium would be suitable for growing sprouts because the sprouts grow quickly (about 3 - 7 d); also, sprouts in development do not need substantial nutrition from the growing medium. Because M3 was incubated with lime powder and for only seven days, it demonstrated the lowest nutrient levels. However, hydroponic vegetables primarily absorb nutrients from the hydroponic nutrient solution, rather than from the medium, so the M3 medium does not need to be rich in nutrients. For sprout and hydroponic-vegetable production, an essential requirement is that the growing medium is clean and safe for vegetables.

Heavy metals and pathogenic microorganisms are limiting factors for organic fertilisers and substrates processed from wastes. These factors risk harming plants, causing human and animal diseases, polluting the environment and affecting food safety. Sprouts are extremely sensitive to the toxins present in the medium. This, it is mandatory that the growing medium contains low levels of heavy metals and no pathogenic microorganisms (Nguyen and Nguyen, 2019). According to the analysis, levels of heavy metal content (Cu, Zn, Cd, Pb, As) in M1, M2 and M3 were all within the limits set by Decree 108/2017/ND-CP/BNNPTNT. No *E. coli* and *Salmonella* spp. presence was detected in any product, which meets the requirements for the existence of pathogenic microorganisms in fertilisers and organic mediums set by Decree 108/2017/ND-CP/ BNNPTNT.

3.3 Quality assessment

3.3.1. Compost maturity and quality of the sprout-growing medium

Table 3 shows the germination of *Brassica integrifolia* cress seeds in the phytotoxicity test.

Immature compost may contain substances such as methane, ammonia and acetic acid, which are detrimental to plant growth. Even mature compost can contain substances inhibiting plant growth (Trautmann and Krasny, 1998). The maturity test confirmed the stability of the final compost products (Manu et al., 2019).

Data from Table 3 shows that the seed germination rates for both the M1 and M2 filtrate were exceptionally high. The germination rate of seeds for the 10-fold diluted filtrate of M1 was higher than the rate for the full-strength filtrate, while the seed germination rate for the full-strength filtrate of M2 was higher than the rate for the 10-fold diluted filtrate. The root lengths derived from the compost and medium extracts were almost all shorter than lengths derived from the control, with the exception of the roots of the 10-fold diluted M1 filtrate. The GI value of M1 was in the > 80 % range suggested as describing non-phytotoxic composts (Thompson,

2002). More specifically, the GI for *Brassica integrifolia* cress in compost and SGM extracts was in the range of 94.8 – 104.3 higher than 80 %, indicating that M1 was mature and could be used with plants and that M2 was safe and could be used to grow sprouts.

Table 3: Germination and root lengths of Brassica integrifolia cress in compost and medium extracts

Products	Treatment	Mean seed germination	Mean root length (mm)	Germination index (GI)
Compost M1	Distilled water	9.0 ± 1.0	11.0 ± 1.2	-
	10x dilution	9.3 ± 0.6	11.1 ± 1.3	104.3
	Full strength	9.6 ± 0.7	10.6 ± 1.6	102.8
Medium M2	Distilled water	9.0 ± 1.0	11.0 ± 1.2	-
	10x dilution	9.2 ± 0.4	10.2 ± 1.0	94.8
	Full strength	9.4 ± 0.3	10.5 ± 0.6	99.7

3.3.2. Quality assessment of hydroponic-vegetable-growing medium

Table 4 presents quality assessment results for M3. Table 4 shows that lettuce grown in M3 with the proposed nutrient solution by Howard (2013) produced a high yield (3.108 kg/m^2). Additionally, vegetables were not contaminated by nitrate (121 mg/kg of fresh vegetables), or heavy metals (Cu, Pb, Cd, As), according to the standards of FAO/WHO 1993 and QCVN 8-2: 2011/BYT (Vietnam). Neither *E. coli* nor *Salmonella* spp. was detected in the harvested lettuce, allowing the conclusion that M3 is clean and suitable for hydroponic vegetable cultivation.

Table 4: Evaluation of the quality of hydroponic lettuce grown from medium M3

Lettuce	Yield (kg/m^2)	NO_3^- (mg/kg)	Heavy metal content (ppm)					*E.coli* (MPN/g)	*Salmonella* spp. (MPN per 25 g)
			Cu	Zn	Pb	Cd	As		
Value	3.108 ± 0.252	121.0 ± 3.51	0.48	3.86	1.1	<0.01	<0.01	Negative	Negative

4. Conclusions

The used SGM was recycled using different methods capable of minimising environmental pollution and creating useful products for safe and sustainable agricultural development in urban areas. The compost M1 was generated through a 63-day composting process and featured a high OM (58.44 %) and nutrient content (1.77 % T-N, 1.62 % T-P_2O_5, 4.01 % T-K_2O, and a C: N ratio of 15), meeting the requirements of Vietnam's fertiliser management decree. The mediums M2 and M3 were created to grow sprouts and hydroponic vegetables; these featured sufficient nutrient content; M2 featured 58.70 % OM, 1.16 % T-N, 0.86 %T-P_2O_5, 0.98 % T-K_2O, and a C: N ratio of 23, while M3 included 72.07 % OM, 0.54 % T-N, 0.55 % T-P_2O_5, 0.58 % T-K_2O, and a C: N ratio of 63. However, the time required to convert used SGMs into growing mediums was rather short, making M2 and M3 suitable for application in urban areas. None of the products created was contaminated by heavy metals (Cu, Zn, Pb, Cd, As) or pathogenic microorganisms (*E. Coli, Salmonella* spp.). Phytotoxicity testing of M1, M2 and M3 indicated that all of these products were safe and ready to use for plants. The results of this research suggest ways to reduce the environmental pollution caused by sprout production, while also delivering economic benefits, reducing waste, and creating a premise for the sustainable development of sprout production in urban areas of Vietnam.

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