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The influence of fiber size distribution of type IIB on carcass traits and meat quality in pigs

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ABSTRACT

The effects of detailed characteristics such as the size and proportion of type IIB fibers in *longissimus thoracis* muscle on carcass traits and pork quality were investigated. A total of 96 pigs were classified into four groups by the proportion of different IIB fiber sizes. Group NS (high proportion of both small- and normal-sized IIB fibers) had a higher total number (136.4) and density (231.31) of type IIB fibers, backfat thickness (37.20 mm) and intramuscular fat content (4.77%) than the other groups ($P<0.05$), whereas Group NS had the lowest values of cross-sectional area (3413.85 μm^2) and diameter (60.15 μm) of type IIB fiber among the groups ($P<0.05$). Pig muscles with higher percentage of large IIB fibers exhibit tougher, lighter and more exudative meat than pig muscles with a higher proportion of small- or normal-sized IIB fibers. Therefore, an increase in the proportion of large IIB fibers causes poor quality of pork.

1. Introduction

Skeletal muscle is composed of several types of fiber, each having different morphological and biochemical characteristics. Muscle fibers are commonly classified as type I (slow-twitch, oxidative), IIA (fast-twitch, oxidative glycolytic), and IIB (fast-twitch, glycolytic), based on stains for enzymes involved in oxidative metabolism (Peter, Barnard, Edgerton, Gillespie, & Stempel, 1972) and myosin ATPase activity (Brooke & Kaiser, 1970). Individual fibers differ in oxidative capacity and myosin ATPase activity as well as size, lipid and myoglobin content (Cassens & Cooper, 1971; Essén-Gustavsson, Karlstrom, & Lundstrom, 1992; Rosser, Norris, & Nemeth, 1992). These varying characteristics of different fiber types are related to meat quality and carcass traits in various species, such as cattle (Hwang, Kim, Jeong, Hur, & Joo, 2010; Ozawa et al., 2000; Picard, Juire, Duris, & Renand, 2006), pigs (Fiedler, Rehfeldt, Dietl, & Ender, 1997; Ryu & Kim, 2006) and poultry (Dransfield & Sosnicke, 1999; Kim et al., 2008). For example, increasing the proportion of type I fiber is associated with lightness decreasing and water-holding capacity improving in pigs (Choi, Ryu, & Kim, 2006; Gil et al., 2003; Ryu & Kim, 2005) and with tenderness and juiciness improving in cattle (Maltin et al., 1998). Also, type IIB fibers are closely related to toughness, paleness, protein denaturation and low water-holding capacity in porcine *longissimus* muscle (Choi et al., 2006; Karlsson et al., 1993; Kauffman et al., 1998; Larzul et al., 1997; Renand, Picard, Touraille, Berge, & Lepetit, 2001; Ryu et al., 2008).

In general, the *longissimus* muscle of pigs has a greater size and higher percentage of type IIB fiber than of type I or IIA fibers. There is also a large variation in size among type IIB fibers within the same species and the same muscle. It has been reported that the proportions of type IIB fibers were 69.7–90.3% of area and 70.92–94.73% of number in porcine *longissimus* muscles from various breeds, such as Berkshire, Yorkshire, Landrace, Duroc and their crossbred pigs (Lee et al., 2012; Ruusunen & Puolanne, 2004; Ryu et al., 2008). The size distribution of type IIB fiber has been reported to range from 2771 μm^2 to 8522 μm^2 in cross-sectional area and from 61.32 μm to 71.51 μm of diameter (Larzul et al., 1997; Lee et al., 2012; Miller, Garwood, & Judge, 1975; Ryu, Rhee, & Kim, 2004). In our previous study, it was observed that the proportion and size distribution of type IIB fiber in *longissimus* muscle from crossbred (Korean native black × Landrace) pigs were 75.72–82.62% of area and 70.78–82.17% of number, and 76.07–83.93 μm in diameter, respectively (Kim et al., 2013).

However, most researchers studied the characteristics of muscle fiber types by comparing their mean values of size. Up to now, specific studies on the large variations in size and proportion among individual fibers of type IIB have not been conducted. Therefore, in the present study, we investigated the size distribution and proportion of type IIB fiber, and the influence of these factors on meat quality and carcass characteristics in porcine *longissimus* muscle.

2. Materials and methods

2.1. Samples and carcass traits

A total of 96 crossbred (Korean native × Landrace) F_2 pigs (56 gilts and 40 castrated males) were fed the same commercial diet. Pigs of 202 ± 5 days old (112 ± 6 kg of live weight) were slaughtered at a commercial slaughtering house according to the standard commercial

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procedures of the Korean livestock production system. Carcass weight, loin-eye area and backfat thickness (at the 4th–5th thoracic vertebra) were measured immediately after slaughtering. Samples of *longissimus thoracis* muscle were taken at the adjacent 5th *thoracic vertebra* for histochemical analysis within 1 h post-mortem and were frozen by isopentane chilled with liquid nitrogen according to the method proposed by Dubowitz and Brooke (1973). After 24 h of chilling of the carcasses, the *longissimus thoracis* muscles were taken to evaluate the meat quality traits.

2.2. Histochemical analysis

Transverse serial sections of 10 μm were cut from entire blocks (1.0 × 1.0 × 2.0 cm) on a cryostat microtome (HM525, Microm GmbH, Walldorf, Germany) at −27 °C. The sections were subsequently incubated for the histochemical demonstration of myosin adenosine triphosphatase (mATPase) following alkaline (pH 10.75) and acid (pH 4.65) pre-incubation, using a modification of the Brooke and Kaiser (1970) method (Fig. 1). An image analysis system (Image-Pro® plus 5.1, Media Cybernetics Inc., MD, USA) was used to examine the stained sections. Then the muscle fibers were classified into fiber types I, IIA and IIB according to the nomenclature of Brooke and Kaiser (1970). Approximately 400 fibers per sample were counted to analyze the muscle fiber characteristics. The total number of fibers, fiber density, fiber proportions (area % and number %), cross-sectional area, fiber diameter, and detailed characteristics of type IIB fibers such as fiber number and proportion in the order of diameter (small, diameter < 40 μm; large, diameter > 100 μm; normal, diameter > 40 μm and diameter < 100 μm), were determined for the individual IIB fibers.

2.3. Meat quality

The pH was measured on homogenates of 3.0 g muscle in 27 ml of de-ionized water, using a pH-meter (MP230, Mettler toledo, Switzerland). Meat color (CIE L^*, a^* and b^*) was measured on the muscle surface, using a Minolta Chromameter CR-300 (Minolta Co., Tokyo, Japan) that was standardized with a white plate (Y = 93.5, X = 0.3132, y = 0.3198). The drip loss (%) was determined by suspending muscle samples standardized for surface area in an inflated plastic bag for 24 h at 4 °C using the method developed by Honikel (1987) with modifications. The moisture content (%) and intramuscular fat content (%) of the samples were determined using the oven-drying method (AOAC, 1995) and the Folch, Lees, and Sloane-Stanley (1957) procedure, respectively. Warner–Bratzler shear force (WBSF, kg/cm^2) values were determined using an Instron Universal Testing Machine (Model 4400, Instron Corp., MA, USA). The samples were 1.3-cm diameter cores obtained from steaks cooked to 70 °C internal temperature for 30 min. Cooking loss (%) was also recorded for each sample by weighing before and after cooking.

2.4. Statistical analysis

The experimental data were analyzed by the analysis of variance procedure of statistical analysis systems (SAS, 2002). The pig groups

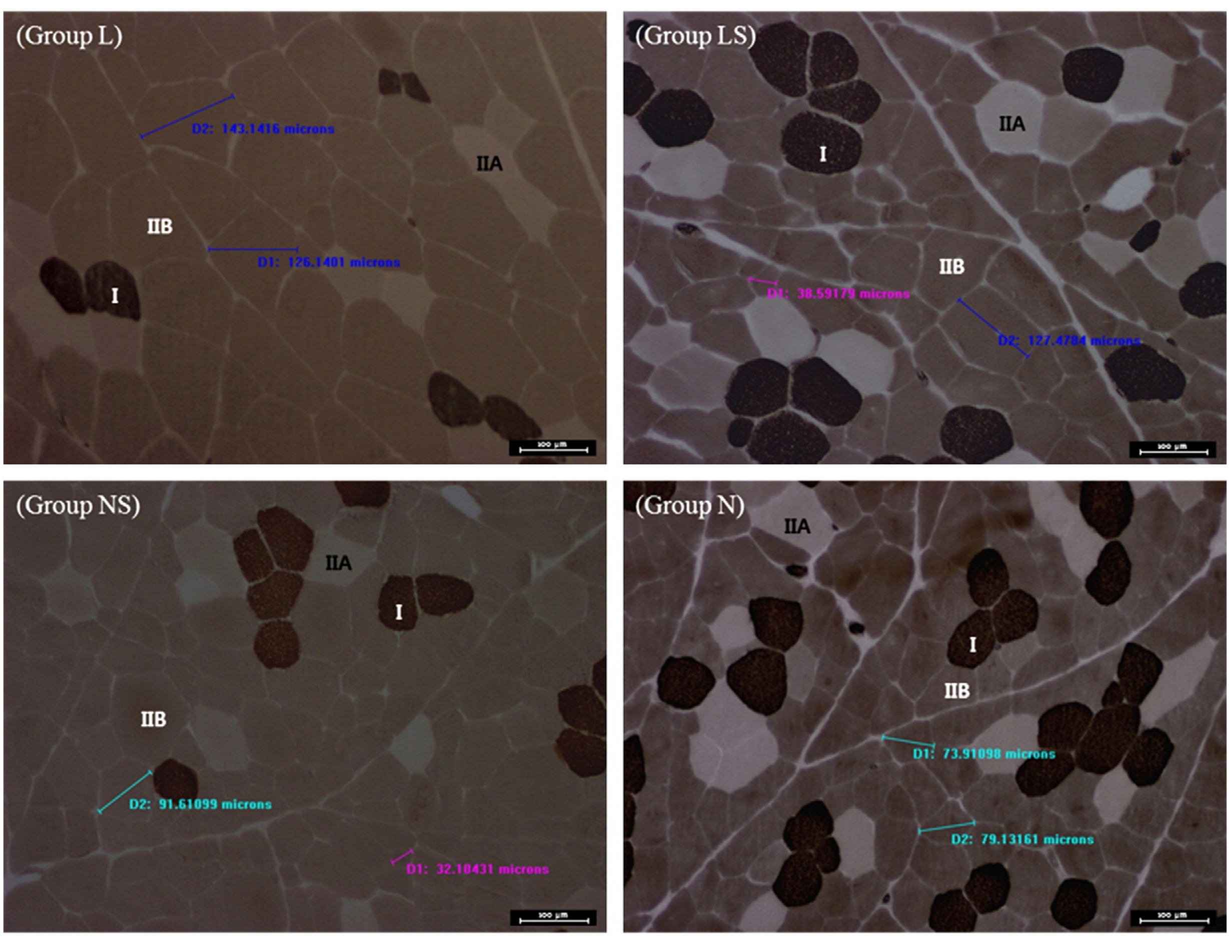

Fig 1. Cross-sections of *longissimus* muscle stained for myosin ATPase after pre-incubation in pH 4.65. Magnification of 100× was used (bar = 100 μm). I: fiber type I; IIA: fiber type IIA; IIB: fiber type IIB. Group L (n = 24): high proportion (> 40%) of large-sized (diameter > 100 μm) fiber; Group LS (n = 24): high proportion (> 20%) of both large- and small-sized (diameter < 40 μm) fiber; Group NS (n = 24): high proportion of both normal- (> 60%) (diameter > 40 μm, < 100 μm) and small- (> 30%) (diameter < 40 μm) sized fiber; Group N (n = 24): high proportion (> 80%) of normal-sized (diameter > 40 μm, < 100 μm) fiber.