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Component Analysis of Acorns of *Quercus mongolica* and *Quercus Variabilis*

Hyunseok Lee[1,2], Chanhoon An[1,3,*], Sangurk Han[2], Wiyoung Lee[2] and Kyunghwan Jang[2]
[1]*Department of Forestry, Graduate School, Kangwon National University, Chuncheon 24341, Republic of Korea*
[2]*Department of Forest Genetic Resources, National Institute of Forest Science, Suwon 16631, Republic of Korea*
[3]*Herbal Crop Research Division, Department of Herbal Crop Research, National Institute of Horticulture and Herbal Science, Rural Development Administration, Eumseong 27709, Republic of Korea*

Abstract

To compare seed components of plus trees, seed powder ground after seedcoat removal was analyzed for two oak species, i. e., *Quercus monglica* (white oak) and *Quercus variabilis* (red oak), which are typical oak trees in Korea but have different fruiting characteristics. Thus we aimed at analyzing and comparing many ingredients including minerals, sugars, etc. Two species were similar to each other in the content of water, crude ash, crude protein and carbohydrates, but crude lipid content in *Q. variabilis* was 2.5 times higher than that in *Q. mongolica*. Crude proteins of Clone 124 was 1.5 times higher than that of Clone 75 in *Q. mongolica*. Crude lipid content showed the highest value in Clone 0511 of *Q. variabilis*, and more phosphate and iron was found in *Q. monglica* than in *Q. variabilis*. Glucose showed 85.4% and 88.3% on average of the total monosacchrides in two species, and galactose and arabinose were also found. In the content of phosphate, iron, and crude lipid, differences were found between two species and among clones of two species.

Key Words: acorn, component analysis, plus tree, *Quercus mongolica*, *Quercus variabilis*

Introduction

Oak species including *Quercus mongolica* F. and *Q. variabilis* B. are widely distributed in Korea forming 75% of natural broad-leaved forest of the country, and they are also of worldwide distribution (Suh and Lee 1998). Among them, the typical Korean native tree species such as *Quercus mongolica*, *Q. variabilis*, *Q. serrata*, and *Q. acutissima* account for about 27% (39.5 million m^3) of total forest stock in Korea (Cho 1990). The broadleaved trees including oak species were treated as 'broadleaved brushwood' in the past, thus unnoticed and neglected for a long time in business and administration. They have selected and bred mostly for the purpose of timber production, and recently have received attention as furniture materials. However, as the recent interest in LOHAS (Lifestyles of Health And Sustainability) has increased the consumption of environment-friendly food and traditional food, value of the seeds of oak species has risen too. Some reports showed large amount of minerals and carbohydrates in seed powder (Jung et al. 2007; Yang et al. 2011). The seeds of oak species are regarded as a single type of seeds, generally called as 'acorns', and thus it is necessary to study the component properties according to the tree species.

Q. mongolica and *Q. variabilis* are highly valuable tree species in Korean forest, but there are differences in their

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Corresponding author: Chanhoon An

Herbal Crop Research Division, NIHHS, RDA, 92 Bisanro, Eumseong, Chungbuk 27709, Republic of Korea
Tel: 82-43-871-5633, Fax: 82-43-871-5569, E-mail: an.chanhoon@korea.kr

growth and fruiting aspects. *Q. mongolica* is a white oak showing light color in its bark, and flowering and fruiting in the same year, like *Q. serrata*, *Q. aliena* and *Q. dentate* (Miller and Lamb 1984). Unlike those, *Q. variabilis* and *Q. acutissima* are red oaks, showing black color in their bark, and take 2 growing periods from flowering to seed maturity (Song 2002). Such physiological differences of trees may lead to the differences of component properties of acorns. Since the studies on the acorns have been carried out mainly from the food aspect, most studies reported are without clear distinction of species of seed trees and their producing areas, such as studies on the characteristic and components of acorn powder (Shim et al. 2004; Jung et al. 2007; Yang et al. 2011), and others on the quality characteristics of acorn powder used as food additives (Kim et al. 2012; Lee et al. 2012). However, there have been studies on various tree species, exhibiting the different component properties of seeds according to tree species, seed quality, or collection area. For example, an analysis of general components and functional components of fruits of domestic mulberry trees has displayed the different components depending upon the variety (Kim et al. 2010; Choi et al. 2012). And difference of components content has been reported from collection areas in black beans (Yi et al. 2008). It can thus be claimed that through the component evaluation according to breeds and collection areas, the utility value can be increased through the selection of breeds and clones that match the purpose of utilization.

Therefore, this study was carried out to analyze the component sugars and the general components of acorns of *Q. mongolica* and *Q. variabilis* which are most widely distributed and highly valuable tree species in Korea. In addition, attempts to provide basic data for *Quercus* spp. breeding as acorns production.

Materials and Methods

Plant Material

10 families of both *Q. mongolica* and *Q. variabilis* were chosen in the clone bank of theNational Institute of Forest Science; acorns were collected from them, and used for component analysis. The characteristics of the selected families are shown in Table 1. The acorns were collected manually, sorted out by the family, and only good ones without

Table 1. Clones selected for this study from the bank located in Suwon, Korea

Species	Clone	Planted year	Age of plus trees (year)	Height (m)	DBH (inch)	Volume (m^3)
Quercus mongolica	124	1989	49	23	46	1.53
	129	1991	72	18	30	0.51
	513	1991	63	17	31	0.51
	72	1981	36	12	23	0.25
	74	1981	32	15	24	0.27
	75	1981	31	15	28	0.37
	76	1981	36	14	20	0.18
	77	1981	37	16	24	0.29
	83	1982	51	16	39.8	0.80
	828	1991	36	17	26.5	0.38
Quercus variabilis	110	1991	49	19	38	0.86
	216	1981	72	23	56.2	2.28
	220	1981	25	17.5	23.2	0.30
	54	1991	43	21	32	0.68
	511	1991	48	18	36	0.73
	68	1991	37	16.5	23.6	0.29
	616	1991	29	21	30.4	0.65
	77	1991	34	14	31	0.42
	83	1981	24	20	28	0.49
	San-cheong	1995	12	12	26	0.26

insect or pathogen damages were chosen among the collected fruits. Just after sorting, the outer and inner seed coats were removed, dried, and then ground by Grindomix GM200 (Retsch GM6H, Germany) for the analysis.

General Component Analysis

The moisture content was determined by the ambient drying method at 105°C; the crude lipid content by the soxhlet extraction method using Gerhardt's Soxtherm (Germany); and the crude protein content by the protein automatic analyzer (2300 Kjeltec Analyzer Unit, Foss Tecator Co., Sweden) and multiplied by nitrogen coefficient 6.25 for the indication of crude protein content (%). The crude ash content was determined by heating at 550°C until to give light gray to white ash. The carbohydrate content was determined by subtracting the sum (%) of crude lipid, crude protein, crude ash, and moisture content out of 100 (%).

Mineral Component Analysis

The samples were resolved by sulfuric acid (nitric acid wet digestion method), and then measured for iron (Fe), zinc (Zn), magnesium (Mg), manganese (Mn), potassium (K), copper (Cu) and sodium (Na), using atomic absorption spectrophotometer (Varian Spectra AA-300, Australia). In order to avoid phosphate (P) interruption, potassium chloride (KCI) was added for the analysis of calcium (Ca) and lead (Pb) according to the manual of atomic absorption spectrophotometer, and nitrous oxide-acetylene gas was used. P was determined by molybdenum blue colorimetric method using UV/VIS Spectrophotometer 8452A (Hewlett-packard Co.).

Content Analysis of Monosacchrides

Component sugars were determined by the method proposed by Blakeney et al. (1983). 10 mg (fresh weight basis)

Table 2. General components of acorns of *Quercus mongolica* and *Quercus variabilis* (unit: %)

Species	Clone	Moisture	Crude ash	Crude lipid	Crude protein	Carbohydrates
Quercus mongolica	124	41.29	1.49	1.24	6.14	49.34
	129	43.04	1.65	0.70	4.80	49.38
	513	37.55	1.48	1.12	4.71	55.14
	72	39.05	1.50	1.26	4.65	53.54
	74	42.38	1.37	0.85	4.09	51.31
	75	40.07	1.42	1.12	3.68	53.71
	76	39.36	1.64	0.71	4.96	53.33
	77	38.50	1.51	1.28	5.32	53.39
	83	42.23	1.60	0.85	5.21	49.91
	828	36.56	1.31	0.99	5.48	55.66
	Mean	40.07	1.50	1.01	4.90	52.52
	S.E.	0.71	0.03	0.07	0.22	0.72
Quercus variabilis	110	42.27	1.00	1.70	3.52	51.51
	216	42.81	1.06	2.42	4.35	49.36
	220	42.29	0.94	2.83	4.37	49.57
	54	43.46	1.14	1.97	4.30	49.13
	511	39.00	1.21	3.81	4.96	51.02
	68	40.88	1.26	2.68	4.47	50.71
	616	47.00	1.38	1.40	4.63	45.59
	77	46.12	1.11	1.68	4.70	46.39
	83	41.08	1.17	3.15	4.17	50.43
	San-cheong	40.05	1.39	3.40	4.09	51.07
	Mean	42.50	1.17	2.50	4.36	49.48
	S.E.	0.8	0.05	0.26	0.12	0.64

of ground sample was taken, mixed with 125 μL of 72% (w/v) sulfuric acid (H_2SO_4), and left at room temperature for 45 minutes. 1.35 mL of distilled water was added into the mixture, and hydrolyzed at 100°C for 3 hours; and 320 μL of 15 M ammonium hydroxide (NH_4OH) was added to neutralize, and then 1 mL of 2% sodium borohydride ($NaBH_4$) DMSO (dimethyl sulfoxide) liquid was added to react at 40°C for 90 minutes. 100 μL of 18 M glacial acetic acid was added into the reaction solution, 200 μL of 1-methylimidazole added, 2 mL of acetic anhydride added, and left for 10 minutes at room temperature. After that, 5 mL of distilled water was added to dissolve excessive acetic anhydride, and mixed with 1 mL of dichloromethane. Later the precipitation was taken into the micro-centrifuge tube and analyzed by using gas liquid chromatograph (GLC). The analysis conditions were controlled as: column used was DB-225 (30 m×0.25 mm id×0.25 μm df, J & W Scientific Inc., Folsom, CA, USA), the oven temperature was 235°C, the injector temperature 285°C, detector temperature 300°C (FID), carrier gas flow rate was 1.0 mL/min, and the split ratio was 10 : 1.

Results

General Component

The analysis results of general components of *Q. mongolica* and *Q. variabilis* showed that the moisture and crude lipid content was higher in the latter than those in the former (Table 2). Especially, the crude lipid content was 2.5% in the latter, which was 2.5 times higher than that (1.01%) in the former. On the contrary, the contents of ash, crude protein and carbohydrate were a little higher in the former than those in the latter. For carbohydrates, because it is in an inverse ratio to the moisture, the former showed higher content than the latter, which contained relatively high moisture.

Table 3. Mineral content of acorns of *Quercus mongolica* and *Quercus variabilis* (unit: mg 100 g^{-1})

Species	Clone	Ca	Fe	Zn	Mg	Mn	P	K	Na	Cu	Pb
Quercus mongolica	124	59.45	0.84	0.75	43.84	3.62	268.73	252.44	55.86	0.31	0.00
	129	49.02	0.99	0.53	44.77	4.41	326.80	161.76	51.63	0.30	0.00
	513	110.84	1.02	0.70	46.52	2.99	308.54	177.22	57.28	0.46	0.32
	72	55.13	1.28	0.76	56.13	1.50	298.01	163.58	68.21	0.48	0.43
	74	40.22	0.16	0.39	35.33	1.53	315.46	167.19	55.05	0.18	0.00
	75	42.76	1.36	0.44	34.21	3.21	320.72	215.46	83.88	0.32	0.01
	76	13.13	0.12	0.08	18.38	0.56	240.07	156.79	61.26	0.00	0.00
	77	43.79	1.19	0.63	50.49	1.85	326.80	202.61	64.87	0.43	0.39
	83	35.76	0.27	0.48	39.90	3.74	355.96	216.89	65.56	0.21	0.00
	828	46.70	0.92	0.48	35.81	2.34	338.28	181.52	65.84	0.28	0.00
	Mean	49.68	0.82	0.52	40.54	2.57	309.94	189.55	62.94	0.30	0.11
	S.E.	7.87	0.15	0.06	3.31	0.38	10.73	9.88	2.91	0.05	0.06
Quercus variabilis	110	24.02	0.96	0.25	36.40	3.17	581.57	234.14	47.58	0.09	0.00
	216	12.05	1.14	0.30	37.30	4.32	581.57	177.78	63.81	0.14	0.00
	220	31.96	1.90	0.38	43.35	2.96	674.60	202.53	63.13	0.10	0.00
	54	32.76	1.82	0.51	37.42	2.76	688.29	161.49	77.17	0.08	0.00
	511	29.08	4.37	0.49	52.31	6.69	683.23	213.85	61.08	0.21	0.00
	68	25.50	3.51	0.59	48.34	3.82	700.00	243.38	61.09	0.43	0.07
	616	24.68	2.44	0.61	55.22	4.07	745.03	268.99	59.65	0.27	0.07
	77	26.36	3.39	1.00	50.36	3.73	719.94	221.21	63.94	0.59	0.03
	83	29.84	0.97	0.36	34.92	4.71	757.58	190.48	54.92	0.22	0.53
	San-cheong	35.63	1.34	0.39	51.91	2.26	730.16	167.16	51.03	0.22	0.16
	Mean	27.19	2.18	0.49	44.75	3.89	686.20	208.10	60.34	0.23	0.09
	S.E.	2.07	0.38	0.07	2.45	0.3	19.40	11.03	2.57	0.05	0.05

When compared in the content of general components among the clones in *Q. mongolica*, Clone 129 showed the highest content in moisture (43.04%) and ash (1.65%), while Clone 828 showed the lowest values in moisture (36.56%) and ash (1.31%). In the crude lipid content, Clone 77 showed the highest (1.28%), and Clone 129 the lowest (0.70%); and in the crude protein content, Clone 124 the highest (6.14%), Clone 75 the lowest (3.68%). The carbohydrate content in Clone 124 was lower (49.34%) than in any other clone, while its crude protein content was higher. Clone 828 showed the highest moisture content (55.66%).

Among clones of *Q. variabilis*, the moisture content was the highest in Clone 616 (47.00%), and the lowest in Clone 511 (39.00%). On the contrary, in the crude lipid content the highest was found in Clone 511 (3.81%), while the lowest in Clone 616 (1.40%). The ash content showed the highest in Clone San-cheong (1.39%), and the lowest in Clone 220 (0.94%). The crude protein content was the highest in Clone 511 (4.96%), and the lowest in Clone 110 (3.52%). The carbohydrate content showed the smallest value in Clone 616 (45.59%), and the largest one in Clone 110 (51.51%), of which the crude protein content was the lowest among 10 clones.

The content distribution of general components among clones of each tree species showed that there were small differences in several components, that is, 7% in moisture, 0.4% in ash, and 6% in carbohydrate, respectively. However, the difference in crude protein content was about 2 times among *Q. mongolica* clones; that in crude lipid content was about 2.5 times among *Q. variabilis* clones. When compared in several components content among all the clones of both species, Clone 616 of *Q. variabilis* showed the highest moisture content (47.00%), which was more than 10% higher than the content (36.56%) of Clone 828 of *Q. mongolica*, which was the lowest content within the species. The crude lipid content, 3.81%, in Clone 511 of *Q. variabilis* was about 5 times higher than that (0.70%) of Clone 129 in *Q. mongolica*, which was the lowest within the species. In crude protein content *Q. mongolica* Clone 124 showed 6.14%, which was 2 times higher than the content, 3.52%, of *Q. variabilis* Clone 110. In carbohydrate content, it was shown that *Q. mongolica* Clone 828 contained the highest value, 55.66%, which was 10% higher than that (45.59%) of Clone 0616, which was the lowest among *Q. variabilis* clones. When the general components of acorn starch powder sold in the market compared with those acquired in this research, moisture content in the former was about 10% lower, and the contents of crude ash, crude lipid, and crude protein was also slightly lower data not shown. As the result of the decrease in moisture content of market acorn starch, its carbohydrate content was found much higher (about 80%) than that (Kim and Shin 1975; Chae and Yu 1973; Shim et al. 2004) of the acorn powder used in this research.

Mineral Content Analysis

The mineral content analysis of *Q. mongolica* and *Q. variabilis* revealed that: on average, zinc (Zn) was 0.52±0.06 mg 100 g^{-1} in the former, and 0.49±0.07 mg 100 g^{-1} in the latter; copper (Cu) was 0.30±0.05 mg 100 g^{-1} in the former, 0.23±0.05 mg 100 g^{-1} in the latter; and sodium (Na) was 62.94±2.91 mg 100 g^{-1} in the former, and 60.34±2.57 mg 100 g^{-1} in the latter (Table 3). The analysis of heavy metal content showed that lead (Pb) content was 0.11±0.06 mg 100 g^{-1} in *Q. mongolica*, and 0.09±0.05 mg 100 g^{-1} in *Q. variabilis*. For calcium (Ca), *Q. variabilis* showed 27.19±2.07 mg 100 g^{-1}, and *Q. mongolica* showed 49.68±7.87 mg 100 g^{-1}, which is about 2 times higher than the former. On the contrary, iron (Fe) was 2.18±0.38 mg 100 g^{-1} in *Q. variabilis*, and 0.82±0.15 mg 100 g^{-1} in *Q. mongolica*; magnesium (Mg) was 44.75±2.45 mg 100 g^{-1} in the former, and 40.54±3.31 mg 100 g^{-1} in the latter. Manganese (Mn) and potassium (K) showed 3.89±0.38 mg 100 g^{-1} and 208.10±11.03 mg 100 g^{-1} in *Q. variabilis*, respectively. Each content of Mn and K in *Q. variabilis* was a little bit higher than that in *Q. mongolica* (2.57±0.38 mg 100 g^{-1} and 189.55±9.88 mg 100 g^{-1}, respectively). The phosphorus (P) was 686.20±19.40 mg 100 g^{-1} in *Q. variabilis*, while 309.94±9.88 mg 100 g^{-1} in *Q. mongolica*.

The maximum and minimum values of minerals among clones in each species were compared. For *Q. variabilis*, Ca was about 3 times higher in Clone San-cheong (35.63 mg 100 g^{-1}) than in Clone 216 (12.05 mg 100 g^{-1}); Fe was about 4 times higher in Clone 511 (4.37 mg 100 g^{-1}) than in Clone 110 (0.96 mg 100 g^{-1}); and Zn was 4 times higher in Clone 77 (1.00 mg 100 g^{-1}) than in Clone 110 (0.25 mg 100 g^{-1}). Every content of Mg, Mn and Cu was higher in Clone 616 (55.22 mg 100 g^{-1}) than in Clone 83 (34.92 mg 100

g^{-1}); higher in Clone 511 (6.69 mg 100 g^{-1}) than in Clone San-cheong (2.62 mg 100 g^{-1}); and 6 times higher in Clone 77 (0.59 mg 100 g^{-1}) than in Clone 110 (0.09 mg 100 g^{-1}), respectively. For P, K and Na, of which the average value is generally high among other mineral components, P was much higher in Clone 83 (757.58 mg 100 g^{-1}) than in Clones 110 (581.57 mg 100 g^{-1}) and 216 (581.57 mg 100 g^{-1}); K was much higher in Clone 616 (268.99 mg 100 g^{-1}) than in Clone 54 (161.49 mg 100 g^{-1}); and Na was much higher in Clone 54 (77.17 mg 100 g^{-1}) than in Clone 110 (47.52 mg 100 g^{-1}). The content of heavy metal, Pb, was very little, but relatively high in Clone 83 (0.53 mg 100 g^{-1}), which was 1.5 times higher than those in the other clones. In general, for *Q. variabilis*, as presented in Table 4, each clone showed high mineral content in less than 2 kinds of mineral components, but, overall, no clone showed high mineral contents in other major components. However, Clone 110 showed low contents of Fe, Zn, P, Cu and Na, generally.

For *Q. mongolica*, Ca content was 10 times higher in Clone 513 (110.84 mg 100 g^{-1}) than in Clone 76 (13.13 mg 100 g^{-1}). The contents of Fe, Zn, Mg and Cu were 3-10 times higher in Clone 72 (1.28 mg 100 g^{-1}, 0.76 mg 100 g^{-1}, 56.13 mg 100 g^{-1} and 0.48 mg 100 g^{-1}, respectively) than in Clone 76 (0.12 mg 100 g^{-1}, 0.08 mg 100 g^{-1}, 18.38 mg 100 g^{-1} and 0.0 mg 100 g^{-1}, respectively). Mn, P and K in Clone 129 (4.41 mg 100 g^{-1}), in Clone 83 (355.96 mg 100 g^{-1}) and Clone 124 (252.44 mg 100 g^{-1}), in order and respectively, showed higher values than those in Clone 76 (0.56 mg 100 g^{-1}, 240.07 mg 100 g^{-1} and 156.79 mg 100 g^{-1}, respectively). The content of Na was higher in Clone 73 (83.88 mg 100 g^{-1}) than that in Clone 129 (51.63 mg 100 g^{-1}). The content of heavy metal, Pb, was, though a tiny amount, relatively higher in Clones 72 (0.43 mg 100 g^{-1}), 513 (0.32 mg 100 g^{-1}) and 77 (0.39 mg 100 g^{-1}), when compared with those (0.0 mg 100 g^{-1}) of other clones. Clone 76 showed generally low content of Ca, Fe, Zn, Mg, Mn, P, K, and Cu.

Table 4. Polysaccharides amount of acorns of *Quercus mongolica* and *Quercus variabilis* (unit: mg 100 g^{-1})

Species	Clone	Rhamnose	Frucose	Ribose	Arabinose	Xylose	Allose	Mannose	Galactose	Glucose
Quercus mongolica	124	0.47	0.00	0.00	0.78	0.00	1.52	1.34	1.68	12.5
	129	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	1.19
	513	0.00	0.00	1.22	1.01	0.00	0.00	1.58	2.19	7.80
	72	0.66	0.00	0.00	0.61	0.00	0.00	0.00	0.65	20.53
	74	0.45	0.00	0.25	0.84	0.00	0.00	1.04	1.42	10.77
	75	0.52	0.00	0.00	0.61	0.00	0.00	0.00	0.64	22.31
	76	0.49	0.00	0.00	0.64	0.00	0.00	0.00	0.69	20.10
	77	0.94	0.00	0.00	0.57	0.00	0.00	0.00	0.62	22.98
	83	0.47	0.00	0.00	0.59	0.00	0.00	0.27	0.82	19.50
	828	0.51	0.00	0.00	0.54	0.00	0.00	0.00	0.71	22.70
	Mean	0.45	0.00	0.15	0.62	0.00	0.15	0.42	0.95	16.04
	S.E.	0.09	0.00	0.12	0.08	0.00	0.15	0.20	0.20	2.38
Quercus variabilis	110	0.00	0.00	0.00	0.66	0.00	0.00	0.76	1.05	13.84
	216	1.01	0.00	1.09	0.93	0.00	0.00	1.53	2.28	8.23
	220	0.00	0.00	0.00	0.59	0.00	0.00	0.37	0.68	20.73
	54	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.52	19.37
	511	0.58	0.00	0.60	0.96	0.00	0.00	1.47	2.20	12.26
	68	0.00	0.00	0.00	0.65	0.00	0.00	0.35	0.66	25.20
	616	0.00	0.00	0.00	0.56	0.00	0.00	0.26	0.57	19.98
	77	0.00	0.00	0.00	0.64	0.00	0.00	0.64	0.70	20.31
	83	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.48	24.58
	San-cheong	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.47	21.42
	Mean	0.16	0.00	0.17	0.63	0.00	0.00	0.54	0.96	18.59
	S.E.	0.11	0.00	0.12	0.06	0.00	0.00	0.18	0.22	1.72

When compared all the clones of the two tree species, each content of Ca and Na in *Q. mongolica* Clone 513 (110.84 mg 100 g^{-1}, 57.28 mg 100 g^{-1}) and Clone 75 (42.76 mg 100 g^{-1}, 83.88 mg 100 g^{-1}), respectively, showed 2-9 times higher than those in *Q. variabilis* Clone 216 (12.05 mg 100 g^{-1}, 163.81 mg 100 g^{-1}) and Clone 110 (47.58 mg 100 g^{-1}, 24.02 mg 100 g^{-1}). Fe and Mn were higher in *Q. variabilis* Clone 511 (4.37 mg 100 g^{-1}, and 6.69 mg 100 g^{-1}, respectively) than in *Q. mongolica* Clone 76 (0.12 mg 100 g^{-1}, and 0.56 mg 100 g^{-1}, respectively). The content of Zn and Cu were, though small, higher in *Q. variabilis* Clone 77(1.00 mg 100 g^{-1}, and 0.59 mg 100 g^{-1}, respectively) than in *Q. mongolica* Clone 76 (0.08 mg 100 g^{-1}, and 0.0 mg 100 g^{-1}, respectively).

P and K were higher in *Q. variabilis* Clone 83 (757.58 mg 100 g^{-1}, 190.48 mg 100 g^{-1}) and Clone 616 (268.99 mg 100 g^{-1}, 745.03 mg 100 g^{-1}) than those in *Q. mongolica* Clone 76 (240.07 mg 100 g^{-1}, and 156.79 mg 100 g^{-1}, respectively). The content of heavy metal, Pb, was found highest in *Q. variabilis* Clone 83 (0.53 mg 100 g^{-1}).

Component Sugar Content

The content of component sugars in the two species showed that glucose was higher than 80%, and then galactose, arabinose, mannose, rhamnose, ribose and allose in order of content; but fucose and xylose were not found (Table 4). When comparison made in content, the content of ribose, arbinose, mannose and galactose were similar in both species on average. Rhamnose showed about 3 times higher amount in *Q. mongolica* than in *Q. variabilis*; and allose was not found in *Q. variabilis*, but 1.52 g 100 g^{-1} was found in *Q. mongolica* Clone 124, especially. Glucose content (18.59 g 100 g^{-1}) in *Q. variabilis* which was 2 g 100 g^{-1} higher than that in *Q. mongolica* (16.04 g 100 g^{-1}).

Rhamnose was, although a small amount observed, shown in all 8 clones of *Q. variabilis*, but only in Clone 216 and Clone 511 of *Q. mongolica*, and Clone 216 showed the highest content (1.01 g 100 g^{-1}) in two species.

Ribose was detected in *Q. mongolica* Clone 513 (1.22 g 100 g^{-1}) and Clone 74 (0.25 g 100 g^{-1}), but the difference in content was almost 5 times. In *Q. variabilis*, Clone 216 (1.09 g 100 g^{-1}) and Clone 511 (0.60 g 100 g^{-1}) showed about 2 times difference of content. For arabinose, all the clones of the two species showed 0.3 g 100 g^{-1} to 1.0 g 100 g^{-1}, but *Q. mongolica* Clone 129 showed none. It was found out that *Q. variabilis* Clone 216 (0.93 g 100 g^{-1}) and Clone 511 (0.96 g 100 g^{-1}), and *Q. mongolica* Clone 513 (1.01 g 100 g^{-1}) showed a bit higher value than others, but *Q. variabilis* Clone 83 (0.38 g 100 g^{-1}) and Clone San-cheong (0.43 g 100 g^{-1}) a small amount. Mannose was found in four *Q. mongolica* clones (Clones 124, 513, 74 and 83) and in seven *Q. variabilis* clones (Clones 110, 216, 220, 511, 68, 16 and 77). Clone 513 of *Q. mongolica* showed 1.58 g 100 g^{-1}, which was about sixfold amount of that in *Q. variabilis* Clone 616. Galactose was identified in all *Q. mongolica* and *Q. variabilis* clones. However, among *Q. mongolica* clones, the difference was 27 times between the highest content (Clone 513-2.19 g 100 g^{-1}) and the lowest one (Clone 129-0.08 g 100 g^{-1}). Also in *Q. variabilis*, Clone 216 (2.28 g 100 g^{-1}) and Clone 511 (2.20 g 100 g^{-1}) belonging to the high-content group showed about 4-5 times higher values than Clone San-cheong (0.47 g 100 g^{-1}). Lastly, for glucose, which has a large share in component sugars, its content was around 20.0 g 100 g^{-1} in most of *Q. variabilis* clones (Clones 72, 75, 76, 77, 83, 828, 220, 54, 68, 616, 77, 83 and San-cheong). However, *Q. mongolica* Clone 129 and *Q. variabilis* Clone 216 showed 1.19 g 100 g^{-1} and 8.23 g 100 g^{-1} each, which means there is a big difference in content among the clones.

Discussion

The general component analysis of the acorns of *Q. mongolica* and *Q. variabilis* revealed that there was 2.5 times difference in crude lipid content at a maximum. According to the Table of Food Composition (Rural Development Adiministration, 2006), the crude lipid and crude protein content of raw acorns were 3.0 g 100 g^{-1} and 4.4 g 100 g^{-1}, respectively. Based on the data found in the Table, the content of crude protein is similar to the results of this research, but in the crude lipid content our results are found a bit lower than the data. Especially, the crude lipid content in *Q. mongolica* was low in general, and that in *Q. variabilis* showed a big difference among clones. The results from the general component analysis of chestnut tree cultivars, which are similar to oak species, also showed differences in their crude protein content, that is, 2.9g 100 g^{-1} in chestnut cultivar 'Dantaek', while 4.0g 100 g^{-1} in chestnut cultivar ‘Yipyeong’ (Rural Development Adiministration 2006).

The carbohydrate content in both *Q. mongolica* and *Q. variabilis* was about 50% (Table 2), which is relatively high when compared to its content of nuts in the Table of Food Composition, which include peanuts, chestnuts, ginkgo nuts, pine nuts and walnuts. It is much higher than that in potato (14.6%) or sweet potato (31.2%), but much lower than those of rice and wheat, whose carbohydrate content ranges from 70% to 80%. From this aspect of carbohydrate content, it has been suggested that oak acorns have been, for a long time, one of hunger crops substituting rice and wheat.

A study on composition of buckwheat (*Frgopyrum esculentum* Moench), which is used along with acorns for jelly food, has revealed that ash showed a big difference of 2.3%-3.8% among the samples, while crude lipid showed small difference of 2.7%-3.1% (Shim et al. 1998). In our research, crude ash of raw acorns showed the content of 0.9%-1.6%, while crude lipid 0.7%-3.4%, which indicates a big difference of content among the two tree species and the clones. In comparison of crude ash and crude lipid in buckwheat, acorns were rather low in crude ash, while similar in crude lipid. From the analysis of crude starch content in the processed acorn powder, crude ash ranged from 0.4% to 0.5%, crude lipid from 0.5% to 0.7%, and crude protein from 1.0% to 1.7% (Yang et al. 2011), which are relatively high in all three components. However, there might be some differences between raw acorns and acorn powder. Furthermore, since crude ash content is related to the total mineral content, it needs to be studied together.

When the minerals, except for the heavy metal (Pb), were compared item by item, the high element between the two tree species was P, K, and Na, in order of content. Ca and then Mg was in *Q. mongolica*, while Mg and then Ca in *Q. variabilis*, in order of content. Among the mineral components, P ranked the first in content among the components surveyed, followed by K. According to the analysis of some nuts and seeds such as hazel nuts, perilla seeds, peanuts, Korean snow-bell nuts, water chestnuts, chestnuts and almonds, P and Ca are the components that take the large part in the mineral components (Rural Development Administration 2006). P showed about 2 times higher content in *Q. variabilis* than in *Q. mongolica*; Ca content was higher in *Q. mongolica* than in *Q. variabilis*. Differences were found in some components among the clones of each species: for *Q. variabilis*, a clone with high content of P also showed high Ca content, while this finding was not recognized in *Q. mongolica*, in which Ca content was high in Clone 513 among others. These results are different from the results of previous studies, which revealed that in the component analysis of acorn powder K showed the highest ratio, and then P, Ca, Mg, and Na followed in order of content (Shim et al. 2004), and that the content of Ca or K was the highest one (Yang et al. 2011).

The different results above seem to come from the processing procedures of acorn powder, that is, removal of inner seed coat, soaking, drying, and so on, which possibly caused differences in the contents of raw stuffs. For imported Japanese powder, especially, the difference in the content of mineral components seems to be caused by using the solid powder material with extremely low moisture. In line with this study (Lee et al. 2009), there was a study on the fruits of *Castanopis cuspidata* var. *sieboldi* Nakai, which are distributed in the southern seacoast of Korean Peninsula, and produces edible fruits as raw or processed jelly. The procedure of the component analysis was to keep the harvested fruits in the freezer, completely remove the outer and inner seed coats, grind and analyze. The analysis showed that P was 88.31 mg 100 g^{-1}, the highest in content, followed by K, Mg and Zn, in order (Lee et al. 2009). In the preparation of acorn powder, the inner seed coats could not be completely removed with easiness, and although these remnants were really very little, the mineral components may differ when assayed. Thus, the analysis of each part of acorn seems to be necessary. The analysis of chestnut part revealed that K content was 948.3 mg% in shelled chestnuts, and 763.9 mg% were found in inner seed coat (Kim et al. 2005). This study showed that K content was fairly higher than those of other mineral components (Mg, Na, Ca, Fe, Zn and Cu), although inner seed coat was somewhat lower than shelled chestnuts in K content. These findings lead to an idea that acorns of *Quercus* species also require a similar study (Kim et al. 2005).

Our content analysis on component sugars revealed that glucose content was the highest (85.4% and 88.3% on average, respectively species), as reported by previous studies (Shim et al. 2004; Yang et al. 2011). Glucose forms 85% to

90% of component sugars. Such content is widely acknowledged in many seeds of various plants, as it is a central compound of carbohydrate metabolism, and contributes to ATP synthesis. *Q. variabilis* clones were similar in glucose content generally, while *Q. mongolica* clones showed much difference between the highest and the lowest content. Clone 129 in *Q. mongolica*, especially, showed 1.19 g 100 g^{-1} of glucose content, which was about 15 times lower than the average. And this clone should be excluded from plus trees for acorn production.

Compared to the previous studies, the results of this research have shown that moisture, crude protein and crude lipid are high in their content. It may be due to the fact that in the previous studies acorns were dried and then ground to obtain powder, while in the present study raw stuffs were ground for powder, which may result in a big difference in moisture and carbohydrate contents among the general contents. This research showed glucose occupied more than 85% in the components sugars, while the previous studies showed more than 97%. However, the content analysis of component sugars in raw chestnuts reported (Nha and Yang 1996) that carbohydrates such as glucose and fructose decreased during storage period, while reducing sugars such as sucrose and maltose increased, which implied that carbohydrates converted into reducing sugars during storage. As reported, the fact that glucose content in acorn powder showed lower ratio when compared with other carbohydrates might imply that they were converted to reducing sugars. Through observing the component sugars by each constituent, the analysis of acorn powder components reported that glucose held the most share in them, and then rhamnose, galactose, arabinose, mannose, fucose and xylose, in order. *Q. mongolica* Clone 129 and 513 showed low content in all component sugars including glucose, and no rhamnose in addition.

The above results from the content analysis of *Q. mongolica* and *Q. variabilis* acorns showed that they differ in content of a few elements by tree species and clones. It is considered that the results can be used for the existing plus tree selection system to improve and utilize acorns that contain highly specific and/or functional elements in several components. In particular, the term 'acorn' which is used for seeds of oak species without distinction from other tree species needs to be classified by the species; and based on component contents obtained in this research, the utilization horizon needs to be broadened. In other words, the current usage only limited for jelly food, which is called 'Muk' in Korean, should be considered carefully and expanded to other purpose such as additional components to diet supplement, medicine, cosmetics, and so on to promote the forest family income from non-wood forest products.

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