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Nutrient compositions of Korean mulberry fruits (*Morus sp.*) dried with low temperature vacuum dryer using microwave

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Abstract

Mulberry was dried with low temperature vacuum dryer using microwave. The nutritional compositions of microwave-dried mulberry including proximate composition, sugar content, mineral content, total phenolic, flavonoids, and anthocyanin, beta-carotene, vitamin C, and amino acid composition were measured. Sugar contents of mulberry were 42.6 mg/100g (Cheongilppong) and 43.27 mg/100g dw (Gwasang No. 2). The main components of mulberry sugars were fructose and glucose. Mineral analysis showed that K, P, Ca, and Mg were abundant regardless of mulberry cultivars.

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Introduction

Mulberry, so called oddi, is a fruit of mulberry tree. Mulberry is used as one of traditional medicines to treat fever, prevent liver damage, tonic, strengthen joints, facilitate urine excretion, and reduce blood pressure (Yang *et al.,* 2016; KFDA, 2012; Tang and Eisenbrand, 2011; Bae and Suh, 2007). Traditionally, mulberry had been considered as a byproduct in sericultural industry for a long time. Recently, the production and consumption of mulberry has rapidly increased in Korea due to its good taste, nutritional value, and biological activity.

In Korea, mulberry is harvested in hot and humid summer season from May to Jun in Korea (Lee *et al.,* 1998). After harvest, mulberry is prone to bruising during storage and distribution rapidly, deteriorates its quality and loses commercial value (Hu *et al.,* 2014; Park *et al.,* 2013). Therefore, the shelf life of mulberry is very short. Now in Korea, mulberry is distributed mainly as fresh state or frozen state. To extend the shelf life of mulberry, many researchers have studied on the drying process, preservation method, ripening characteristics of mulberry (Kim *et al.,* 2020; Lee and Hwang, 2017; Lee *et al.,* 2015; Fazaeli *et al.,* 2013). Various drying process including multipurpose agricultural products dryers (Lee *et al.,* 2015), microwave dryer (Evin, 2011; Fazaeli *et al.,* 2013), spray dryer (Fazaeli *et al.,* 2012), sun and sun heat drying (Doymaz 2004b, Akpinar, 2008; Akbulut and Durmuş, 2009), hot wind dryer (Doymaz 2004a) air dryer (Taser *et al,* 2007), vacuum freezing dryer (Kim *et al.,* 2015), hot air drying after honey coating (Kim *et al.,* 2018), and Infrared dryer (Kim *et al.,* 2017) had been reported. However, these methods require high temperature and long time and affect aversely texture, color, flavor, and nutritional value of the product for example for 23.3 h at 34.8℃ (Teng and Lee, 2014; Kim *et al,* 2015; Kim *et al.,* 2018; Fazaeli *et al.,* 2013).

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Vacuum assisted microwave drying has been successfully used to preserve chemical and textural attributes of food products. Successful application of microwave vacuum technology in drying of food products has been reported for many food products and herbal materials, including carrots (Lin *et al.,* 1998), echinacea (Kim *et al.,* 2000), saskatoon berries (Kwok *et al.*, 2004), and pomegranate (Frzaeli *et al.,* 2013).

In this study, the nutritional compositions of Korean mulberry dried with low temperature vacuum dryer using microwave were analyzed.

Materials and methods

Mulberry fruits, Cheongilppong oddi and Gwasang no 2 oddi, (Fig. 1.) were purchased from sericultural farms in Buan and Jeongeup. Unripe Cheongilppong mulberry (UCM) and ripe Cheongilppong mulberry (RCM), unripe Gwasang no. 2 mulberry (UGM), and ripe Gwasang no. 2 mulberry (RGM) was used for nutrient composition analysis.

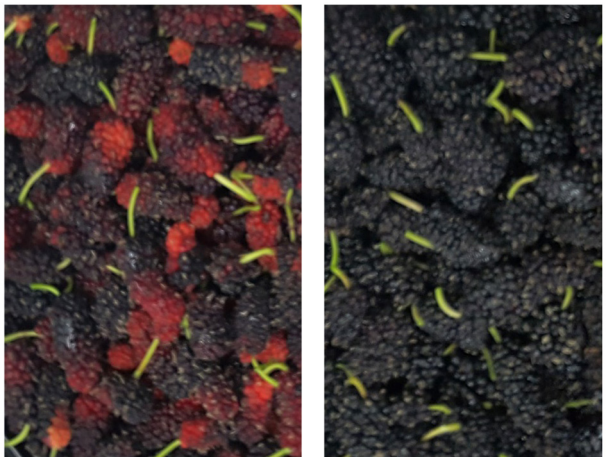

Fig. 1. Typical photographs of mulberry with unripe one (a) and ripe one (b).

Mulberry was dried using low temperature vacuum dryer using microwave (Farmindor MVD-A04, Farmindor Inc., Iksan, Korea). Sample over 30 kg of mulberry was put on the shelf under low vacuum microwave condition. The condensed water was drained during drying.

Proximate composition

The proximate compositions of dried mulberries, including crude ash, and protein were determined using methods AOAC 930.05, and AOAC 2001.11 (AOAC, 2005), respectively. Moisture content was determined by two-stage drying method (AACC, 1995). Crude fat was determined with ethyl ether using an automated Soxhlet extraction apparatus.

Sugar contents

Sugar contents were measured as follows. Dried mulberries (1 g) were mixed with 50 mL 50% (v/v) ethanol (Fisher Scientific Korea Ltd.) in stirrer at 200 rpm for 15 min, and then extracted in water bath at 80°C with ultrasonication for 25 min. Free sugars were analyzed by HPLC (Agilent Technologies 1200 Series, Agilent Technologies) with an evaporative light scattering detector (Agilent Technologies).

Mineral contents

Dried mulberries (0.5 g) were dissolved in 10 mL nitric acid (Wako Pure Chemical Industries) and wet-digested using a microwave digestion system (MARS 5, CEM Co., Matthews,

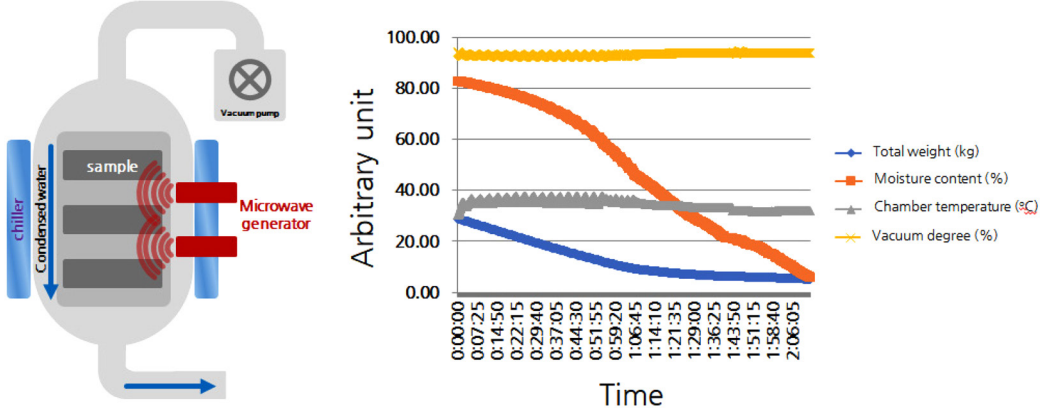

Fig. 2. Scheme of low temperature vacuum dryer using microwave (a) and drying profile (b).

NC).The conditions of the wet-digested system were as follows: Temperature was increased linearly to 190℃ for 15 min and held at190℃ for 1 h. The digested solution was cooled to room temperature. The minerals were determined by an inductively coupled plasma optical emission spectrometer (ICP-OES, Varian 730-ES, Melbourne, VIC, Australia) after appropriate dilution. Certified reference material (CRM-3244, ephedra-containing protein powder, obtained from NIST, Gaithersburg, MD) was also analyzed at the same time in order to calculate recoveries of minerals.

Total phenolic content, total flavonoids and total anthocyanin

Total phenolic content was determined by the Folin–Ciocalteu's reagent method adapted to microscale (Mena *et al.,* 2013). Total phenolic content was evaluated by measuring the variation in absorbance at 760 nm after 1 h of reaction. Results were expressed as mg of gallic acid equivalents per 100 g of dry material.

Total flavonoids (TF) were determined by spectrocolorimetric method. Briefly, 5 g sample was extracted from 80% ethanol at 70℃ for 1 h under ultrasonication. After filtered the sample was mixed with 2 mL ethanol and 0.1 mL 10% (w/v) aluminum nitrate (Wako Pure Chemical Industries). Then, 0.1 mL 1.0 M potassium acetate (Wako Pure Chemical Industries) and 2.6 mL distilled water were also added to the mixture. After 40 min at room temperature, absorbance at 510 nm was read immediately. The level of total flavonoid content was expressed as quercetin eq mg/100 g dw.

Total anthocyanin was determined. Mulberry extracts were diluted and filtered. Absorbance was measured using the UV–vis spectrophotometer at 530 and 600 nm.

Betacarotine and vitamin C

Extraction of β-carotene was performed according to the National Laboratory System (NLS) method with slight modifications (Shin *et al*., 2016). Sample (0.5 g) put into 3% pyrogallol solution and 60% potassium hydroxide (KOH) solution in waterbath at 70°C for 20 min. Test solution was added into 1% sodium chloride solution and then added extraction solvent (n-hexane : ethyl acetate, 85 : 15, v/v, butylated hydroxytoluene [BHT] 0.01%). All supernatants were collected after completely removed colorant. β-Carotene content was measured by high performance liquid chromatography (HPLC).

Ascorbic acid was determined using an HPLC (Agilent 1200Series, Agilent Technologies, Waldbronn, Germany) with a column (Shiseido MG, 4.6 mm × 250 mm). Dried mulberries (0.5 g) were soaked in 15 mL 5% (v/v) metaphosphoric acid (Wako Pure Chemical Industries) and at 18℃ for 10 min. The supernatant was filtered using a 0.45 um filter and then analyzed Ascorbic acid was detected at 520 nm.

Amino acid composition

Amino acids in the dried mulberries were determined by acid hydrolysis. Briefly, approximately 0.1 g of dried mulberries was decomposed in 40 mL 6 N HCl (Wako Pure Chemical Industries) at 110℃ for 24 h under nitrogen gas, evaporated, diluted with distilled water, filtrated, and then analyzed with amino acid analyzer (L-8900, Hitachi, Japan).

Results and Discussion

Proximate composition of mulberry with ripening and cultivars was shown in Table 1. With ripening, crude protein, crude fat, and ash decreased, regardless of cultivars. This result was agreed to the previous report by Lee and Hwang (2017). With increased ripening, crude ash and dietary fiber decreased with ripening, meanwhile, crude fat increased until the middle stage and then decreased at the last stage. Kim and Shin (2011) reported that raspberry showed similar trends.

Five sugars including fructose, glucose, sucrose, lactose, and maltose were measured with cultivars and mature stage, and the results were shown in Table 2. In this experiment, fructose and glucose, and sucrose of RCM were detected 21.8 mg/100g dry weight, 19.15, and 1.62, respectively. However, lactose and maltose were not detected. Mulberry harvested from Cheongilppong has relatively higher fructose and glucose contents then that of Gwasang no. 2. Sucrose from Cheongilppong relatively

Table 1. Proximate composition in mulberry (g/100g, dry weight basis)

	RCM	UCM	RGM	UGM	Lee and Hwang (2017)
Moisture	11.34	12.10	12.88	13.93	
Crude protein	6.14	6.23	7.03	7.49	
Crude fat	3.58	3.90	0.77	0.99	8.3
Ash	4.12	4.36	4.41	4.68	4.3
Crude fiber					12.7

Table 2. Sugar content in mulberry (mg/100 g, dry weight basis)

	RCM	UCM	RGM	UGM	Lee and Hwang (2017)
Fructose	21.83	18.48	14.79	14.48	10.2
Glucose	19.15	15.97	12.90	12.72	10.6
Sucrose	1.62	0.96	5.58	5.15	5.1
Lactose	nd*	nd*	nd*	nd*	
Maltose	nd*	nd*	nd*	nd*	

* not detected

Table 3. Minerals in mulberry (mg/100 g, dry weight basis)

	RCM	UCM	RGM	UGM
Ca	388.7	205.4	222.7	606.4
Cu	0.7	0.1	0.2	0.5
Fe	9.1	4.5	4.4	4.5
K	2032.2	1274.9	1455.0	1572.4
Mg	182.9	107.5	125.1	173.2
Na	66.3	23.2	25.5	37.0
P	509.0	314.9	348.9	382.0

lowers than Gwasang no. 2. With ripening, sugars contents were increased regardless of cultivars. These results were similar to previous reports (Lee and Hwang, 2017; Lin and Lay, 2013; Lou *et al.,* 2012).

Mineral contents in mulberry were shown in Table 3. Regardless of cultivars and mature stage, K, P, Ca, and Mg were the most minerals in mulberry. The abundant mineral contents of silkworm powder are K, P, S, Ca, and Mg (Kweon *et al.,* 2019). The similar pattern of mineral contents between mulberry and silkworm powder is interesting.

Total anthocyanin, flavonoids, phenolics, rutin, and quercetin are shown in Table 4. TA, TP, and TP from Gwasang no. 2 are higher than those from Cheongilppong. The contents of mulberry Cheongilppong were similar with ripening. However total anthocyanin, flavonoids, phenolic, and rutin in mulberry Gwasang no. 2 increased with ripening. Lee and Hwang (2017) and Lou *et al.* (2012) reported total anthocyanin, flavonoids, and phenolic were increased with ripening. Total anthocyanins, flavonoids, phenolic of ripe Cheongilppong mulberry were 1.07 g/100 g, 1.14, and 1.85, respectively. Those of Gwasang no 2 were 1.89, 1.76, and 2.31 g/100 g, respectively. Lee and Hwang (2017) reported that those 2.0, 0.4, and 3.2, respectively. Kim *et al*. (2010)

Table 4. Total anthocyanins, total flavonoids, total phenolics in mulberry (mg/100 g, dry weight basis)

	RCM	UCM	RGM	UGM
Total anthocyanins mg/100g	1068.81	1080.44	1887.14	1194.54
Total flavonoids mg/100g	1135.60	1202.28	1759.59	1316.21
Total phenolics mg/100g	1849.80	1866.55	2307.69	1946.67
Rutin ug/g	394.42	437.28	1128.04	917.70
Qurecetin ug/g	13.93	14.17	9.29	12.21

analyzed and compared the nutritional constitute of mulberrys from seven cultivars and reported that TA, TF, and TP were 0.42-1.15, 0.13-0.34, 0.99-2.25 g/100 g respectively. Our results was somewhat different with the previous reports (Lee and Hwang, 2017; Kim *et al.,* 2010). The variation of phenolics in the berries is known to depend on various factor such as maturity degree, genetic diversity, and cultivation condition including climate situation (Pawlowska *et al.,* 2008; Moyer *et al.,* 2002; Zadernowski *et al.,* 2005). Thus, further studies should be carried out.

Rutin and quercetin are one of typical flavonoids isolated from mulberry (Lee *et al.,* 2020; Ju *et al.,* 2018). Rutin from ripe Gwasang No. 2 mulberry, 1128 mg/100 g, was higher than that from Cheongilppong mulberry, 394 mg100 g.

Beta-carotene and ascorbic acid content were shown in Table 5. Beta carton contents were 65.1 – 141.7 ug/100 g and ascorbic acid 8.52 – 18.9. With ripening, the contents tend to decreased. Ercisli and Orhan (2007) reported that ascorbic acid of mulberry is 19.4 – 22.4 mg/100 mL fruit juice.

Total amino acids were decreased from 5.03 to 4.60% (Cheongilppong) and from 6.04 to 5.70% (Gwasang no.2), respectively. Sung *et al*. (2007) reported that total amino acids

Table 5. Proximate composition in mulberry (g/100 g, dry weight basis)

	RCM	UCM	RGM	UGM
Betacarotene ug/100 g	65.1	88.9	108.1	141.7
Ascorbic acid mg/100 g	12.48	8.52	15.1	18.9

Table 6. Amino acid composition of mulberry (g/100 g, dry weight basis)

	RCM	UCM	RGM	UGM	Lee and Hwang (2017)	Kim *et al.* (2004)
Trp	0.06	0.06	0.06	0.07		
Cys	0.07	0.07	0.06	0.06	0.0	0.01
Asp	0.50	0.55	1.14	1.20	0.6	0.60
Met	0.07	0.08	0.06	0.06	0.1	0.04
Thr	0.19	0.22	0.24	0.25	0.2	0.29
Ser	0.26	0.29	0.33	0.33	0.3	0.22
Glu	0.72	0.76	0.98	0.89	0.9	0.88
Gly	0.24	0.26	0.22	0.25	0.3	0.49
Ala	0.24	0.26	0.42	0.40	0.3	0.30
Val	0.26	0.29	0.29	0.33	0.3	0.20
Iie	0.19	0.22	0.20	0.24	0.2	0.08
Leu	0.33	0.37	0.33	0.39	0.4	0.15
Tyr	0.15	0.16	0.14	0.14	0.2	0.01
Phe	0.30	0.31	0.26	0.31	0.3	
Lys	0.30	0.32	0.30	0.35	0.4	0.02
His	0.17	0.17	0.17	0.18	0.1	0.09
Arg	0.32	0.34	0.19	0.22	0.5	0.30
Pro	0.25	0.29	0.33	0.28	0.1	0.22
total	4.60	5.03	5.70	6.04	5.8	3.91

of Cheongilppong and Daesungppong were 3.9 and 4.9 %, respectively. This difference is depending on the cultivation conditions, and so on. Aspartic acid and glutamic acid are major amino acids in mulberry, which is similar to the previous report mulberry and black raspberry (Lee and Hwang, 2017; Cha *et al.,* 2007).

It needs to further systematic study to know the shape and flower of mulberry cultivars and to elucidate the relationship between the morphological characters and mulberry cultivars.

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References

Akbulut A, Durmuş A (2009) Thin layer solar drying and mathematical modeling of mulberry. Int J Energy Res 33, 687-695.

Akpinar EK (2008) Mathematical modeling and experimental investigation on sun and solar drying of white mulberry. J Mech Sci Technol 22, 544-1553.

Bae S, Suh H (2007) Antioxidant activities of five different mulberry cultivars in Korea. LWT-Food Sci Technol 40, 955-962.

Cha H, Youn A, Park P, Choi H, Kim B (2007) Physicochemical characteristics of *Rubus coreanus* Miquel during maturation. Kor J Food Sci Tech 39, 476-479.

Doymaz I (2004a) Drying kinetics of white mulberry. J Food Eng 61, 341-346.

Doymaz I (2004b) Pretreatment effect on sun drying of mulberry fruits (*Morus alba* L.). J Food Eng 65, 205-209.

Ercisli S, Ohan E (2007) Chemical composition of white (*Morus alba*),

red (*Morus rubra*) and black (*Morus nigra*) mulberry fruits. Food Chem 103, 1380-1384.

Evin D (2011) Microwave drying and moisture diffusivity of white mulberry: experimental and mathematical modeling. J Mech Sci Technol 25(10), 2711-2718.

Fazaeli M, Emanm-Djomeh Z, Ashtari AK, Omide M (2012) Effect of spray drying conditions and feed composition on the physical properties of black mulberry juice powder. Food Bioprod Process 90, 667-675.

Fazaeli M, Yousefi S, Emam-Djomeh Z (2013) Investigation on the effects of microwave and conventional heating methods on the phytochemicals of pomegranate (Punica graantum L.) and black mulberry juices. Food Res Int 50, 568-573.

Hu H, Shen W, Li P (2014) Effects of hydrogen sulphide on quality and antioxidant capacity of mulberry fruit. Intl J Food Sci Technol 49:399-409.

Ju W, Kwon O, Kim Y, Kim H, Sung G, Kim J (2018) Flavonoids analysis about mulberry fruit of Korean mulberry cultivar, 'Daeshim'. Int J Indust Entomol 37, 43-48.

Kim J, Shin M (2011) Characteristics of *Rubus coreanus* Miq. Fruits at different ripening stages. Kor J Food Sci Tech 43, 341-347.

Kim H, Kim S, Kang S (2004) Varietal analysis and quantification of amino acid in mulberry fruits. Korean J Seric Sci 46, 47-53.

Kim EO, Lee YJ, Leem HH, Seo IH, Yu MH, Kang DH, *et al*. (2010) Comparison of nutritional and functional constituents: and physicochemical characteristics of mulberries from seven different Morus alba L. cultivars. J Korean Soc Food Sci Nutr 39, 1467-1475.

Kim H, Kim S, Seok Y, Seo S (2015) A making the method of semi-dried mulberry fruit by vacuum freezing dryer. J Seric Entomol Sci 53(1), 50-54.

Kim H, Ju W, Sung GB, Lee M, Seo S (2017) Drying characteristics of mulberry fruit according to storage condition using far-infrared dryer for the production of semi-dried mulberry fruit. Int J Indust Entomol 35(1) 45-50.

Kim H, Kwon O, Ju W, Kim Y, Sung GB, Hong S, Kim D (2018) Development of manufacturing method for the honey coating semi-dried mulberry fruit using hot air dryer. Int J Indust Entomol 37(2), 63-68.

Kim H, Kwon O, Kweon H, Jo Y, Ju W, Lee JH, Kim Y (2020) Effect of postharvest conditions on the characteristics of mulberries harvested from various mulberry cultivar *Morus alba*. Int J Indust Entomol 40(2) 33-40.

Korea Food and Drug Administration (KFDA) (2012) National Standard of Traditional Medicinal (Herbal and Botanical) Materials, 4th ed. Korea Food and Drug Administration (KFDA), Cheongju, Korea, URL: http://www.mfds.go.kr.

Kweon H, Jo Y, Kim H, Ju W, Lee JH (2019) Proximate and nutritional compositions of freeze-dried silkworm powder as edible insect resources. J Seric Entomol Sci 55(2), 33-39.

Kwok BHL, Hu C, Durance T, Kitts DD (2004). Dehydration techniques affect phytochemical contents and free radical scavenging activities of saskatoon berries (*Amelanchier alnifolia* Nutt.). J Food Sci 69, 122-126.

Lee Y, Hwang KT (2017) Changes in physicochemical properties of mulberry fruits (*Morus alba* L.) during ripening. Sci Horticul 217, 189-196.

Lee HW, Shin DH, Lee WC (1998) Morphological and chemical characteristics of mulberry (Morus) fruit with varieties. Korean J Seric Sci 40, 1-7.

Lee S, Park H, Hong S, Park J, Kim H (2015) Studies on the drying characteristics of mulberry fruits with multipurpose agricultural products dryers. J Seric Entomol Sci 53(2) 101-109.

Lee S, Kim SH, Koo B, Kim H, Jo Y, Kweon H, Ju W (2020) Flavonoids analysis in leaves and fruits of Korean mulberry cultivar, Baeokwang, having white fruits. Int J Indust Entomol 41(2), 45-50.

Lin C, Lay H (2013) Characteristics of fruit growth, component analysis and antioxidant activity of mulberry (*Morus* spp.). Sci Hortic 162, 285-292.

Lin TM, Durance TD, Scaman CH (1998). Characterization of vacuum microwave, air-dried and freeze-dried carrot slices. Int Food Res J 31, 111-117.

Lou H, Hu Y, Zhang L, Sun P, Lu H (2012) Nondestructive evaluation of the changes of total flavonoid, total phenols, ABTS and DHHP radical scavenging activities, and sugars during mulberry (*Morus alba* L.) fruits development by chlorophyll fluorescence and RGB intensity values. LWT Food Sci Tech 47, 19-24.

Mena P, Vegara S, Marti N, García-Viguera C, Saura D, Valero M (2013) Changes on indigenous microbiota, colour, bioactive compounds and antioxidant activity of pasteurized pomegranate juice. Food Chem 141, 2122-2129.

Moyer RA, Hummer KE, Finn CE, Frei B, Wrolstad RE (2002) Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: *Vaccinium, Rubus,* and *Ribes*. J Agric Food Chem 50, 519-525.

Park JH, Hong SI, Jeong MC, Kim DM (2013) Quality characteristics and changes in mulberry (*Morus alba* L.) depending on their maturity during distribution. Korean J Food Preserv 20, 304–316.

Pawlowska AM, Oleszek W, Braca A (2008) Quali-quantitative analyses of flavonoids of *Morus nigra* L. and *Morus alba* L. (Moraceae) fruits.

J Agri Food Chem 56, 3377-3380.

Shin J, Heo Y, Seo M, Choi Y, Lee K (2016) Effects of cooking methods on the β-carotene levels of selected plant food materials. Food Sci Biotech 25, 955-963.

Sung GB, Kim H, Hong IP, Nam SH, Chung IM (2007) Characteristics of newly bred mulberry cultivar Daesungppong (*Morus lhou* (Ser) Koidz) for mulberry fruits production. Korean J Seric Sci 49, 56-59.

Tang W, Eisenbrand G (2011) Handbook of Chinese Medicinal Plants (1st ed.), pp. 777–781, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.

Taser OF, Tarhan S, Ergunes G (2007) Effects of chemical pretreatments on air-drying process of black mulberry (*Morus nigra* L.). J Sci Ind Res 66, 477-482.

Teng H, Lee WY (2014) Optimization of drying conditions for quality semi-dried mulberry fruit (*Morus alba* L.) using response surface methodology. Curr Res Agric Life Sci 32(2), 67-73.

Yang C, Han B, Zheng Y, Liu L, Li C, Sheng S, *et al.* (2016) The quality changes of postharvest mulberry fruit treated by chitosan-g-caffeic acid during cold storage. J Food Sci 81, C881-C888.

Zadernowski R, Naczk M, Nesterowicz J (2005) Phenolic acid profiles in some small berries. J Agric Food Chem 53, 2118-2124.