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**Woo-Sik Jo · So-Deuk Park · Seung-Chun Park
Zhi-Qiang Chang · Geon-Sik Seo · Jae-Youl Uhm
Hee-Young Jung**

Changes in quality of *Phellinus gilvus* mushroom by different drying methods

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Abstract This study was conducted to investigate the changes in characteristics of the *Phellinus gilvus* mushroom as influenced by drying methods after harvest. The lowest weight loss rate of *P. gilvus* mushroom was 75.8% with drying in the shade and 80% by dryer (60°C). The size loss rate of pileus was 19.3% of that in a hot air dryer (60°C). The hardness of dried material context using a hot air dryer (60°C) was the lowest (20 kg/cm^2), and that by a dry oven (60°C) was the highest (457 kg/m^2). For ΔE value, 4.9 of context and 2.6 of tubes using drying in the shade (20°C) were found to be the lowest. The survival rate of sarcoma 180 treated with *P. gilvus* dried in the sun was the lowest (51.8%), and this was considered the most effective method for antitumor activity against sarcoma 180.

Key words Antitumor activity · Drying method · Mushroom · *Phellinus gilvus*

Genus *Phellinus* is taxonomically classified into Hymenochaetaceae (Aphyllophorales, Basidiomycota) (Larsen and Cobb-Poulle 1990) and has been also known as a plant pathogen that causes white pocket rot and severe plant diseases such as canker or heart rot in living trees (Gilbertson 1980). Recently, many reports demonstrated that *Phellinus* species contained medicinally valuable substances. In Asian countries such as China, Korea, and Japan, *Phellinus* species have been considered to cure stomachache and arthritis when used as an oriental medicine (Ying et al. 1987). It was reported that polysaccharides from *P. linteus* showed immunostimulating activity (Kim et al. 1996; Lee et al. 1996) and an inhibitory effect on tumor growth and metastasis (Han et al. 1999). Furthermore, water extracts of *Phellinus linteus*, *P. baumii*, and *P. gilvus* have been found to have antitumor activity against both sarcoma 180 and P388 (Bae et al. 2004).

Fresh mushrooms are highly perishable, with deterioration marked primarily by a brownish discoloration of the surfaces. Enzyme activity in the mushrooms could also be changed, leading to flavor deterioration (Mau and Ziegler 1993). Therefore, it is necessary to improve the quality of dried *P. gilvus* mushrooms by using the optimal drying conditions or other drying methods.

The objectives of this study were to compare the quality of dried *P. gilvus* mushrooms by different drying methods and to investigate the effect of processing variables on the quality of dried *P. gilvus* mushrooms.

The fruiting bodies of *P. gilvus* used in this study were experimentally cultivated at Gyeongbuk Agricultural Technology Administration (Daegu, Korea) and grown rapidly for 3 months in artificial cultures (Jo et al. 2002). The drying methods are represented in Table 1. As drying temperature increased, there was a tendency that the size-loss rate of *P. gilvus* mushrooms was augmented. The size-loss rate by the oven drying experiment at 40°C and 50°C was lower than in the experiment at 60°C and with a hot air dryer (60°C). By various drying methods, the exterior view of the *P. gilvus* mushroom was not good with oven drying (60°C) and a hot air dryer (60°C), whereas other methods such as sun drying and far-infrared ray produced good results (Table 2, Fig. 1). It was reported that the hotter the temperature, the higher the equilibrium moisture content, by research on the drying process of *Lentinus edodes* and *Pleurotus ostreatus* (Song 1994). The hot air drying of root vegetables brought about quality variation such as shrinking deformation and a hardening phenomenon of the exterior (Cho et al. 1989).

W.-S. Jo (✉) · S.-D. Park
Department of Agricultural Environment, Gyeongbuk Agricultural Technology Administration, Daegu 702-708, Korea
Tel. +82-53-320-0233; Fax +82-53-320-0295
e-mail: jowoosik@yahoo.co.kr

S.-C. Park · Z.-Q. Chang
College of Veterinary Medicine, Kyungpook National University, Daegu, Korea

G.-S. Seo
Department of Industrial Crops, Korea National Agricultural College, Hwasung, Korea

J.-Y. Uhm · H.-Y. Jung
College of Agriculture and Life Sciences, Kyungpook National University, Daegu, Korea

Table 1. Various drying methods used in the present study

Drying method	Temp (°C)	Days	Types of machine
Far-infrared ray	40	1	Far-infrared ray/SAB-800; Subung Ind., Gimpo, Korea
Drying in the sun	30	3	–
Drying in the shade	20	3	–
Dryer	40	1	Forced convection oven/HB-501L; Hanbeck Co., Bucheon, Korea
Dryer	50	1	Forced convection oven/HB-501L; Hanbeck Co., Bucheon, Korea
Dryer	60	1	Forced convection oven/HB-501L; Hanbeck Co., Bucheon, Korea
Hot air dryer	60	1	Hot wind dryer/SH-390; Sin-heung Ind., Cheongju, Korea

Table 2. Changes in pileus size and loss rate of *Phellinus gilvus* KCTC 6653 with various drying method

Treatment			Pileus size of raw material (mm)		Pileus size of drying material (mm)		Size loss rate (%)		Exterior view[b]
Drying method	Temp (°C)	Days	Diameter of pileus	Thickness of pileus	Diameter of pileus	Thickness of pileus	Diameter of pileus	Thickness of pileus	
Far-infrared ray	40	1	71.3 ± 4.9[a]	3.6 ± 1.2	61.8 ± 5.6	2.8 ± 0.9	13.3 ± 2.4	23.9 ± 2.3	++
Drying in the sun	30	3	82.7 ± 21.1	3.5 ± 0.3	71.0 ± 17.3	2.7 ± 0.3	14.1 ± 2.2	23.8 ± 7.6	++
Drying in the shade	20	3	107.7 ± 29.0	3.3 ± 0.4	87.7 ± 22.8	2.6 ± 0.3	18.6 ± 3.9	21.2 ± 6.1	++
Dryer	40	1	84.3 ± 12.7	3.6 ± 0.1	69.7 ± 10.2	2.9 ± 0.2	17.4 ± 0.6	18.7 ± 4.3	++
Dryer	50	1	92.0 ± 46.2	4.3 ± 0.3	74.7 ± 34.3	3.3 ± 0.4	18.8 ± 3.3	23.3 ± 4.5	++
Dryer	60	1	97.3 ± 43.9	4.8 ± 1.1	79.3 ± 35.8	3.6 ± 0.8	18.5 ± 0.1	25.0 ± 1.4	+
Hot air dryer	60	1	81.3 ± 14.6	3.8 ± 0.4	65.7 ± 12.5	2.8 ± 0.3	19.3 ± 0.9	27.0 ± 6.4	+

[a] Results are mean ± standard deviation of three replicates
[b] ++, good; +, not good

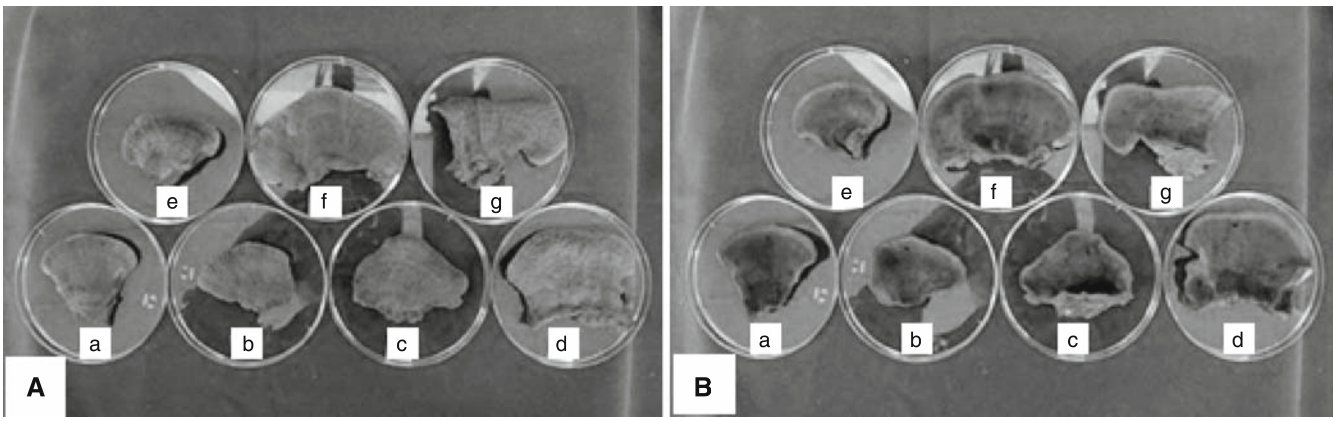

Fig. 1. Characteristics of *Phellinus gilvus* KCTC 6653 with various drying methods. **A** Context. **B** Tubes. *a*, far-infrared ray (40°C); *b*, drying in the sun; *c*, drying in the shade; *d*, dryer (40°C); *e*, dryer (50°C); *f*, dryer (60°C); *g*, hot air dryer (60°C)

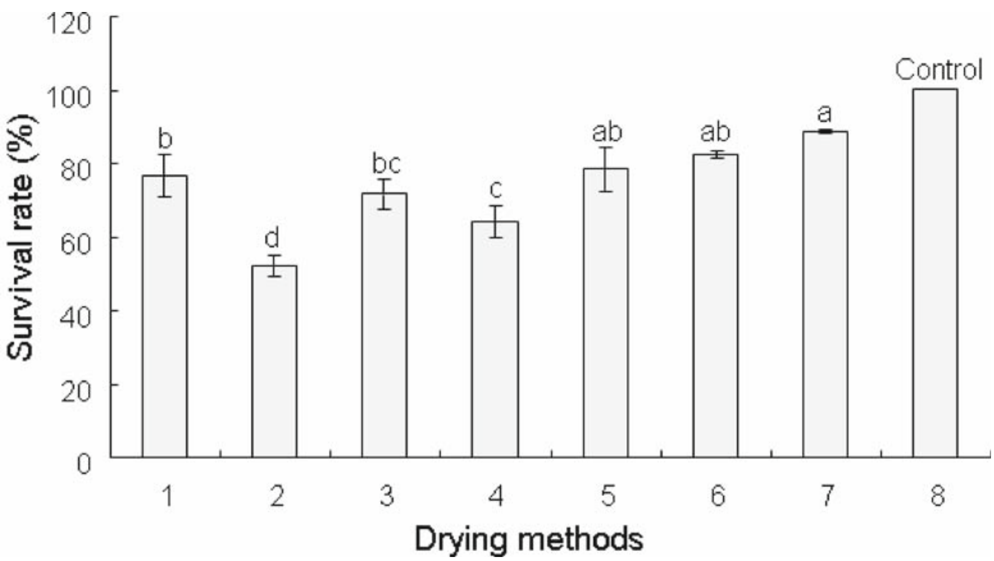

Fig. 2. Sarcoma 180 cells were cultured in RPMI 1640 medium containing 10% fetal bovine serum (FBS) in 96-well plates and treated with 30 μg/ml *Phellinus gilvus* KCTC 6653 produced by various drying methods. Cell survival rates were determined by sulforhodamine B (SRB) assay. Data points are the mean of triplicate experiments (mean ± SD). *Bars with different characters* mean a significant difference ($P < 0.05$). *1*, far-infrared ray (40°C); *2*, drying in the sun; *3*, drying in the shade; *4*, dryer (40°C); *5*, dryer (50°C); *6*, dryer (60°C); *7*, hot air dryer (60°C); *8*, control

Table 3. Changes in chromaticity of *Phellinus gilvus* KCTC 6653 with various drying methods

Treatments			Color of raw material[a]						Color of drying material[a]						ΔE[b]	
Drying method	Temp (°C)	Days	L_1		a_1		b_1		L_2		a_2		b_2			
			Context	Tubes	Context	Tubes	Context	Tubes	Context	Tubes	Context	Tubes	Context	Tubes	Context	Tubes
Far-infrared ray	40	1	30.8 ± 5.3	26.4 ± 1.6	10.4 ± 0.4	9.2 ± 0.5	19.6 ± 0.3	18.0 ± 2.1	35.6 ± 4.3	31.9 ± 7.8	10.7 ± 0.5	8.8 ± 0.7	17.1 ± 9.7	17.1 ± 4.7	12.3 ± 0.7[ab]	7.3 ± 5.5[a]
Drying in the sun	30	3	24.9 ± 4.1	30.6 ± 0.7	8.0 ± 2.0	10.4 ± 0.8	14.2 ± 2.5	16.7 ± 1.4	29.8 ± 2.0	28.3 ± 5.5	10.3 ± 0.8	9.1 ± 0.9	18.2 ± 1.5	18.0 ± 1.6	6.7 ± 2.5[ab]	5.2 ± 3.5[a]
Drying in the shade	20	3	30.8 ± 2.5	25.5 ± 1.9	11.6 ± 0.5	7.9 ± 0.4	23.1 ± 1.9	15.4 ± 1.5	33.6 ± 2.9	25.3 ± 2.8	10.6 ± 0.2	7.3 ± 0.1	20.7 ± 2.5	14.4 ± 1.7	4.9 ± 2.2[b]	2.6 ± 2.0[a]
Dryer	40	1	29.7 ± 2.2	26.9 ± 8.9	10.8 ± 1.3	8.4 ± 1.2	18.1 ± 2.0	15.3 ± 2.3	34.7 ± 5.8	29.1 ± 2.9	11.1 ± 1.4	9.6 ± 0.8	24.8 ± 2.4	21.0 ± 2.2	9.7 ± 5.5[ab]	7.8 ± 3.3[a]
Dryer	50	1	26.6 ± 4.2	28.5 ± 3.9	5.5 ± 0.4	9.2 ± 0.4	11.4 ± 1.0	18.1 ± 2.8	38.1 ± 1.7	29.7 ± 5.9	9.4 ± 0.3	9.7 ± 1.7	23.2 ± 3.1	20.9 ± 5.5	16.9 ± 3.9[a]	5.8 ± 2.9[a]
Dryer	60	1	26.6 ± 4.6	28.4 ± 7.7	8.4 ± 0.5	8.6 ± 3.1	10.8 ± 11.2	13.7 ± 4.6	28.7 ± 14.3	26.8 ± 0.9	9.9 ± 1.7	9.0 ± 1.8	20.9 ± 5.3	19.0 ± 4.2	17.1 ± 4.5[a]	8.2 ± 1.4[a]
A hot wind dryer	60	1	34.5 ± 13.7	29.6 ± 1.5	11.5 ± 2.4	9.3 ± 2.4	19.8 ± 4.1	14.7 ± 6.4	29.9 ± 3.4	24.1 ± 1.1	9.4 ± 0.1	8.3 ± 0.4	20.3 ± 0.6	17.5 ± 0.5	12.9 ± 6.4[ab]	8.4 ± 0.2[a]

[a] L, luminosity; a, red color degree; b, yellow color degree

[b] $\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$

Values in the same line with different letters differ at Duncan's multiple range test ($P < 0.05$), and results are mean ± standard deviation of three replicates

The results of color parameters obtained from the seven drying processes are presented in Table 3 for L, a, and b values, respectively. The total color difference, ΔE, which is a combination of parameters L, a, and b values, is a colorimetric parameter extensively used to characterize the variation of colors in food during processing. The analysis results of ΔE by various drying methods showed that 4.9 of context and 2.6 of tubes using drying in the shade (20°C), and 6.7 of context and 5.2 of tubes using drying in the sun (30°C) were low, whereas 17.1 of context and 8.2 of tubes using oven drying (60°C) and 12.9 of context and 8.4 of tubes using a hot air dryer (60°C) were high (see Fig. 1). Ha et al. (2001) reported that the ΔE values of *Agaricus bisporus* mushroom obtained by drying methods were gradually accumulated under high temperature, rapid air speed, and low vacuum degree. Our results mostly agreed with the previous reports.

The results of the changes in hardness of *P. gilvus* mushrooms by various drying methods are shown in Table 4. The hardness of raw materials revealed that the context parts were 22–119 kg/cm^2 and the tubes parts were 60–150 kg/cm^2. These results were similar to a previous report in which the tube hardness of the *Ganoderma lucidum* mushroom was found to be higher than the context parts (Kim 2000). The hardness of the dried material context by a hot air dryer (60°C) was the lowest (20 kg/cm^2), and that using a dry oven (60°C) was the highest (457 kg/cm^2). In hardness of dried tubes, 96 kg/cm^2 by hot air dryer (60°C) was the lowest, and 636 kg/cm^2 by drying oven (60°C) was the highest. The highest hardness increase rates were the context, 540%, of drying oven at 50°C and the tubes, 761%, of drying oven at 40°C, respectively.

The sulforhodamine B (SRB) assay and sarcoma 180 cells were used to investigate comparative antitumor activity of *P. gilvus* mushrooms dried by different methods in this study. Antitumor activity was measured according to the method reported previously (Kim et al. 1996). *P. gilvus* TMC-1117 showed biphasic vasodilator activity on rat aorta with endothelium (Hosoe et al. 2006), and *P. rimosus* possessed significant antitumor activity (Ajith and Janardhanan 2003). As to the results found in the study, the tumor cell (sarcoma 180) was treated with *P. gilvus* extract (30 µg/ml). The survival rate of sarcoma 180 with different methods, i.e., far-infrared ray (40°C), sun drying method (30°C), drying in the shade (20°C), drying oven (at 40°C), drying oven (at 50°C), drying oven (at 60°C), and hot air dryer (60°C), were 77%, 52%, 72%, 64%, 79%, 82%, and 89%, respectively. The results showed that *P. gilvus* extract inhibited the proliferation of sarcoma 180. The sun drying method of *P. gilvus* was the most effective in antitumor activity against sarcoma 180 (Fig. 2). In conclusion, the method of sun drying is both superior to a hot air dryer (60°C) for general practice in quality (exterior view, chromaticity, antitumor activity) and economical.

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Table 4. Changes in hardness of *Phellinus gilvus* KCTC 6653 with various drying method

Treatment			Hardness of raw material (kg/cm^2)		Hardness of drying material (kg/cm^2)		Hardness increase rate (%)[a]	
Drying method	Temp (°C)	Days	Context	Tubes	Context	Tubes	Context	Tubes
Far-infrared ray	40	1	67.1 ± 11.9	149.1 ± 11.3	181.4 ± 43.1	515.2 ± 48.7	275.9 ± 73.8[ab]	345.5 ± 14.1[bc]
Drying in the sun	30	3	22.1 ± 0.7	61.2 ± 35.9	75.6 ± 10.6	178.6 ± 35.2	341.4 ± 38.1[ab]	332.4 ± 137.6[bc]
Drying in the shade	20	3	29.2 ± 9.9	110.9 ± 2.9	100.4 ± 18.9	513.9 ± 21.5	353.7 ± 55.4[ab]	463.9 ± 31.4[abc]
Dryer	40	1	25.8 ± 14.2	77.8 ± 15.1	74.9 ± 3.2	576.4 ± 10.6	339.0 ± 174.2[ab]	761.6 ± 159.4[a]
Dryer	50	1	31.4 ± 13.8	60.5 ± 32.7	154.8 ± 11.5	392.4 ± 109.3	540.9 ± 164.5[a]	702.7 ± 199.3[ab]
Dryer	60	1	109.7 ± 5.6	150.8 ± 49.8	457.9 ± 48.8	636.2 ± 52.5	419.2 ± 66.1[a]	452.1 ± 183.9[abc]
Hot air dryer	60	1	119.6 ± 41.8	74.5 ± 19.3	20.8 ± 0.6	96.4 ± 26.1	18.0 ± 5.7[b]	142.6 ± 76.8[c]

[a]Values in the same line with different letters differ at Duncan's multiple range test ($P < 0.05$), and results are mean ± standard deviation of three replicates

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