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Differences in muscle and fat accretion in Japanese Black and European cattle

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ABSTRACT

The development of different muscles and adipose tissues during growth was investigated in commercial Japanese Black (JB) cattle and compared with breeds of the largest variation to be found in Europe. Animals, reared under typical conditions for Japanese and European beef production systems, gained similar body weights but different carcass composition at 24 months of age. The carcass of JB contained more adipose tissue and the least proportion of muscle. The *longissimus* muscle of JB developed extraordinary amounts of 23.3% intramuscular fat (IMF) at 24 months of age, compared from 0.6% to 4.7% in European breeds. The relationships between IMF content in the *longissimus* muscle and different adipose tissue weights indicate that a large amount of "waste fat" is accreted with every percent of IMF. However in JB, the good ability of IMF deposition is associated with relatively least development of "waste fat", as a result of unique breed characteristics combined with special feeding system.

1. Introduction

As the requirements for high quality beef markedly differ among the consumers of Japan and Europe, a beef production system characteristic of each country has been developed in various ways. In Japan highly marbled beef is required for Japanese traditional cooking methods. Depending on these demands, the use of steers instead of bulls and the intensive feeding system, together with the genetic ability of the JB, results in greater fat deposition compared with European breeds. On the other hand, in Europe all possible efforts have been exerted to produce lean beef. Beef production is characterized by the use of bulls and a moderate feeding system, which leads to leaner carcasses and muscles.

Intramuscular fat (IMF) improves beef quality at least in juiciness and flavor (Hornstein & Wasserman, 1987; Wheeler, Cundiff, & Koch, 1994). Therefore, marbling is an accepted indicator for meat quality and is assessed in abattoirs by meat graders in various countries, e.g. USA and Japan. A study of Cameron et al. (1994) showed that more than 90% of the carcasses from Japanese Black (JB) cattle and only 3% from US beef cattle were selected as USDA Prime grade beef with more than 8.5% ether-extractable fat content in the rib-eye. Other studies confirm that American Wagyu and its sired steers are able to develop more adipocytes within a skeletal muscle than Angus and its sired steers (Lunt, Riley, & Smith, 1993; Xie et al., 1996). JB shows severe deposition of excess fat compared to Holstein and Japanese Shorthorn based on the difference of the genetic ability (Zembayashi & Inayama, 1987). This genetic ability of JB cattle is unique compared with those of the cattle types in Europe, North America, and Australia (Smith, Lunt, & Zembayashi, 2000). Zembayashi (1987), Zembayashi (1994) and Zembayashi and Inayama (1987) reported developmental changes in carcass fat and IMF of *longissimus* muscle by using JB of different slaughter ages with more than 300 kg body weight. However, there are no reports about accumulation of subcutaneous, omental, intestinal, perirenal fat, and IMF during growth in JB. The relationship among them is still not clear.

The beef production system today has to be improved for reducing the deposition of "waste fat", such as subcutaneous and visceral adipose tissues, however simultaneously to maintain a good beef quality which is characterized by highly marbled beef. The relationship between accretion of IMF and "waste fats", and the patterns of changes during growth are not clear. In the present study, two independent experiments in Germany and Japan were accomplished. The objective of this study was to quantify the great differences in muscle and fat accretion in Japanese and European beef production systems. This study was conducted to clarify the characteristics of accretion of the adipose tissues within the carcass, development of the IMF and muscles in the typically commercial JB steers compared with commercial European bulls of a large variation in terms of breeds, namely double-muscled Belgian Blue (BB), German Angus (GA), and Holstein–Friesian (HF).

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2. Materials and methods

2.1. Experimental design

Experiment I in Japan: The JB were cared for and killed according to Japanese rules and regulations for animal care. Forty three JB steers were obtained from crossing Takaramasa bull (a sire of Kagoshima prefecture, Japan) with the cows from Kagoshima. Takaramasa bull was bred from one of the popular JB lines "Kedaka" and represents the breed of JB very well. Steers were raised in a pen with group feeding using the standard feeding system for a marbling beef production. Before 3 months of age the calves were suckled on their dams. All steers were permitted *ad libitum* access to roughages. Consumed feed was recorded daily. The average composition of diets was the following in each feeding stage. During the early growth stage of 3–8 months of age, the common diet was composed of 47% roughages (Italian ryegrass hay, 86% dry matter (DM)) and 53% concentrate (88% DM and 14% crude protein (CP)) and was fed *ad libitum*. In the 2nd stage of 9–14 months of age, the feed consisted of 35% roughages (Bermuda grass hay, 87% DM) and 65% concentrate (87% DM and 13% CP), and in the 3rd stage of 15–20 months of age, the feed consisted of 4% roughages (rice straw, 88% DM) and 96% concentrate (87% DM and 9% CP). From 20 to 26 months of age the amount of concentrate was increased to 98%. Against acute or chronic acidosis, pH values of intra-rumen juices and the composition of lower fatty acids were regularly checked. However, we could not observe any abnormal pH values (always 6–7) or any abnormal composition regarding lower fatty acids. Throughout the experimental period, 100 g fish meal per animal and day (90% DM, 60% CP) was fed additionally to prevent urolithiasis, a disproportion of minerals. All steers were permitted access to mineral salt blocks (Cowstone A, Nippon Zenyaku Kogyo Co., Ltd., Japan) that contained minerals, salt, and a diuretic.

Between 8 and 15 steers were slaughtered at 8, 14, 20, and 26 months of age (Table 1) in an abattoir according to Japanese regulations.

Experiment II in Germany: All animals in Germany were cared for and killed according to German rules and regulations for animal care. The experiment was approved by the institutional authorities and by the responsible office of the County of Mecklenburg–Vorpommern, Germany. Bulls of double-muscled BB, a lean and large-framed beef breed, GA, an early maturing beef breed, and HF, a dairy breed, were raised using a tethering system with individual feeding twice a day. Calves of HF and BB received a milk replacer diet and GA calves were suckled on their dams up to 4 months of age. After weaning calves received a common diet composed of 30% roughage (wilted grass silage of 1.8 kg DM and maize silage of 0.5 kg DM) and 70% concentrate (5.1 kg DM), based on barley grain (92% organic matter, 15% CP, 25% crude fiber) and soybean extraction meal (92% organic matter, 48% CP, 8.9% crude fiber). Additionally, bulls got a vitamin and mineral premix. The level of energy was 1.6- to 1.7-fold greater than the maintenance requirement of 530 kJ/kg metabolic BW ($BW^{0.75}$). Animals were fed restricted for concentrates, depending on the body weight, and *ad libitum* for silage. Between 8 and 17 bulls of each breed were slaughtered at 6, 12, 18, and 24 months of age (Table 1).

Table 1
Number of animals per breed and age group.

Breed	Slaughter age, month 6	8	12	14	18	20	24	26
Japanese Black		8		14		6		15
Belgian Blue	8		9		16		14	
German Angus	10		10		14		17	
Holstein–Friesian	10		10		12		12	

2.2. Carcass traits

The collaborating scientists of both facilities followed the same experimental procedures by use of the standardized protocols. The body weight was recorded just before slaughter after fasting for 24 h. The weights of hot carcass, muscles, bones, and adipose tissues were measured as basic carcass traits. The hot carcass weight was measured 45 min after slaughter and defined as the carcass weight of the slaughtered animal's body after being skinned, bled and eviscerated, and after removal of the external genitalia, the limbs at the carpus and tarsus, the head, the tail, the kidneys, as well as perirenal, omental, and intestinal fat. Subcutaneous adipose tissue was dissected from the surface of carcass and inside of skin. Total weights of muscle, bone, and adipose tissue were measured after separating them by dissection of the cold carcass 24 h after slaughter. The left side of the cold carcass was dissected in various cuts (round of beef, roast beef, filet, chuck, rib, hind leg, flank, plate, brisket, and shank). Furthermore, every cut of the carcass was dissected in muscle, intermuscular fat, bones, and tendons.

2.3. Tissue collection

From the left side of dressed carcass, after chilling at 6 °C for 24 h, *longissimus*, *semitendinosus, gluteobiceps*, and *triceps brachii* muscles were removed and weighed without external adipose tissue. A chop (3 cm thick) of the *longissimus* muscle from European breeds at 24 months of age and JB at 26 months of age was taken at the level of the 12th rib and fixed in 5% formaldehyde for measuring the cross sectional area of muscle and the area and number of marbling flecks. The JB samples were shipped to Germany for further processing. Another sample (about 1 cm^3) was taken from the central region of *semitendinosus* muscle, frozen in liquid nitrogen, and kept at −70 °C for histology and adipocyte size measurement. The IMF content of *longissimus* muscle and *semitendinosus* muscle samples were obtained in triplicates via the Soxhlet extraction method using petroleum ether as solvent and determined gravimetrically after evaporating the extracting solvent (AOAC, 2000).

2.4. Image analysis of marbling and adipocyte size

The *longissimus* muscle chops were cut into thin sections (2 mm thick) using a universal cutting machine (A2501, Graef, Germany). The sections were stained with Oil Red O for 6 h, as described in detail by Albrecht, Wegner, and Ender (1996), to distinguish adipose tissue from connective tissue and blood vessels. Sections were analysed for marbling pattern using a computerized image analysis system (ImageC, Aquinto, Berlin, Germany) according to the method of Albrecht, Teuscher, Ender, and Wegner (2006). The marbling fleck area was determined as total area of all marbling flecks of a muscle cross section. The proportion of marbling flecks was calculated as marbling fleck area related to muscle cross section area in percent.

The semitendinosus samples were cut into transverse sections (10 μm thick) using a cryostat microtome (2800 Frigocut, Leica, Germany) and stained with azan–hematoxylin in JB or hematoxylin–eosin in European breeds. In JB microphotographs were used to measure the diameter of adipocytes as the average of maximum dimension of the long axis and that of the axis perpendicular to the long axis. Based on both values an average diameter was calculated for at least 50 cells per animal. In European breeds the adipocyte size was determined as mean diameter of at least 100 cells per