

Influence of Food Waste Compost on the Yield and Mineral Content of *Ganoderma lucidum*, *Lentinula edodes*, and *Pholiota adipose* Fruiting Bodies

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Abstract The objectives of this study were to evaluate applicability of food waste compost (FWC) as a substrate for cultivation of *Ganoderma lucidum*, *Lentinula edodes*, and *Pholiota adipose*, and to determine contents of Ca, Mg, Na, and K in fruiting bodies (FB). FB yield per substrate in FWC-free controls was 53 ± 4 g/kg for *G. lucidum*, 270 ± 90 g/kg for *L. edodes*, and $1,430 \pm 355$ g/kg for *P. adipose*. Substrates supplemented with FWC showed the highest FB production at FWC content of 10% for *G. lucidum* (64 ± 6 g/kg), and 13% for *L. edodes* (665 ± 110 g/kg) and *P. adipose* ($2,345 \pm 395$ g/kg), which were 1.2–2.5 times higher than the values for the controls. *P. adipose* contained higher amounts of mineral elements than the other species. Ca, Mg, Na, and K content in FB did not show a significant relation to FWC content.

Keywords *Ganoderma lucidum*, *Lentinula edodes*, Organic waste, *Pholiota adipose*, Solid state

Raw materials and preparation of selective compost are major cost inputs in mushroom production. Therefore, growers are seeking ways to reduce their production costs by maximizing mushroom yield while reducing the quantity of raw materials used [1]. As mushroom production becomes more competitive and profit margins decrease, growers willing to optimize their production media may have an advantage in the marketplace. Ultimately, such optimization will benefit consumers by reducing the price of mushrooms [2]. Although mushrooms are commonly grown on pasteurized straw of wheat or rice, they can be cultivated on a wide variety of substrates containing lignin and cellulose, such

as food wastes.

Large amounts of food waste are produced in Korea; currently, it is recycled in forms such as compost. However, markets for recycled waste have not yet been developed. Food waste compost (FWC) is a nutritionally rich and complex product that is low in toxic constituents. Thus, it could be fed to heterotrophic organisms such as mushrooms [3]; this strategy could contribute to management of organic wastes [4].

Several kinds of mushrooms are commercially cultivated in solid media consisting of a mixture of sawdust and nutrients. However, information on mushroom cultivation using FWC in the growth medium is currently limited. The combination of crop production and waste mitigation represents an economic potential for both mushroom growers and waste handlers [3].

Contents of biologically active compounds in mushrooms may vary, and are affected by differences in strain, substrate, cultivation and fruiting conditions, the developmental stage of the mushroom, and the age of the fresh mushroom sample [5, 6]. As a result of developments in cultivation techniques, which in turn affect the mineral contents in mushrooms, new nutritional data are needed [5]. Thus, the objectives of this study were to evaluate the applicability of FWC as a substrate for cultivation of mushrooms, to estimate the FWC content at which mushroom production is greatest, and to determine the mineral element contents

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of the mushrooms.

MATERIALS AND METHODS

Mushroom strains. The current study was conducted using strains of three species of mushrooms (Basidiomycota, Agaricomycetes): a bracket fungus (shelf mushroom), *Ganoderma lucidum*, used in traditional oriental medicine; and the edible mushrooms *Lentinula edodes* and *Pholiota adipose*. The strain of *G. lucidum* was obtained from a mushroom farm in Chuncheon, South Korea. The strains of *L. edodes* and *P. adipose* (GFRI200601P) were obtained from Gangwon Forest Research Institute, South Korea.

Substrate preparations and experimental set-up. The growth media used consisted of sawdust and rice bran (for *G. lucidum*) or oak sawdust, rice bran, beet pulp, and cottonseed hull (for *L. edodes* and *P. adipose*) supplemented with FWC obtained from a food waste treatment plant in Wonju, South Korea (Table 1). The FWC was produced by aerobic composting of municipal-source separated food waste. The characteristics of FWC, sawdust, and rice bran for *G. lucidum* were reported in our previous study [7]. *G. lucidum* was grown at the mushroom farm; *L. edodes* and *P. adipose* were grown at the Gangwon Forest Research Institute (Table 2).

Experiments were performed for evaluation of the effect of FWC contents on fruiting body (FB) production [7]. For *G. lucidum*, FWC contents were 0, 5, 10, 15, 20, 25, 30, 35, and 40% (w/w); the remainder of the medium consisted of 80% (w/w) sawdust and 20% (w/w) rice bran. For *L.*

edodes and *P. adipose*, FWC contents were 0, 8, 13, 17, 25, and 42% (w/w). The remainder of the medium consisted of 84% (w/w) sawdust, 8% (w/w) cotton seed hull, 4% (w/w) rice bran, and 4% (w/w) beet pulp.

Analytical methods. All analyses were duplicated, and the results are given as mean values with standard deviations. pH was determined in 1:5 (w/v) sample: water extracts using a pH electrode (Model 735P; Istek, Inc., Seoul, Korea). Moisture content of samples was determined after drying to constant weight at 105°C in a hot air oven. Organic matter content was determined after combustion in a muffle furnace at 550°C for 2 hr [8, 9]. Total nitrogen was determined using the Macro-Kjeldahl method [8, 9].

Mineral contents were measured in dried samples (1 g) after mineralization using 10 mL of a mixture of 60% HClO₄ (9 mL) and 98% H₂SO₄ (1 mL). Phosphorus content was measured colorimetrically using ultraviolet spectrophotometry (Cary 3; Varian, Palo Alto, CA, USA) at 470 nm; analysis of Ca, Mg, Na, and K contents was performed using atomic absorption spectrophotometry (nov AA300; Analytik Jena AG, Jena, Germany) in an air-acetylene flame.

RESULTS AND DISCUSSION

FB production with FWC. FB production increased with FWC content to a maximum and then decreased at higher FWC content; the highest FB production was observed at 10% FWC for *G. lucidum*, and at 13% FWC for *L. edodes* and *P. adipose* (Fig. 1). The FB yield per substrate in the control was 53 ± 4 g/kg for *G. lucidum*, 270 ± 90 g/kg for *L.*

Table 1. Characteristics of substrate for culture medium of *Lentinula edodes* and *Pholiota adipose*

	Sawdust	Rice bran	Cotton seed hull	Beet pulp
pH	6.84 ± 0.01	6.73 ± 0.01	7.11 ± 0.01	5.14 ± 0.01
Moisture (%)	16.8 ± 0.21	12.26 ± 1.49	15.31 ± 0.54	15.12 ± 1.35
OM (%)	78.65 ± 0.34	80.68 ± 2.19	71.87 ± 2.11	81.67 ± 1.02
T-N (%)	0.09 ± 0.01	1.36 ± 0.02	1.22 ± 0.02	0.52 ± 0.02
K (g/kg)	0.24 ± 0.02	18.74 ± 0.16	17.25 ± 0.28	3.88 ± 0.07
Ca (g/kg)	0.28 ± 0.03	4.10 ± 0.11	10.67 ± 0.69	5.45 ± 0.12
Mg (g/kg)	0.41 ± 0.01	5.05 ± 0.06	4.33 ± 0.02	3.21 ± 0.03
Na (g/kg)	ND	0.45 ± 0.03	0.72 ± 0.03	0.91 ± 0.03
P (g/kg)	0.24 ± 0.01	25.21 ± 0.07	3.55 ± 0.05	0.76 ± 0.01

OM, organic matter; T-N, total nitrogen; ND, not detected.

Table 2. Experimental conditions for *Ganoderma lucidum*, *Lentinula edodes*, and *Pholiota adipose*

		<i>G. lucidum</i>	<i>L. edodes/P. adipose</i>
Cultivation method		Bottle	Bag
Substrate weight (kg)		0.8	2
Sterilization method	Temperature (°C)	121	121
	Time (min)	40	40
Spawn running condition	Temperature (°C)	23 ± 2	18 ± 1
	Relative humidity (%)	60 ± 5	60 ± 9
Growth condition	Temperature (°C)	28 ± 2	18 ± 1
	Relative humidity (%)	70 ± 7	70 ± 7

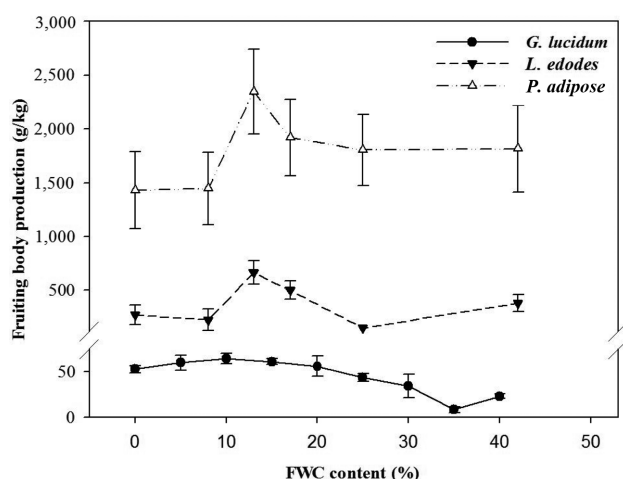


Fig. 1. Fruiting body production with content of food waste content for *Ganoderma lucidum*, *Lentinula edodes*, and *Pholiota adipose*. FWC, food waste compost.

edodes, and $1,430 \pm 355$ g/kg for *P. adipose*. The highest FB yield was 64 ± 6 g/kg for *G. lucidum*, 665 ± 110 g/kg for *L. edodes*, and $2,345 \pm 395$ g/kg for *P. adipose*; these yields were 1.2~2.5 times higher than in the controls. Addition of more FWC than the optima caused lower FB production compared with the control, possibly due to inhibition by

Na [10, 11]. Therefore, addition of FWC can result in increased FB production; however, too much FWC can reduce it.

Ca has important functions in regulation of the growth of hyphal apices and formation of branches. FB production is higher on substrates amended with Ca than on substrates that contain no additional Ca [2]. In this study, the Ca content increased as the FWC content increased [7]; therefore, FB production can be increased when FWC containing high Ca content is used as a growth medium.

Mineral elements of fruiting bodies in control.

Knowledge of the levels of trace elements in mushrooms is necessary because of the effects of these elements on human health [12]. Mushrooms are good sources of many mineral elements [5, 13], however, the amounts are highly variable [13]. In this work, K appeared to be the most abundant mineral (Tables 3 and 4); this result is in agreement with those of previous reports [5, 13-15]. Based on previous reports [15], Na/K ratio varied from 0.01 to 0.2. In the current study, the Na/K ratio was low (0.01~0.07), which is considered an advantage from the nutritional point of view because the intake of NaCl and diets with a high Na/K ratio have been associated with incidence of hypertension [5, 12, 15]. The lowest Na/K ratio (0.01) was observed in *L. edodes*. The K content in *G. lucidum* was

Table 3. Cation contents in fruiting body of *Ganoderma lucidum*

FWC content (%)	Ca (g/kg)	Mg (g/kg)	Na (g/kg)	K (g/kg)
0	0.30 ± 0.01	0.86 ± 0.01	0.30 ± 0.01	5.66 ± 0.05
5	0.18 ± 0.01	0.81 ± 0.01	0.09 ± 0.01	4.84 ± 0.04
10	0.14 ± 0.01	0.44 ± 0.01	0.15 ± 0.01	4.47 ± 0.02
15	0.20 ± 0.01	0.44 ± 0.01	0.62 ± 0.01	4.77 ± 0.02
20	0.31 ± 0.01	1.46 ± 0.01	2.15 ± 0.01	11.23 ± 0.02
25	0.41 ± 0.01	1.05 ± 0.01	2.48 ± 0.01	10.90 ± 0.02
30	0.16 ± 0.01	1.09 ± 0.01	2.54 ± 0.01	14.52 ± 0.02
35	0.12 ± 0.01	1.44 ± 0.01	2.77 ± 0.01	14.68 ± 0.02
40	0.08 ± 0.01	1.06 ± 0.01	2.76 ± 0.01	13.50 ± 0.03

FWC, food waste compost.

Table 4. Cation contents in fruiting body of *Lentinula edodes* and *Pholiota adipose*

Mushroom	FWC content (%)	Ca (g/kg)	Mg (g/kg)	Na (g/kg)	K (g/kg)
<i>L. edodes</i>	0	0.31 ± 0.01	0.42 ± 0.01	0.23 ± 0.01	22.07 ± 1.02
	8	0.36 ± 0.01	0.40 ± 0.02	0.78 ± 0.01	22.88 ± 0.75
	13	0.24 ± 0.01	0.37 ± 0.01	0.39 ± 0.02	22.90 ± 0.74
	17	0.40 ± 0.02	0.47 ± 0.01	0.66 ± 0.01	27.56 ± 1.54
	25	0.29 ± 0.01	0.35 ± 0.01	0.17 ± 0.02	17.42 ± 0.94
	42	0.40 ± 0.01	0.34 ± 0.01	0.24 ± 0.01	17.25 ± 1.12
<i>P. adipose</i>	0	0.85 ± 0.01	1.51 ± 0.01	2.50 ± 0.01	34.46 ± 0.03
	8	0.40 ± 0.01	1.39 ± 0.01	1.48 ± 0.01	39.49 ± 0.07
	13	0.27 ± 0.01	1.18 ± 0.01	0.99 ± 0.01	34.96 ± 0.09
	17	0.24 ± 0.01	1.13 ± 0.01	1.15 ± 0.01	34.24 ± 0.03
	25	0.30 ± 0.01	1.28 ± 0.01	1.15 ± 0.01	39.24 ± 0.09
	42	0.28 ± 0.01	1.30 ± 0.02	1.69 ± 0.01	37.67 ± 0.13

FWC, food waste compost.

lower than in the other mushrooms and the Na content in *P. adipose* was higher than in the others. These findings are generally in accordance with previous findings [5]. In the current study, K levels were between 3 and 18 times higher in FBs in the substrates; this is lower than previously reported ratios (20~105) [14, 16], and was consistent with the result showing that the K content ratio between fungi and substrate was different among species [16].

Ca content was relatively lower in the mushrooms. Ca content of *P. adipose* was higher than that for the other species. Ca levels in FBs were lower than in the substrates. Mg, Na, and K contents were also higher in *P. adipose* than in the other species. The rich nutritional composition of *P. adipose* makes it appropriate for use as a functional food and nutritional supplement [15] and therefore may help to increase demand from consumers.

Mineral elements of fruiting bodies in substrate with FWC. Mg, Na, and K increased with FWC content in *G. lucidum* FBs (Table 3), but were not consistently related to FWC content in *L. edodes* and *P. adipose* (Table 4). Bioaccumulation of Na and Ca was not observed. Mg levels in FBs were lower than in substrates [14]. Most data from this study did not indicate whether the composition of the substrate influences the mineral content of the FB [13]. However, some previous studies [6, 13, 17, 18] reported a direct effect of the chemical composition of the growth medium on the chemical composition of FBs.

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