Introduction

Maize (Zea mays L.) is the world’s third largest food crop after rice and wheat, and contains large amounts of nutrients, unique flavors, and vitamins (Redaelli et al. 2016). Maize has a wide variety of uses, including its use as a raw material for edible and processed food, in animal feed, and in industrial applications (Jung et al. 2001). In many countries, maize grains are transformed into various products. They can be roasted, boiled, fried, or ground and fermented to produce bakery products or alcoholic beverages (Rooney and Serna-Saldivar 2003). There are a variety of maize species worldwide, and maize can be divided into white, yellow, red, purple, and black varieties by the color of the grain (Lee et al. 2016). In South Korea, maize has been cultivated for edible purposes includes sweet corn, super sweet corn, fried corn, and waxy corn (Hwang and Jeong 2012).

Maize grain is 72% starch, with the remainder composed mainly of protein, fat, and fiber, and contains a large amount of linoleic acid, which is an essential fatty acid (Yu et al. 2010). Maize grain consists of rich in molecules with antioxidant characteristics, such as phenol compounds, flavonoids, carotenoids, anthocyanins, and tocots (Adom and Liu 2002; Lopez-Martinez et al. 2009). The general activity of all the antioxidant components present in a raw material can also be expressed as total antioxidant activity (Brewer 2011). Many studies have measured the content of antioxidant compounds and antioxidant activity in maize grains (Adom and Liu 2002; Del Pozo-Insfran et al. 2006; Tafuri et al. 2014). The maize has received increased attention from a nutraceutical perspective due to its potential health benefits (Corrales-Bañuelos et al. 2016).

Bakhtavar et al. (2015) reported that early sown maize crop improved the performance, such as stand establishment,
chlorophyll and phenolic contents, increased leaf area duration and grain filling period. The protein content and quality characteristics of green rice differ according to the cultivation period during the 2004-2005 (Lee et al. 2006). The anthocyanin content of black soybean is affected by environmental factors such as seeding time, harvest time, and cultivation years (Joo et al. 2004). Based on analysis of the effects of different planting and sowing dates on the quality of soybean seeds, it has been suggested that variety-specific characteristics, such as protein content, isoflavone content, water absorption rate, and germination rate, should be considered to improve the quality of the seedlings (Kim et al. 2006). Woo et al. (2012) reported that phenolic compounds and radical scavenging activity of millets showed significant differences according to cultivation variety and time. Also, antioxidant compound contents and antioxidant activity of proso millet (Lee et al. 2011) and sorghum (Woo et al. 2011) showed significant differences according to the cultivated areas and variety.

The aim of this study was to define the functional components and radical scavenging activities of the grain of various Korean maize hybrid cultivars in two different cropping seasons. We also determined the optimal cropping seasons for each of the maize hybrids with enhanced antioxidant activity in South Korea.

**Materials and Methods**

**Chemical reagents and sample preparation**

Amylose, free sugars (fructose, glucose, sucrose, and maltose), a fatty acid standard, carotenoid, Folin-Ciocalteu reagent, sodium carbonate, gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2-azinobis(3-ethylbenothiazoline-6-sulphonic acid) diammonium salt (ABTS), potassium persulfate, and trolox were purchased from Sigma-Aldrich (St. Louis, MO, USA). HPLC-grade water was purchased from J.T. Baker (Phillipsburg, NJ, USA). All reagents used were of the highest grade quality.

Maize (Zea mays L.) cultivars were grown at the National Institute of Crop Science, Rural Development Administration, Suwon, South Korea (37°26′N and 126°98′W) during the 2015 cropping season and were stored at -20°C. The cropping seasons included two growing periods; the first began on 5th April and the second began on 5th July. In South Korea, planting on 5th April is early-season cultivation, and planting on 5th July is late-season cultivation. The cropping system was planted triple replications by spacing 15 × 70 cm and one plant per stubble according to the standard method of Rural Development Administration. The kernels of the Andaok, Cheongbaek, Dapyeongok, Gangilok, Jangdaok, Kwangpyeongok, and Pyeonggagok cultivars are the dent type, while those of the Cheonganok, Darok, Gandaok, and Pyeonganok cultivars are the semi-flint type, and the Singwagok and Yanganok cultivars are the intermediate type. Maize kernels were pulverized using a micro hammer-cutter mill (Type 3, Culatti Ag., Zürich, Switzerland).

**Analysis of compositions**

The AOAC standard method (AOAC 1995) was used to determine moisture, crude ash, fat, and protein contents. The moisture content was measured by the atmospheric pressure drying method at 105°C. The crude ash and fat contents were determined following incineration at 550°C in an electric furnace (F-2F; Kong Soong Co., Seoul, Korea) and Soxhlet extractor (Soxtec System HT 1043 extraction unit, Foss Tecator, Mulgrave, Australia). The crude protein content was measured by the Kjeldahl method (Kjeltec 2400 AUT, Foss Tecator). The total starch content was analyzed using a Megazyme kit (K-TSTA, Chicago, IL, USA). The amylose content was measured following the method used by Juliano et al. (1987).

**Analysis of the free sugar composition**

Free sugars (fructose, glucose, sucrose, and maltose) were measured by extracting 5 g of homogenized sample in 20 mL of water, which was then filtered through a 0.45-μm membrane and analyzed by HPLC (Waters e2695; Waters, New Castle, DE, USA). The analysis conditions followed the method used by Park et al. (2002). Here we used a carbohydrate analysis column (4.6 × 150 mm; Waters), refractive index (RI) detector (Waters 2414; Waters), and an acetonitrile/water 75:25 (v/v) mobile phase at a flow rate of 1 mL/min.

**Analysis of fatty acids**

Fatty acids in sample extracts were trans-esterified to methyl esters (FAMEs) using a base-catalyzed transesterification followed by a boron trifluoride-catalyzed esterification according to AOCS (1998). The FAMEs (1.5 μL) were injected into a gas chromatography (GC) system (Agilent 6850, Agilent, Palo Alto, CA, USA) equipped with a 30-m capillary column coated with HP-INNOWAX (0.25 mm film thickness, Agilent). The injector temperature was set to 250°C and the flame ionization detector temperature was 300°C. The initial oven temperature was 120°C and was programmed to rise to 230°C at 5°C/min. Nitrogen gas (99.999%) was used as carrier gas at a velocity of 1.3 cm/s. FAMEs were identified based on their retention times in relation to authentic lipid standards and fatty acid compositions were expressed as an area percentage of total fatty acids.

**Determination of carotenoid contents**

The total carotenoid content of yellow kernels was determined by the method of Al-Farsi et al. (2005). Two g of samples were extracted using an acetone/ethanol mixture (1:1, v/v). All extract manipulations were conducted in dark conditions, and extracts were centrifuged at 1,200 rpm for 10 min at 4°C. The supernatants were collected after being filtered through a Whatman No. 42 filter and then the collected supernatants were measured based on their absorbance at 470 nm using a spectrophotometer (Model Evo 600PC, Thermo Fisher Scientific, Waltham, MA, USA).