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Life Cycle Assessment of Edible Fungi Residue Compost - A Case Study of Beijing

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ABSTRACT

Based on large quantity and low resource utilization of edible fungi residue in Beijing, the life cycle assessment of edible fungi residue compost was carried out. The environmental impacts including global warming (GW), acidification (AC), eutrophication (EU) and photochemical ozone (PO) were evaluated. Results indicated that edible fungi residue compost was the major risk to acidification and eutrophication. On the contrary, global warming and photochemical ozone were at a low level of potential environmental impact. The potential environment impact of four impact classes and the sum of them were 3.58×10^{-7} PE, 1.93×10^{-5} PE, 1.75×10^{-5} PE, 3.40×10^{-6} PE and 4.06×10^{-5} PE respectively, all lower than China's per capita impact potential. The data indicated that developing edible fungi residue compost to replace part of using of the landfill and random stacking treatment could effectively reduce environment potential impact. Applied to edible fungi residue compost, life cycle assessment could quantify the effect of different environment impact classes, which provide a scientific basis for selecting recycle technology and management plan.

INTRODUCTION

In recent years, China's edible mushroom industry has expanded continuously accompanying with the process of agricultural industrialization. In 2008, it has already become the largest production of edible mushroom in the world, accounting for more than 70% of global output (Wei et al. 2010). In 2009, total output of edible fungi of Beijing reached 1.40 million tons, the production of edible fungi residue mainly in Fangshan District, Tongzhou District and Daxing District, their output accounted for 37%, 34% and 12% of the total output of Beijing. The main edible fungi species are Oyster mushroom, Shiitake mushroom and Enoki mushroom, respectively, of the total output of 34%, 30% and 11% (Wang & Lu 2015).

Thus, the amount of edible fungi residue turns to be an ecological environment problem that cannot be ignored. For example, the resident population of Beijing reached 17.55 million in 2009, like how a pound of a bacteria stick can produce a pound of edible fungi, the total amount of edible fungi residue also reached 1.40 million tons, which means each person will make 0.008 ton edible fungi residue resource per year. The huge potential of the China market maintains steady and rapid growth of supply and demand. In Beijing, most edible fungi residue compost was simply randomly stacked or burned with without classifying by source (Wang et al. 2007). It is not only wastage of the organic resource, but bacterial breeding can also easily pollute soil, air and water, seriously affecting the health of residents and environmental sustainability.

Compared with original agricultural waste, edible fungi residue contends a lot of rich protein, cellulose, amino acids, mycelium and bacteria. In the process of the growth of the mycelium by enzymatic hydrolysis, it produce a variety of sugars, organic acids, enzymes and biological active substances (Hu & Zhang 2013). Therefore, edible fungi residue is a better material for composting than other agricultural wastes. The edible fungi residue composting often mix up edible fungi residue with rotten vegetables, faded flowers, chicken manure, pig manure and other wastes suitable for composting to get high quality compost products (Wen et al. 2010). It is considered as the most effective way to deal with the edible fungi residue.

There is no edible fungi residue comprehensive treatment plant in Beijing making the utilization at a low level. The researches on the edible fungi residue in China are all around the resources technology (Zou et al. 2009), and does not assess the environmental impact of treatment methods. Since the environmental problem along with the edible fungi residue has become increasingly serious, the public has begun to attach importance to the impact of edible fungi residue in environmental sustainable development. In other countries, such as Italy, it has been devoted to the environmental assessment for the compost, servicing for urban waste management and legislative (Blengini 2008, Andersen et al. 2012). Accordingly, the establishment of a scientific system evaluation and technology comparison method on edible fungi residue compost is an important step for China to realize recovery of edible fungi residue resource.

Assessing the environmental impact of edible fungi residue compost technology and improving the processing mode of this special waste is important to resources recycling and sustainable development. Due to the lack of study on the life cycle assessment of the edible fungi residue compost technology, this paper aims at assessing the environmental impact of edible fungi residue compost and providing a more scientific data for edible fungi residue resource recovery technology, and based on the life cycle assessment (LCA) theoretical framework to analyse the edible fungi residue compost in Beijing.

MATERIALS AND METHODS

Introduction and implication: LCA is an objective evaluation of products, processes or activities of environmental load method, as one of the effective environmental management tools that can reflect resource consumption and environmental impact study of all aspects (Fan et al. 2007). This method is seeking to identify and quantify material and energy and environmental emissions, to evaluate the environmental impact results, evaluate and implement opportunities to improve the environmental performance. ISO 14040 1998 adopted the “Life Cycle Assessment - Principles and Framework” in the theoretical framework of the provisions of the LCA: the targeting and scope, inventory analysis, impact assessment and interpretation of results (ISO 14040 2006, Peng 1998).

Goal and scope definition of LCA: LCA aims at analysing the substance input and pollutant emission of edible fungi residue compost in Beijing. LCA system boundary of edible fungi residue compost in Beijing is reported in Fig. 1.

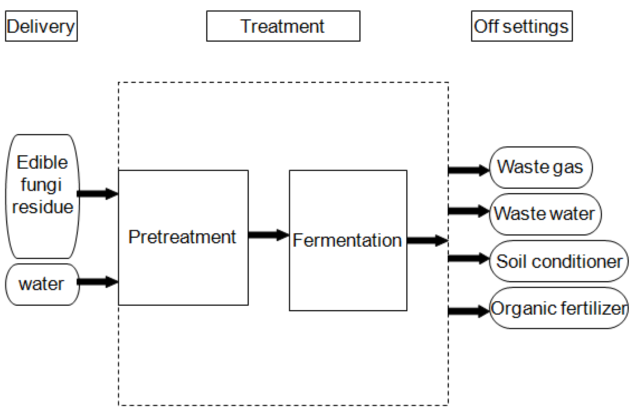

Fig. 1: LCA system boundary of edible fungi residue compost in Beijing.

The functional unit is “one ton edible fungi residue”, which is used as the basis of the environmental assessment (Boldrin et al. 2011a). Using the method of “zero burdens” hypothesis (Boldrin et al. 2011b), the LCA does not include the part of collection from generation of edible fungi residue; it calculates research scope from the input of material up to the final output. Except for the transport, the LCA ignored the environmental impacts of the second level. The study of waste life cycle should consider the transportation consumption, but the research object is the edible fungi residue compost. Edible fungi residue was composted in natural pile so that collection and transportation is mostly manual, which can neglect the environmental impact of the collection and transportation process.

Life cycle inventory analysis: First processing step is pretreatment. The material need to homogenize by mixing water and zymogens to optimize the water content (about 55%) and pore volume before it piled up about 2 meter long, 1.5 meter wide, 1 meter high.

In the following fermentation step, 3 times cooling stage is done at the high temperature period and the cooling period respectively, and the time interval was equal. Note the pile moisture loss situation and ensure the water content maintained at around 50%. The pile reached maturity after stored for around 55 days.

Natural pile composting cannot collect leachate which finally becomes organic fertilizer or substrate with the rest of the material, so the leachate is not included in the discharge.

By calculating the range of content, finally get the LCI (Life cycle inventory, LCI) of the edible fungi residue compost in Beijing (Table 1).

Impact assessment of life cycle: The process of life cycle assessment can be divided into three parts: classification, characterization, and normalization. The normalization includes standardization and weighing. Impact assessments classify, calculate and compare all the impact effect of various impact factors.

Based on the geographical position and environmental characteristics of edible fungi production base, the study refers to the methodology of life cycle assessment for Chinese products, made by Yang et al. (1999). Calculating classification and target distance method of Yang et al. (1999) to get the potential reference value of Chinese environmental impacts and the weight, and to weight the environmental impact.

Classification divides the environmental impact factors

Table 1: Life cycle inventory analysis of edible fungi residue compost in Beijing.

Resource consumption	Freshwater (kg/(p·a))	4.63×10^{-3}
Gaseous pollutants	CO_2(kg/(p·a))	2.05×10^{-2}
	CH_4(kg/(p·a))	6.96×10^{-4}
	H_2S(kg/(p·a))	1.08×10^{-4}
	NH_3(kg/(p·a))	3.83×10^{-4}
	SO_2(kg/(p·a))	1.45×10^{-7}
	NO_X(kg/(p·a))	7.15×10^{-7}

Table 2: Environmental interference factor and the equivalent relation of reference substance.

Impact classes	Environmental interference factor	Reference material	Characteristic factor
GW	CO	CO_2	2
	CO_2		1
	CH_4		25
AC	H_2S	SO_2	1.88
	NH_3		1.88
	SO_2		1
	NO_x		0.7
	HCL		0.88
EU	NO_x	NO_3^-	1.35
	NH_3		3.64
	COD		0.23
PO	CO	C_2H_4	0.03
	CH_4		0.007

into 4 classes: global warming (GW), photochemical ozone (PO), eutrophication (EU) and acidification (AC). Considering the research objects are not affected by metal or other toxic substances, the human toxicity classes can be neglected in the research.

Characterization is to calculate the environmental potential impact of all the impact classes. Environmental potential impact follows the equation:

$$EP(j) = \sum EP(j)_i = \sum [Q(j)_i \times EF(j)_i] \quad ...(1)$$

In the equation, EP(j) is the EP of the environment impact type j. $Q(j)_i$ is the emission of the environment interference of the environmental impact type j. $EF(j)_i$ is the characteristic factor of the environmental impact type i with the environment interference (Table 2).

Normalization includes standardization and weighting. Comparing the effect of environment impact types, we got the relative value of effect through the standardization, while the total effect through the weighting. Then we can compare the effect of different treatment methods.

After weighting we can get the environmental influence value (EI). EI follows the equation:

$$EI = \sum [EPn(j) \times \eta(j)] \quad ...(2)$$

In the equation, EPn (j) is the EP after standardization, η(j) is the weighting factor of the environment impact j. Environment potential impacts after weighting are represented.

RESULTS AND DISCUSSION

The potential environment impact of edible fungi residue compost in Beijing: By calculating the life cycle potential environment impact, we can obtain the results on environment potential impact of edible fungi residue compost in Beijing (Table 3). The environmental effect of global warming, acidification, eutrophication, photochemical ozone and the total potential impact is 3.58×10^{-7} PE, 1.93×10^{-5} PE, 1.75×10^{-5} PE, 3.40×10^{-6} PE and 4.06×10^{-5} PE respectively.

Analysis on the influence of the environment of edible fungi residue compost in Beijing: The comparisons of potential impacts of four different impact classes of edible fungi residue compost are represented in Fig. 2.

In the four classes of environmental impact, the acidification showed the heaviest contribution which took up 47.59% of the total environmental impact in comparison with the other three impact classes, especially in terms of global warming (0.88%) and photochemical ozone (8.38%). Eutrophication gives the second heaviest contribution, accounting for 43.15% of the total environmental impact.

Different from factory composting, the composting in natural piled is not related to the devices input or output such as electric energy, diesel and coal which will greatly increase the production of SO_2, NO_X and CO_2. Thus, photochemical ozone and global warming played a minor role, while acidification and eutrophication became the main environmental impacts.

CONCLUSION

Using the method of life cycle assessment to make quantitative analysis, which is about the environmental

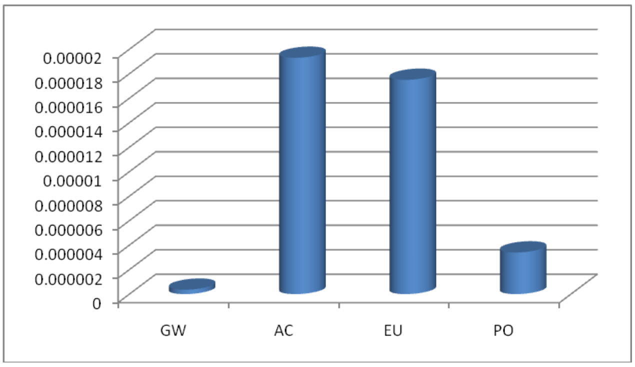

Fig. 2: Potential environment impacts of five treatment methods.

Table 3: The characterization and normalization results on environment potential impact of edible fungi residue compost in Beijing.

Impact class	Reference material	Environment impact potential (kg/(p·a))	Base value (kg/(p·a))	Standardization	Weighting	Potential impact after assignment	Total potential impact
Global warming	CO_2	3.79×10^{-2}	8700	4.36×10^{-7}	0.82	3.58×10^{-7}	
Acidification	SO_2	9.24×10^{-4}	35	2.64×10^{-5}	0.73	1.93×10^{-5}	
Eutrophication	NO_3^-	1.40×10^{-3}	59	2.37×10^{-5}	0.74	1.75×10^{-5}	4.06×10^{-5}
Photochemical ozone	C_2H_4	4.87×10^{-6}	0.76	6.41×10^{-6}	0.53	3.40×10^{-6}	

impact of the Beijing edible fungi residue compost processes, the conclusion are as follows:

The environmental effect of global warming, acidification, eutrophication, photochemical ozone and the total potential impact is 3.58×10-7 PE, 1.93×10-5 PE, 1.75×10-5 PE, 3.40×10-6 PE and 4.06×10-5 PE respectively.

Acidification and eutrophication are main impact of the four impact classes, accounting for 47.59% and 43.15% of the total environmental impact, mainly because of the high proportion of H2S and NH3. Global warming and photochemical ozone have far less effect than the other two impact classes, the proportion is 0.88% and 8.38%, respectively. The main reason is composting in natural pile, reducing the CO2, SO2 and NOX in the process of devices working. In general speaking, the regional effects of the edible fungi residue compost were higher than the global influence.

However, all of four impact classes are lower than China's per capita impact potential. Therefore, the use of composting can effectively mitigate environmental impacts of global warming, acidification, eutrophication and photochemical ozone.

In summary, contrast with the current fact that edible fungi residue disposed together with agricultural waste, the best way to boost social ecological economic benefit is composting part of edible fungi residue and as feed additives, fuel, development of biogas and ecological environment restoration materials.

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