Abstract  Wheat is a staple food in the Korean diet, which is increasingly becoming westernized. Because most domestic wheat consumption relies on imported wheat, we aimed to evaluate the allergy-inducible protein contents of commercial flours from imported and domestic wheat. Analysis of the protein contents by densitometry suggested that domestic wheat flours contain lower levels of high molecular weight glutenin and omega-gliadin (50 and 34% lower, respectively) than imported wheat flours. Therefore, domestic wheat flours are less likely to cause allergic reactions than imported wheat flours are. Based on the findings of our study, we commend increased consumption of domestic wheat flours to those who are sensitive to allergy.

Keywords  domestic wheat · gliadin · glutenin · imported wheat · wheat allergy

For many years, wheat has been consumed as an important component of bread, pasta, and noodles (Wan et al., 2014). However, allergy-inducible proteins in wheat have been known to cause various food allergies, such as wheat-dependent exercise-induced anaphylaxis (WDEIA) and celiac disease (Pasha et al., 2013). These proteins are classified into two groups: the albumin/globulin, water/salt-soluble fraction; and the gluten, water/salt-insoluble fraction (Morita et al., 2009). Gluten fractions are composed of gliadin and glutenin subunits and are known to be the causative agent of wheat-related food allergies (Morita et al., 2009). Among the gliadin types (alpha-, beta-, gamma-, and omega-gliadin), omega-gliadin is mainly responsible for wheat-related food allergies; and among the glutenin types (high and low molecular weight glutenin [HMW and LMW, respectively]), HMW glutenin is the main culprit (Matsuo et al., 2005; Morita et al., 2009).

Despite increased demand for wheat flours in the domestic market, wheat consumption depends heavily on imported wheat flours. Although considerable research on the allergic activity of standardized wheat samples has been performed, there have been few reports of scientific comparative analysis of the allergy-inducible components of domestic versus imported wheat in Korea. Thus, we evaluated the major allergy-inducible protein contents of commercial domestic and imported wheat flours. Our results may provide preliminary evidence that domestic wheat has lower allergenic activity than imported wheat.

To compare wheat allergy-inducible protein contents in domestic and imported wheat flours, we purchased eight wheat flour samples from a commercial market. We divided the flour samples according to their gluten content (as this determines the flour’s use), into strong, medium, and soft flours (Palacios et al., 2004). The samples were further divided into domestic and imported wheat flours (Table 1). Protein contents are presented in Table 1 based on the nutrition labels of the respective products.

To extract the total protein in wheat flours, 100 mg of wheat flour was treated with 1 mL of borate extraction buffer (pH 10.0)
containing 12.5 mM sodium borate (Sigma-Aldrich, USA), 1% sodium dodecyl sulfate (SDS; Sigma-Aldrich), and 2% β-mercaptoethanol (Sigma-Aldrich). Each sample was incubated for 2 h with shaking at 37°C, and was centrifuged at 15,890 g for 15 min. The supernatant containing the total protein was then carefully transferred to another tube (Wallace et al., 1990). Total protein was diluted 1:1 in 2× Laemmli sample buffer (Bio-Rad, USA) containing 5% β-mercaptoethanol, and then boiled for 10 min at 99°C. Each sample was separated by discontinuous SDS-polyacrylamide gel electrophoresis (SDS-PAGE; Bio-Rad) with a 10% polyacrylamide separating gel and a 5% stacking gel; 20 µL of each sample was loaded into the respective wells. Protein contents of each sample were not quantified at this point, so that levels of allergy-inducible proteins were assessed based on a comparative number of samples rather than on comparative protein contents. Each sample was run at 80 V for 30 mins, followed by 100 V for 120 min. Each sample was then stained with Coomassie brilliant blue G-250 dye (Bio-Rad) and analyzed by densitometry (ImageJ Software, USA).

After extraction from the wheat flours, the total protein was separated by SDS-PAGE (Figs. 1A, 2A, and 3A). The HMW glutenin subunits showed bands ranging from 75 to 110 kDa. Bands in the gliadin subunits ranged from 50 to 67 kDa (omega-gliadin) and 33 to 45 kDa (alpha-, beta-, and gamma-gliadin) (Comino et al., 2012). In this study, omega-gliadin was observed around 63 kDa (Fig. 3A). Total protein levels of domestic wheat flours (numbers 7 and 8 in Table 1) were observed as relatively weak bands of allergy-inducible proteins such as HMW glutenin and omega-gliadin (Figs. 1A and 3A). Generally, HMW glutenin has been described as a major allergen in comparison to LMW glutenin (Matsuo et al., 2005; Baar et al., 2014). When the protein contents were analyzed by densitometry, we confirmed that domestic wheat flours (numbers 7 and 8, Figs. 1B and 3B) have lower contents of HMW glutenin (an average of 7.7%) and omega-gliadin (an average of 12.3%) than imported wheat flours (an average of 17.4 and 18.6%, respectively; numbers 1–6, Figs. 1B and 3B). Thus, domestic wheat flours contain lower levels of high molecular weight glutenin and omega-gliadin (50 and 34% lower, respectively) than imported wheat flours. However, LMW glutenin contents were much less different between domestic wheat flours (an average of 16.8%) and imported wheat flours (an average of

| No. | Blend            | Protein Contents | Character          |
|-----|------------------|------------------|--------------------|
| 1   | USA+Canada       | 24%              | Strong flour       |
| 2   | USA+Australia    | 16%              | Medium flour       |
| 3   | USA              | 15%              | Soft flour         |
| 4   | USA+Cancada      | 24%              | Strong flour       |
| 5   | USA+Australia    | 18%              | Medium flour       |
| 6   | USA+Australia    | 16%              | Soft flour         |
| 7   | Korea            | 18%              | Medium flour       |
| 8   | Korea            | 19%              | Medium flour       |

*Eight wheat flour samples purchased from a commercial market were divided according to origin and gluten content. Protein contents are presented based on the nutrition labels of the respective products.

Fig. 1 Contents of high molecular weight (HMW) glutenin in total proteins of homegrown and imported wheat flours. (A) After SDS-PAGE, gel was stained with Coomassie blue dye. The HMW glutenin subunits showed bands ranging from 75 to 110 kDa. (B) Data are expressed by densitometry as the mean ± SE of 3 independent experiments. Numbers on x-axis correspond to those assigned to the various types of flour indicated in Table 1.

Fig. 2 Contents of LMW glutenin in total proteins of homegrown and imported wheat flours. (A) After SDS-PAGE, gel was stained with Coomassie blue dye. The LMW glutenin subunits showed bands ranging from 40 to 45 kDa. (B) Data are expressed by densitometry as the mean ± SE of 3 independent experiments. Numbers on x-axis correspond to those assigned to the various types of flour indicated in Table 1.

Fig. 3A: Percentage of HMW glutenin in total protein.

Fig. 3B: Percentage of LMW glutenin in total protein.

Table 1 Characteristics of domestic and imported wheat flours*

| No. | Blend            | Protein Contents | Character          |
|-----|------------------|------------------|--------------------|
| 1   | USA+Canada       | 24%              | Strong flour       |
| 2   | USA+Australia    | 16%              | Medium flour       |
| 3   | USA              | 15%              | Soft flour         |
| 4   | USA+Cancada      | 24%              | Strong flour       |
| 5   | USA+Australia    | 18%              | Medium flour       |
| 6   | USA+Australia    | 16%              | Soft flour         |
| 7   | Korea            | 18%              | Medium flour       |
| 8   | Korea            | 19%              | Medium flour       |

*Eight wheat flour samples purchased from a commercial market were divided according to origin and gluten content. Protein contents are presented based on the nutrition labels of the respective products.
In addition, levels of alpha-, beta-, and gamma-gliadin subunits were also similar between domestic and imported wheat flours (data not shown).

The levels of wheat-related allergy-inducible proteins are dependent on the gluten levels, which accounts for 90% of the protein in wheat (Hischenhuber et al., 2006). The present study has shown that the selected domestic wheat flours had lower wheat-related allergy-inducible potency than imported one. In addition, these results suggest that the allergy-inducible protein contents of imported flours were not significantly different among the various kinds of flour, i.e., strong, medium, and soft flours. Thus, regarding allergy-inducible protein levels, the selected domestic wheat flours could be major competitors on the domestic market in comparison to imported wheat flours. Wheat has gradually become an integral part of the Korean diet. However, production of homegrown wheat has been very limited and accounts for only a small percentage of wheat flour consumption in Korea. Thus, domestic wheat consumption has been largely supported by imported wheat flour. We recommend further development of Korean wheat varieties that have low allergy-inducible protein contents, to meet a potential increase in demand for homegrown wheat flour.

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