

# **Cattle Genetic Resources in Japan: One Successful Crossbreeding Story and Genetic Diversity Erosion**

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## **I. Beef cattle production background**

### **I-1. Historical features influencing cattle production**

Besides pigs and ducks, *Sus scrofa* and *Anas sp.*, no ancestral domesticated animals naturally inhabited Japan. Domestic animals, such as pigs, cattle and chickens were introduced in the late Jomon (~ B.C. 500) to Yayoi Eras (B.C. 500 – A.D. 300). A Chinese historical book (~ A.D. 250) described that there were no cattle, horses or sheep in Japan. Because no descriptions of pigs and chickens were found in the book, the possibility of their existence could not be denied.

Several books written in the mid 7<sup>th</sup> century referred to cow's milk. Engishiki (A.D. 927), written in the Heian Era, is a description of the milk product, "So", surmised as condensed milk for medical purposes. A reference to a presentation of "So" to the government is made in this book. However, this habit was abolished at the beginning of the 12<sup>th</sup> century. The government banned the slaughtering of animals, cattle, horses, dogs, monkeys and chickens in A.D. 675. Cattle and horse slaughtering were abolished again in A.D. 742. This suggested that the people of this period ate meat.

After the prohibitory edict, meat and milk became less common. A pictorial book, written around A.D. 1700, introduced dairy products. However, the main use of domestic animals was for transportation of goods, farming, or military power. Some agricultural books introduced a feeding system aimed at manure production.

The history of domestic animals for practical food production in Japan is extremely short compared to most other countries. This seems due to two reasons. First, the climatic conditions in Japan are suitable for grain cultivation and the only purpose for cattle was to assist in rice cultivation. Second, for a long time Buddhism was predominant in Japan and prohibited the eating of meats; especially from four legged animals. The utilization of animal products did not become popular until the Meiji era; especially in the central region of Japan. Meat has been consumed in Japan for only about 130 years, the beginning of the Meiji era. Meat eating has only reached widespread popularity in the last 30 years. Therefore, Japanese cattle were not subject to improvement techniques for milk and meat production before the mid 1950's. The "Law for Improvement and Increased Livestock Production" was enacted in 1950. The law stipulated that the government was required to establish the goal of improving and propagating livestock, stating, "The minister of Agriculture, Forestry and Fisheries shall set specific goals by species concerning the improvement and propagation of livestock including cattle, horses, sheep, goats, pigs and other livestock stipulated according to the related ordinances and publicize each goal".

In the Meiji era, many foreign cattle were introduced to Japan and initially extensively crossbred with the native cattle under the leadership of the government. Through this, the gene pool for Japanese cattle were diluted and greatly expanded. After the initial frenzy of crossbreeding was over, cattle breeders began to improve and promote their own breeds without crossbreeding within prefectures. The unique characteristics of Japanese cattle were then established as found today. However, followed by the introduction and breeding efforts made in each region, most of genuine Japanese native cattle diminished and only Mishima and Kuchinoshima cattle remained in two islands, Yamaguchi and Kagoshima Prefectures, respectively (Fig. 1).

## **I-2. Domestic Animals in Japanese daily life**

There are many traditional events related to a variety of livestock that are still held, particularly in relation to cattle and horses. These include "*ushioni*" at the Warei shrine, the cattle festival at Uzumasa, and sacred

rites relating to fieldwork (Tsuda, 2001) in rural Japan. At these events, living farm animals play a leading role, but unimproved indigenous livestock rarely appear. However, improved breeds are now being utilized even at these traditional events and festivals (Fig. 2).

Livestock production now takes place on a large scale. The presence and awareness of farm animals has gradually faded from ordinary life. Only a few species have been bred for specific purposes, such as cattle for bullfights, and Shamo, Onagadori and Naganakidori as fighting cocks and pet animals. Dishes using goat and pig meat in Okinawa Prefecture and “*kiritanpo-nabe*” using Hinaidori in Akita Prefecture are the forms of traditional cuisine utilizing traditional Japanese breeds. Most non-native species have already become familiar in ordinary Japanese life. With the exception of chickens, the handing down of these traditional recipes and breeds does not seem to have led to the protection of native animals.

## **II. Japanese native cattle breeds’ description**

In 2000, there were a total of 2,824,000 beef cattle and 1,764,000 dairy cattle in Japan. The beef cattle can be classified into two categories, indigenous and non-indigenous cattle. The former includes 1,700,000 Japanese beef cattle, named Wagyu, and the latter involves 461,000 non-indigenous dairy cattle and 663,000 corresponding crossbred animal. Wagyu includes four breeds, Japanese Black (93.9%), Japanese Brown (4.2%), Japanese Poll (trace), and Japanese Shorthorn cattle (1.0%). Each breed that developed its own history and distinct characteristics will be described follows. However, exotic cattle breeds contribute most milk production and more than 99% of the dairy cattle are Holsteins. Production from the two genuine Japanese native cattle is in trace proportions (Statistical Data Related to Livestock Improvement, 2001).

### **II-1 Mishima cattle (Fig. 3)**

Mishima Island is situated at latitude 34°46' N and longitude 131°8' E with an area of 7.8 km<sup>2</sup> in the Sea of Japan. Mishima Island is small and with a restricted flat area. The rice fields are therefore small and terraced. Mishima cattle are suitable for small landholding farmers because of its small body size and good temperament. The first official record indicated that 350 cattle were annihilated for rinderpests in 1672. After that, a new herd was established. Four hundred thirty-three cattle were recorded in

1739 and about 400 cattle had been kept up to the Meiji Restoration in 1868. Mishima cattle can be thought of as the original type of Japanese Black cattle. They were designated a natural monument in Japan in 1928. After this designation, Mishima cattle have been kept as farm animals and for *in situ* conservation. More than 300 female Mishima cattle were kept up to 1961. The number decreased after that and only 33 females remained in the middle of the 1970s (Furukawa *et al.*, 1997). The number of females has gradually increased to nearly 100 in 2002.

Mishima is classified as late maturing cattle with dark brown coat color and small horns as well as narrower body compared to the modern Japanese Black. The average wither height, chest girth and body weight of a mature Mishima female (60 months old) are 112.8 cm, 152.1 cm and 261.1 kg, respectively (Harada *et al.*, 1996).

## **II-2. Kuchinoshima feral cattle (Fig. 4)**

Kuchinoshima island is situated at latitude 29°58' N and longitude 129°55' E with an area of 13.3 km<sup>2</sup> at the north end of Tokara Isles 200 km south from Kyushu.

A record, written in 1727, indicated the existence of domesticated cattle in Kuchinoshima (Tomita, 1996). However, Hayashida and Nozawa (1964) suggested that these feral cattle were descendent from cattle of Kagoshima during 1918 and 1919 and that had escaped from pasturage.

The population size of Kuchinoshima feral cattle was 44 – 66 individuals in 1999. However, there were two Kuchinoshima cattle populations with 20 and 24 animals in 2001, respectively, conserved at Kagoshima University and Nagoya University. The body size of the Kuchinoshima cattle is smaller than the Mishima cattle. The average wither height and body length of a mature female are about 110 cm and 120 cm, respectively. The coat color is mainly black with a white spot in the belly and/or four limbs with brown color occasionally occurred.

## **II-3. Japanese Black (Fig. 5)**

Most Japanese Black cattle were crossbred, producing a modern type of this breed. In the Chugoku district, several pre-crossbred strains (Tsuru) were developed during the Edo era (1600 – 1876). The primary function of these cattle was carrying firewood for steel production and used as

draft animals. After the Meiji restoration in 1867, the government encouraged the introduction of foreign cattle breeds for crossbreeding with native cattle to improve body size and milk production. As shown in Table I, various breeds were introduced and crossbred with regional native cattle. In consequence, the genetic diversity of the indigenous cattle was greatly expanded.

After the mid 1950's, agricultural machinery predominated and chemical fertilizer was more popular in agriculture, supplanting and reducing draft cattle use. This forced a shift in the reason for raising these cattle to beef production.

The Japanese Black is now found in all regions of Japan. This breed has increased in number in the Kyushu and Hokkaido regions. However, in the Chugoku region, which was once the main production region for this breed, the number of this breed has decreased.

The characteristics of the breed include dull black coat and skin, small to medium body size with withers height and body weight being 124 cm, 420 kg and 137 cm, 700 kg in mature cow and bull, respectively. This breed has horns, but no humps. The milk yield over 180 days is about 1000 kg. Compared to the other Japanese indigenous breeds, the Japanese Black are noted for their capacity to produce high degree of fat marbling beef with a thin fat layer beneath the skin and surrounding the internal organs.

#### **II-4. Japanese Brown**

The Japanese Brown breed has two distinct strains and reared mainly in Kumamoto and Kochi prefectures, respectively. The developmental processes of these strains are quite different and usually described separately:

##### **II-4-a. Kumamoto strain (Fig. 6)**

The Kumamoto cattle is a red colored strain in Kumamoto prefecture originally developed from imported Korean cattle. After the late 1900's, this breed was crossbred with many imported foreign breeds such as the Simmental and Devon breeds. A large body size crossbred cattle was produced when Simmental cattle was used. The features of this breed are high weight gain rate and large rib eye area. The body weight of mature females and males are 600 kg and 950 kg, respectively.

#### **II-4-b. Kochi strain**

The Kochi strain was developed from crossing the Simmental with Korean cattle introduced from Kyushu Island. This crossbreeding period was substantially shorter than that for the Kumamoto strain. This reduced the dilution of the original breed's characteristics, retaining important differences. These cattle have a yellow-brown coat, which is much lighter than the Kumamoto strain. The cattle with black skin at horns, hoofs, eyelids, muzzle, tongue, switch and anus are more valuable due to its similarity to typical of the original Korean breed. The beef production performance of this strain is similar to that of the Kumamoto strain. The body weight of mature females and males are 600 kg and 950 kg, respectively.

#### **II-5. Japanese Poll (Fig. 7)**

This breed has been developed since 1916 from a cross between the indigenous cattle with Aberdeen Angus bulls imported from England. Furthermore, Japanese Poll cows were crossed with Japanese Black bulls to improve meat quality in 1975. Therefore, it can be expected that not many pure bred Japanese Poll cattle remained currently. However, neither performance nor progeny tests have been practiced since 1986. The phenotypic characteristics include hornless and black coat color with withers height and body weight being 122 cm, 450 kg and 137 cm, 800 kg in mature cows and bulls, respectively.

#### **II-6. Japanese Shorthorn (Fig. 8)**

This breed is the result of crossbreeding begun in 1871 between the imported dairy Shorthorn cattle and indigenous cattle in the northern parts of Honshu Island (Tohoku region). It is claimed that this breed can utilize the rough summer grazing available in the mountainous parts of this region better than other breeds. They are distributed mainly in the Tohoku and Hokkaido regions. The coat color of this breed is a deep red-brown that is darker than the Japanese Brown. The Japanese shorthorn seems superior to the Japanese Black for milk production, forage intake and growth rate. The withers height and body weight of mature females and males are 128 cm, 500 kg and 140 cm, 800 kg, respectively.

### III. Genetic analysis of Japanese native cattle breeds and populations

#### III-1. Genetic variability of Japanese Cattle

The genetic variability of three breeds, Japanese Black, Japanese Brown and Japanese Shorthorn, is almost the same as that of Holsteins from several indices estimated using the blood type, blood protein, milk protein and microsatellite DNA polymorphisms as genetic markers. Mishima cattle revealed low genetic variability, which accounted nearly half of the other breeds (Abe *et al.*, 1977; Kato, 2002). Kuchinoshima Feral Cattle also showed the same level of genetic variability as Mishima cattle using the same set of microsatellite DNA loci (Kato, 2002).

In the mtDNA, inherited through the maternal line, 24 haplotypes were observed based on 18 mutations in the Japanese Black (Mannen *et al.*, 2000). Only two haplotypes were found in the 6 maternal lines known for Mishima cattle (Shi *et al.*, 2002).

Abe *et al.* (1977) reported that the Japanese Poll possessed slightly lower genetic variability than the other Wagyu breeds. However, the population size of this breed has recently been drastically reduced. The level of variability also seems to have been decreased to a critical level.

P.poly, the average heterozygosity and average number of effective alleles in each breed and population are shown in Table 2. The values for these indices in the Japanese native cattle populations are clearly lower than that in the other three Wagyu breeds. The average number of effective alleles of the Holstein, Kuchinoshima Feral and Mishima were 2.51, 1.48 and 1.40, respectively. The average heterozygosity was 0.521, 0.242 and 0.209, respectively. It is clear that the genetic variability of Japanese pure native cattle is quite low (Table 2).

#### III-2. Genetic relationship among Japanese native breeds and populations estimated from genetic distance

One hundred forty two alleles from 23 microsatellite loci were found in the three Wagyu breeds, two pure Japanese native populations and the Holstein breed. Only 58 alleles were observed in the Mishima and Kuchinoshima population. Forty-five of 58 alleles are shared with other groups, the three Wagyu breeds and Holstein. Twelve alleles are shared

with only the Wagyu breeds. Only one allele was specific to the Mishima population. Therefore, it is suggested that many genes inherited from the past native Japanese cattle population still remain in the present Japanese beef cattle breeds.

The genetic distance estimated from the blood type, protein and DNA polymorphism shows that the Wagyu and Holstein have a close relationship. The Japanese native cattle, Mishima and Kuchinoshima reveal a relatively large distance from the Wagyu and Holstein groups. The genetic distance between the Mishima and Kuchinoshima is greater than that to the Japanese Black and Japanese Brown (Table 3).

Although many alleles shared with the pure Japanese native are still left in the Wagyu breeds, Japanese beef cattle breeds are rather close to the Holstein breed presumed from the genetic distance. While the Wagyu originated from native Japanese cattle, they differ greatly genetically from their origin because of crossbreeding with exotic breeds in the early breed development stage.

The large genetic distance between the two Japanese native populations is believed partially due to a genetic drift in different directions after introduction to both islands. This also suggests the existence of geographical differentiation in the past Japanese cattle population. Other phenotypical differences were reported in these two populations too. The coat colors of the two populations are different, as described above. The meat quality of Mishima cattle is similar to the Japanese Black, which is famous for marbled meat. The Kuchinoshima produce lean meat. The muscular marbling in the Japanese Black is deemed to have crossed with indigenous cattle in the Chugoku district where the Japanese Black developed and Mishima cattle originated.

#### **IV. Perspective on Japanese native cattle**

Four beef cattle breeds, the Japanese Black, Japanese Brown, Japanese Poll and Japanese Shorthorn were established in Japan and considered as indigenous to Japan, although they were initially extensively crossbred with foreign breeds in the early 1900's. The breeds used for crossing and the selection criteria varied significantly from prefecture to prefecture. Consequently, a number of distinct strains were established. At present,



however, the genetic diversity is decreasing due to the concentration around a limited number of Japanese Black strains noted for their superior meat quality. After the liberalization on beef importation in 1991, other breeds, with meat quality thought difficult to discriminate from foreign beef breeds, are decreasing steeply.

Japanese native cattle could therefore be categorized into three groups: (i) not at risk, Japanese Black; (ii) presently not at risk but potentially endangered, Japanese Brown and Japanese Shorthorn; (iii) at risk, Japanese Poll, Mishima and Kuchinoshima feral cattle. From the genetic conservation point of view, the systematic conservation of minor Japanese breeds and minor strains of Japanese Black is recommended using frozen semen and embryos for future genetic resource demands such as emergency measures or as supplemental measures for *in situ* and live animal conservation.

From the sustainable cattle breed viewpoint and for making full use of Japanese natural resources without environmental damage, it is necessary to develop appropriate rearing systems for these cattle breeds and the two indigenous populations. The Japanese Brown in Kumamoto and Japanese Shorthorn in the Tohoku region have superior grazing traits compared to the Japanese Black. The Japanese Brown was bred and grazed in grasslands located in mountainous-hilly areas. In 2000, direct payment systems to the mountainous-hilly areas started in accordance with the Basic Law on Food, Agriculture and Rural Areas. In Aso, this grant is used to promote animal production focusing on the maintenance and management of grasslands and the Japanese Brown cattle.

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Table 1. Foreign breeds crossed with native cattle in each Prefecture

| Name of modern breed | Prefecture | Foreign breed                               |
|----------------------|------------|---------------------------------------------|
| Japanese Black       | Kyoto      | Brown Swiss                                 |
|                      | Hyogo      | Shorthorn, Devon, Brown Swiss               |
|                      | Okayama    | Shorthorn, Devon                            |
|                      | Hiroshima  | Simmental, Brown Swiss, Shorthorn, Ayrshire |
|                      | Tottori    | Brown Swiss, Shorthorn                      |
|                      | Shimane    | Devon, Brown Swiss, Simmental, Ayrshire     |
|                      | Yamaguchi  | Devon, Ayrshire, Brown Swiss                |
|                      | Ehime      | Shorthorn                                   |
|                      | Ohita      | Brown Swiss, Simmental                      |
|                      | Kagoshima  | Brown Swiss, Devon, Holstein                |
| Japanese Brown       | Kochi      | Simmental, Korean Cattle                    |
|                      | Kumamoto   | Simmental, Korean Cattle, Devon             |
| Japanese Poll        | Yamaguchi  | Aberdeen-Angus                              |
| Japanese Shorthorn   | Aomori     | Shorthorn                                   |
|                      | Iwate      | Shorthorn                                   |
|                      | Akita      | Shorthorn, Devon, Ayrshire                  |

Table 2. Genetic variability of five Japanese native cattle breeds and populations

| Breed              | P.poly | Mean±SE           |                             |                         |
|--------------------|--------|-------------------|-----------------------------|-------------------------|
|                    |        | Number of alleles | Number of effective alleles | Observed heterozygosity |
| Kuchinoshima       | 56.5%  | 1.78±0.85         | 1.48±0.59                   | 0.242±0.248             |
| Mishima            | 52.2%  | 1.78±0.90         | 1.40±0.48                   | 0.209±0.236             |
| Japanese Black     | 87.0%  | 4.09±2.21         | 2.28±1.09                   | 0.446±0.281             |
| Japanese Shorthorn | 95.7%  | 4.13±1.74         | 2.51±1.17                   | 0.516±0.234             |
| Japanese Brown     | 95.7%  | 4.48±2.11         | 2.90±1.35                   | 0.560±0.267             |
| Holstein           | 87.0%  | 3.78±2.07         | 2.51±1.23                   | 0.521±0.260             |

Table 3. Genetic distance (DA) among Japanese native cattle breeds and populations

| Breed              | Kuchinoshima | Mishima | Japanese Black | Japanese Shrothorn | Japanese Brown | Holstein |
|--------------------|--------------|---------|----------------|--------------------|----------------|----------|
| Kuchinoshima       | *            |         |                |                    |                |          |
| Mishima            | 0.349        | *       |                |                    |                |          |
| Japanese Black     | 0.249        | 0.225   | *              |                    |                |          |
| Japanese Shorthorn | 0.382        | 0.383   | 0.196          | *                  |                |          |
| Japanese Brown     | 0.251        | 0.254   | 0.104          | 0.183              | *              |          |
| Holstein           | 0.411        | 0.323   | 0.184          | 0.181              | 0.178          | *        |

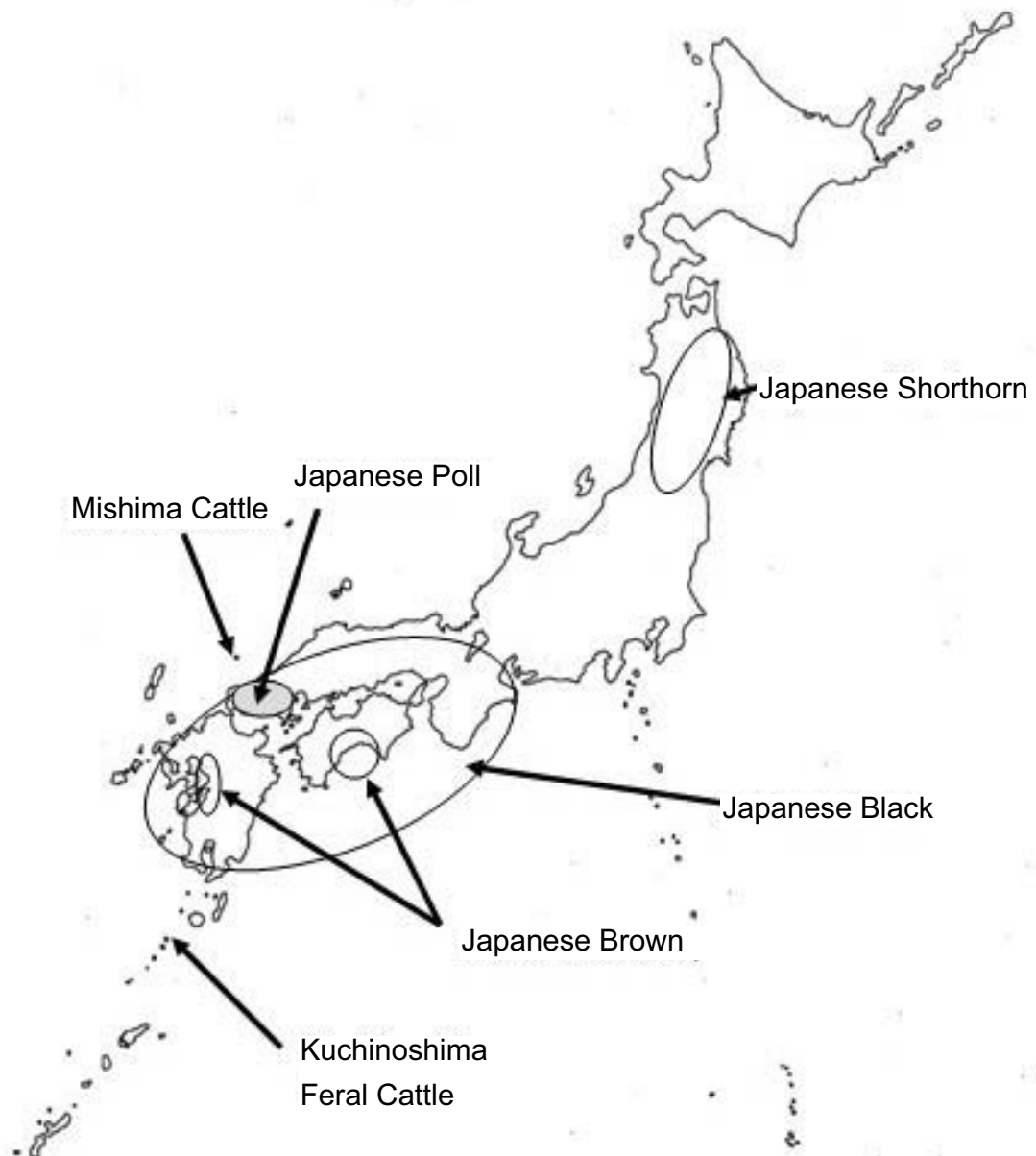


Fig. 1. Original Japanese native cattle breed and population locations





Fig. 2. Cattle in Japanese old fashion style festival



Fig. 3. Mishima Cattle (Bull)





Fig. 4. Kuchinoshima Feral Cattle



Fig. 5. Japanese Black (Bull)



Fig. 6. Japanese Brown, Kumamoto strain (Bull)



Fig. 7. Japanese Poll (Bull)





Fig. 8. Japanese Shorthorn (Cow)