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Relationship between Water Content and Osmotic Potential of *Lentinula edodes*

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This study was conducted to understand how osmotic potentials in *Lentinula edodes* tissues are related to water contents and how they change while a mushroom matures. Water content and osmotic potential of *L. edodes* mushroom tissues from log cultivation and sawdust cultivation were measured and the relationships were analyzed. Osmotic potentials in the tissues were exponentially proportional to their moisture contents and there were strain differences in the potentials. Strain 290 has lower osmotic potential than strain 302, in the tissues at the same water content. As the mushrooms mature, tissue water content maintained ca 94% in head tissues and ca 90% in gills, but significantly decreased from ca 90% to 82% in the stipe tissues. Osmotic potential changes were similar to the tissue water content changes as the mushrooms mature. While osmotic potentials maintained −0.25 to −0.45 MPa in head and gill tissues, the potentials greatly decreased from −0.65 to −1.33 MPa in stipe tissues. Our results show that osmotic potentials in *L. edodes* tissues are exponentially proportional to tissue water contents, that strains differ in osmotic potential related to water, and that stipe tissues can still have nutritional value when they mature.

KEYWORDS : ***Lentinula edodes*, MPa, Osmotic potential, Strain difference, Water content**

Lentinula edodes is a healthy food with lentinan as a physiologically active anticancer (Minato *et al.*, 2001; Yap and Ng, 2001; Ikekawa, 20021), it also contains eritadenine which is an agent for lowering blood cholesterol; as well as ergothioneine which is an effective antioxidant (Bisko *et al.*, 2004; Ng, 2004; Kang *et al.*, 2005). Thus, recent figures show that Korean consumption of fresh *L. edodes* mushroom has continuously increased to ca 1,700 g per person per year (Lee and Kim, 2008). On the other hand, objective data on the quality of the mushroom in terms of nutritional status in market shelves is rarely available. Parameters for determining the quality of *L. edodes* are form, degree of maturation or cap openness, color, freshness etc, but quality evaluation is generally done with the naked eye (Jung *et al.*, 2003).

Water availability is one of the most significant conditions affecting mushroom growth and quality during the mushroom growing period (Ryu and Koo, 2005). Excessive water can cause disease and poor quality, while less water can result in desiccation and poor quality as well. Likewise, excessive water causes problems for mushroom storage. To obtain water from the environment fungi develop a lower water potential in order to retain water in their tissues (Deacon, 2005). It is important to understand how water retention in mushroom tissues is related to the mushroom's quality, particularly nutritional value. Thus, water content and osmotic potential in mushroom tissues need to be measured to understand the presence and concentrations of water and solutes such as soluble carbohydrates, amino acids and minerals in the tissue.

The objectives of this study were to investigate the changes of water content and osmotic potential in oak mushroom tissues while the fruit body matures, and to understand the relationships between the two parameters.

Materials and Methods

Organisms. Mushrooms from three strains of *L. edodes* (strains 290, 302 and B3) were used in this study (Table 1). Strain 290 and 302 were cultivated on logs under shading without a roof while strain B3 was cultivated on saw dust bags inside a shed with a roof during the experiment.

Mushroom cultivation conditions. The mushrooms were cultured at *Lentinula edodes* cultivation shed in Chungbuk National University, Cheongju City during April 2006 to April 2007. Changes in temperature and rainfall in the shed were measured April to October 2006.

During this period the monthly maximum temperature was 28.6°C, the minimum was 7.8°C (Fig. 1). Temperature ranged from 10 to 22.5°C during the fruiting period. The monthly maximum precipitation was 305 mm in August and the minimum was 6.3 mm in October. Thus, various mushroom samples with different water contents were collected during the fruiting season.

Measurement of osmotic potential and water content of mushrooms. Water content of the mushroom samples was measured with fresh weight and dry weight after

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Table 1. Characteristics of *Lentinula edodes* strains used

Strains	Fruiting temperature	Properties	Season
290	7~20°C low temperature	thick pileus, short stipe, heavy, for dry mushroom	spring and fall
302	7~18°C low temperature	large and thick flesh for dry mushroom, the most popular in Korea	spring and fall
B3	10~25°C high temperature	large and thick, fast grow, for saw dust bag cultivation, southern China, Hanam seong Biyang origin	spring, summer and fall

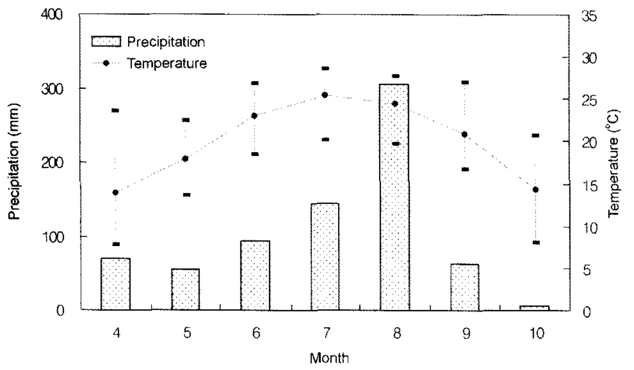

Fig. 1. Monthly mean precipitation and temperature during April to October in 2006. The error bars indicate one standard error.

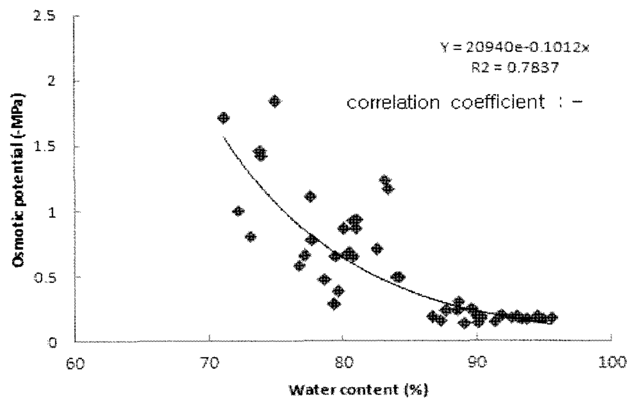

Fig. 2. Relationship between water content and osmotic potential in *Lentinula edodes* strain 290.

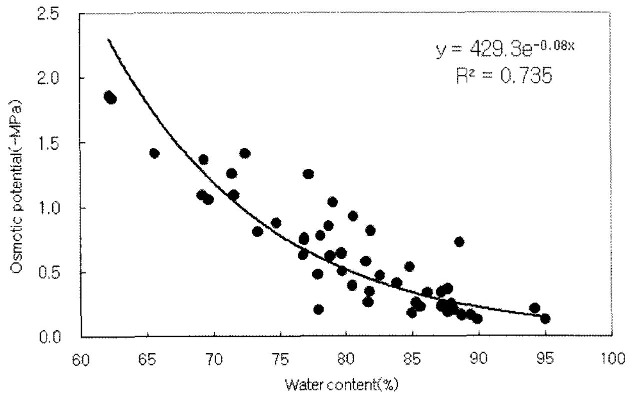

Fig. 3. Relationship between water content and osmotic potential in *Lentinula edodes* strain 302.

drying at 50°C in an oven and calculated as follows: Water content (%) = amount of water in tissue/tissue fresh weight*100.

To measure the osmotic potential of the mushroom tissues, sap was extracted by hard squeezing the fungal tissues. The sap was absorbed using a filtering paper disc of 10 μl, which was then put into a VAPRO Pressure Osmometer 5520 (Wescor Co) chamber for the puropose of measuring molality. This measured the osmotic potential of mushroom sap leaked from a ruptured cell rather than the water potential of an intact cell (Money, 1994). The molality was calculated into MPa (1000 mmol/kg = 2.5 MPa = 25 bars).

Experimental design. To investigate the relationship between water content and osmotic potential in *L. edodes* tissues, and to identify strain difference in the relationship, five mushroom samples each of strain 290 and strain 302 were collected and analyzed every week or every other week during the fruiting season. To investigate how the osmotic potentials change as mushrooms mature, four replicated samples of each stage of button, open and flat were collected and analyzed with three tissues of head, gill and stipe in the sample. For this analysis strain 290 was used.

Results

Relationships between osmotic potentials and water contents. Osmotic potentials in *L. edodes* tissues were exponentially proportional to water contents (Figs. 2 and 3). The relationships of two strains, 290 and 302 respectively, were not significantly different, but strain 302 had lower potential at the same water content than strain 290; that is, when water content in the mushroom tissue was 75 to 80% the osmotic potential was ca −1.0 to −0.65 MPa in strain 290 (Fig. 2), whereas it was ca −0.8 to −0.5 MPa in strain 302 (Fig. 3). This difference becomes greater when water content decreases but becomes less when water content increases. When water content in the tissue was 95% the osmotic potential was ca −1.8 to −1.6 MPa in both strains.

On the other hand in saw dust cultivated strain B3 the osmotic potential of the fresh mushrooms with 67% water content was lower than that of the mushrooms with 85% water content (Fig. 4). Especially in lower stipe tissue osmotic potential of the mushroom with 67% water, −8.2

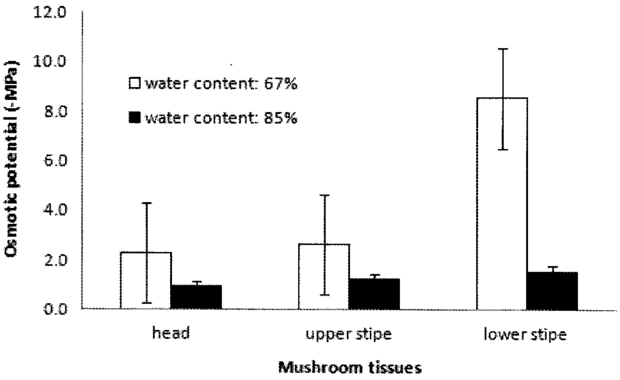

Fig. 4. Osmotic potentials in *Lentinula edodes* strain B3 mushrooms with different water contents, 67% and 85% respectively. The mushrooms were cultivated in sawdust bags. Error bars indicate one standard error.

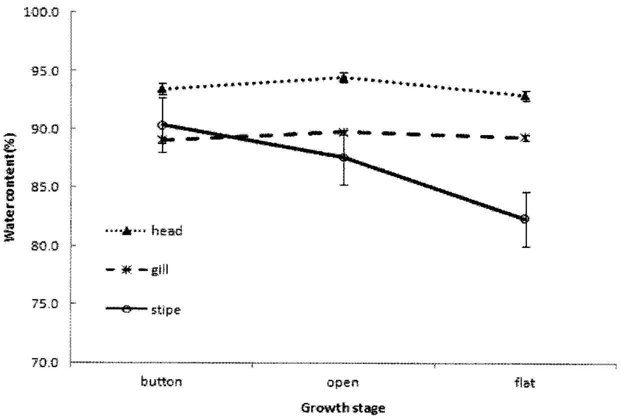

Fig. 5. Water content changes in *Lentinula edodes* tissues as fruit body grows. Error bars indicate one standard error.

MPa, was significantly lower than that of the mushroom with 85% water content, −1.8 MPa.

Water content and osmotic potential change as mushrooms mature. As the mushrooms matured, water content and osmotic potential in tissues changed (Fig. 5). Water contents of the tissues of head, gill and stipe were ca 94, ca 90 and 88~90% in button and open stage mushrooms respectively, whereas 94, 90 and 82% in flat mushrooms. That is, as mushrooms mature water content did not significantly change in head and gill tissues, but water content decreased in stipe tissues.

Osmotic potentials in stipe tissues, −0.65 MPa to −1.33 MPa, were generally lower than in head and gill tissues, −0.25 to −0.45 MPa, regardless of growth stages (Fig. 6). Changing patterns in osmotic potentials of tissues as *L. edodes* matures from button to flat stage were similar to the pattern of tissue water content. In flat mushrooms osmotic potential was ca −0.28 MPa and ca −0.45 MPa in head and gill tissues respectively, the potential greatly

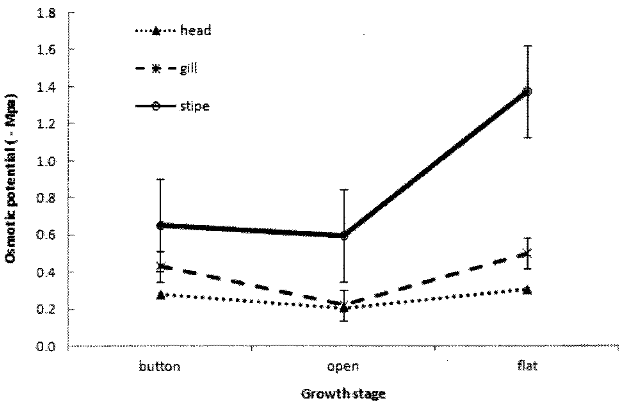

Fig. 6. Osmotic potential changes in *Lentinula edodes* tissues as fruit body grows. The error bars indicate one standard error.

decreased to ca -1.33MPa in the stipe tissue.

Discussion

The osmotic potentials of *Lentinula edodes* tissues were exponentially proportional to the water content of the tissues, i.e., the lower the water content the much lower the osmotic potential. The potentials and water contents were similar in the head, gill and stipe tissues of the young stages of button and slightly open mushrooms. However, the potential values of tissues in the two young stages with relatively high water content were largely higher than those of the mature flat mushrooms with relatively low water. These relationship can mean that solutes in the tissues' sap physically concentrate by drying.

The solutes inducing osmotic potentials in mushrooms can be exo- and endo-polysaccharides, sugar alcohols such as glycerol and mannitol, and nutrients such as amino acids and minerals (Beecher and Magan, 2000). In mineral analysis dry *L. edodes* contained minerals (26 g K/kg, 0.8 g Ca/kg, 1.6 g Mg/kg and 6.0 g P/kg) that can act as solutes and vitamins A and D (Lelley and Vetter, 2004). According to Bisko *et al.* (2004), the protein of *L. edodes* included 17 amino acids with aspartic and glutamic acids predominating and a certain strain had two to three times higher content of lysine and tyrosine than other strains. Our results also showed that there is strain difference: strain 290 was lower than 302 in osmotic potential at 75% water content.

At the present time mushroom appearance in relation to water content is one of the strongest influences in terms of consumers' and producers' choice. *L. edodes* consumers tend to purchase fully round and thick fluffy light brown button mushrooms (Jung *et al.*, 2003). Therefore, mushroom quality needs to be measured by consumer-derived parameters: color, texture, maturity and flavor. Of these, flavor, is a complex set of taste and smell, and is strongly influenced by personal preference. However, the other three can be measured relatively objectively (Burton *et al*., 2000). Water content in tissues can be related to color, texture and maturity in terms of quality. Strain 290, which possesses these high quality characteristics and with a slightly higher water content, tends to be popular in the market (W. S. Goh, *L. edodes* dealer in Cheongju, personal communication). Thus, strain 290 growers can get more returns because the mushrooms are heavier than the other strains.

Our results support Hurukawa (1992), that the amount of sugars such as glucose, trehalose and glycogen did not change in *Flammulina velutipes* stipe tissues when the mushroom matured. However, the author showed that nitrogen compounds such as protein, RNA and DNA decreased in *Polyporus arcularius* stipe tissues while those compounds increased in the head tissues as the mushroom matured. This means that nitrogen compounds in the stipe degrade to be used for the synthesis of head tissues and spores.

Because mushroom drying starts from the lower stipe after the formation of a brown abscission layer between the substrate and the stipe base, the lower stipe of flat mushrooms was drier and lower in osmotic potential than other tissues. However, dried stipe can still have value in nutrition and taste.

In conclusion, our results show that osmotic potentials in *L. edodes* tissues are exponentially proportional to tissue water contents, that strains differ in osmotic potential related to water, and that stipe tissues can still have nutritional value when they mature. These osmotic potentials can be further related to the quality of the mushroom and strain differences. Thus, we suggest water relation characteristics in mushroom tissues be considered to develop new strains of *L. edodes*.

Acknowledgements

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