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Differences in Muscle and Fat Accretion in Japanese Black and European Cattle

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Summary

The objective of this study was to investigate the growth related changes in muscle and fat characteristics of Japanese Black (JB) and European Cattle. The carcass characters of all breeds were determined, including the hot carcass, muscle, and fat depot weights. Intramuscular (i.m.) fat traits were also determined and evaluated by computerized image analysis. This study proved that the super marbled beef of JB was accompanied by high body fat deposition derived from breeding.

Keywords: Gotoh, T., Fat deposition, image analysis, marbling, growth, Japanese Black Cattle

Introduction

Beef production is markedly different between Europe, America, and Japan. In European beef cattle breeding and husbandry extensive efforts have been focused on the efficient production of leaner meat. In the United States (US) and Japan on the other hand, beef industries focus on intramuscular (i.m.) fat as an important factor of meat quality. Fat deposition in the muscle is closely related to the juiciness and flavor of beef (Hornstein and Wasserman, 1987). Smith *et al.* (2000) reported that JB cattle have a unique genetic potential to deposit i.m. fat that cannot be achieved by breed types common in Europe, North America and Australia. Therefore, compared to other breeds, JB cattle serve as a model for fat deposition research.

The advanced way of beef production would be characterized by increased i.m. fat, not by fat depots in other parts of the body, which would be wasted. To address the molecular biological and physiological research required for i.m. fat deposition, patterns of muscle and fat accumulation in different breeds should be clarified in detail. The objective of this study was to evaluate the differences in muscle and fat accretion in JB and European cattle during growth.

Materials and Methods

Animals: Bulls of three European breeds, and JB steers were used in this study. Each breed represents unique properties: JB as an extreme type for fat deposition, double-muscled Belgian Blue (BBDM) as an extreme type for muscle growth, German Angus (GA) as a beef type, Holstein Friesian (HF) as dairy types. All cattle were fed concentrate and roughage. Between 5 and 17 bulls of each European breed were slaughtered at 6, 12, 18, and 24 months of age, and between 5 and 15 JB steers were slaughtered at 8, 14, 20, and 26 months of age.

Carcass characteristics: Standard procedures were used to determine the carcass traits: the hot carcass, muscle, fat depot and bone weights. The longissimus, semitendinosus, biceps femoris, and triceps brachii muscles were removed from the left side of the carcass, trimmed of any external fat, and weighed. The i.m. fat content of the longissimus and semitendinosus muscle samples was obtained via the Soxhlet extraction method.

Image analysis of marbling: Three-cm thick muscle chops were removed from the longissimus muscle on the 12th rib to measure the muscle cross-section area and calculate the i.m. fat depot characteristics by computer image analysis. Thin slices of longissimus muscle were fixed in paraformaldehyde and stained with Oil- Red. Adipocytes, connective tissue and blood vessels were distinguished by this staining. The stained slices were analyzed for marbling using a computerized image analysis system adapted from the method of Albrecht *et al*. (1996).

Adipocytes: Transverse sections (10 µm thick) of semitendinosus muscle were cut using a cryostat and stained with hematoxylin and eosin. After staining, microscopic pictures were taken and the diameters of the adipocytes were measured.

Results and Discussion

The body and hot carcass weights of each breed increased linearly with age. With respect to body weight development, no marked differences between JB, GA, HF and BBDM could be found. The expected body weight values at 24 months did not differ (overlapping 95% confidence intervals), but the hot carcass weights were largest in BBDM and JB, second largest in GA and smallest in HF. No difference in hot carcass weight was found between BBDM and JB, however, their hot carcass compositions were quite different (figure 1). The percentage of subcutaneous fat in the hot carcass was ten-folds higher in JB (17%) than in BBDM (1.7%), conversely the muscle weights of the longissimus, semitendinosus, biceps femoris and triceps brachii were higher in BBDM (1.2, 2.5, 1.9 and 2.0-folds, respectively) than in JB.

There were considerable differences in the patterns of muscle growth between the longissimus, semitendinosus, biceps femoris, and triceps brachii. The BBDM cattle had the largest muscles of these four breeds at all ages. Grobet *et al*. (1997) reported that the myostatin gene, which regulates muscle cell hyperplasia in the fetus, was partially deleted in BBDM. Wegner *et al.* (2000) proved that BBDM had muscle fibers nearly the same size, but 1.5-2 folds more semitendinosus at birth compared with GA and HF. Compared among JB, GA and HF, JB showed the heaviest longissimus muscle. However, JB showed the smallest semitendinosus, biceps femoris and triceps brachii muscles. The largest muscle in JB was the longissimus, as opposed to the biceps femoris in the European breeds. It is supposed therefore that the fore and hindlimbs of JB are inferior to those of GA and HF. On the other hand, JB had higher longissimus muscle growth ability. This was attributed to the accumulation of i.m. fat because in the longissimus muscle i.m. fat contents were 5-37 folds higher in JB than in the other breeds.

In the present study, the accumulation of fat during growth was markedly different between BBDM, GA, HF and JB. JB exhibited the heaviest subcutaneous, omental, intestinal and perirenal fat values, followed by GA and HF, and finally by BBDM at 24 months of age. The increasing rates of fat mass were dependent on the locations of the fat deposits. Each type of fat deposit was present at higher levels during growth in JB and at lower levels in BBDM with respect to GA and HF. Although 4-11 kg intestinal fat was calculated at slaughter in BBDM, GA and HF, the amount of fat in JB had already exceeded 16 kg at 14 months of age, reaching nearly 38 kg at slaughter. Subcutaneous fat increased markedly and linearly during growth in JB but remained low until slaughter in the other breeds. The storage of a considerable amount of subcutaneous fat is one of the specific characters of fat accumulation patterns in JB. BBDM could accumulate only a small amount of subcutaneous and other visceral fats. In addition, the i.m. fat contents of the longissimus and semitendinosus muscles were also less than 0.63 % from 6 months of age to the time of slaughter in BBDM, because of their considerable amounts of muscle and energy required to maintain them. Mcpherron and Lee (2002) revealed that myostatin-deficiency in mice led to a partial suppression of fat accumulation and abnormal glucose metabolism. This suggests that BBDM is genetically suppressed with regards to fat storage in the body. In JB the fat content (%) of the longissimus and semitendinosus muscles increased at a higher rate during growth than in the other breeds. At slaughter, the fat content of the longissimus muscle of JB was up to 26.8 % i.m. compared with 0.6-5.5% for the other breeds. The i.m. fat content percentages at slaughter differed between the longissimus and semitendinosus muscles, and the difference between the fat contents of these two muscles at slaughter was larger in JB (2.6 times) than in the other breeds (1.6-1.7 times). This suggests that the ability for fat accumulation or sensitivity to fat storage differs among different breeds. JB has a marked ability to accumulate fat specifically in the longissimus muscle because the marbled longissimus muscle has been selected for its commercial value in Japan.

The number of fat deposits determined by image analysis in the longissimus muscle of JB are almost unaffected by age. This suggests that in this muscle in JB the single fat deposits are more and more connected to each other giving it its marbled appearance. However, in the European breeds, the number of fat deposits varied, for example, they were four folds greater in GA. This shows that during the formation of marbled beef, both hyperplasia (proliferation) and hypertrophy (lipid filling) of the adipocytes occur concurrently in growing European cattle. In JB, marked differences in adipocyte diameter in the semitendinosus muscle during growth were observed compared with the other breeds.
In this study, relatively different patterns of muscle and fat accretions were clarified during growth in JB compared to European breeds. Based on these results, comparisons among these breeds at a molecular level would provide important information for improved beef quality.

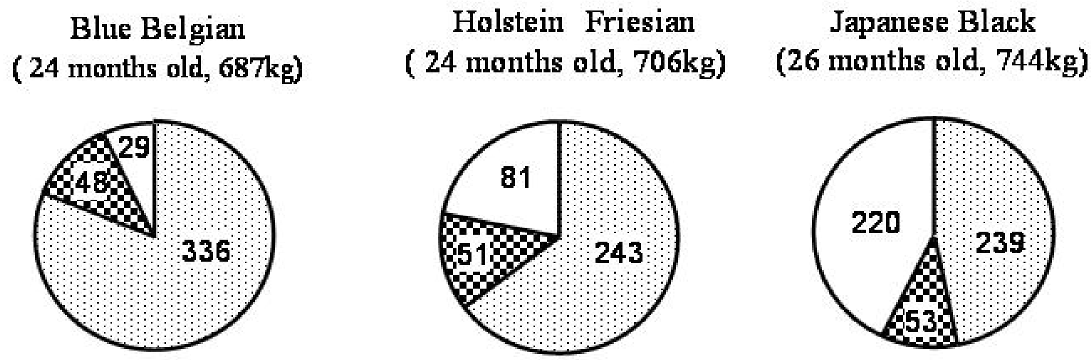

Figure 1. Body weight and carcass composition (kg) of European compared to Japanese Black cattle.
▭ : weight (kg) of all muscles in the cold carcass. ▩ : weight (kg) of all bones in the cold carcass. ▭ : weight (kg) of fat of the cold carcass (calculated from different cuts, for example, intra- and intermuscular fat, and subcutaneous fat; the fat in the edible organs and internal depots were individually determined and weighed).

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