Genetic diversity of horses and chickens – a review

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ABSTRACT

The diversity of farm animals is the result of the domestication of species through a long process of migration, selection, adaptation, and other natural events. This species diversity of farm animals needs to be conserved through demographic characteristics, recording of the production environment, and effective data management. In this process, the data presented based on molecular biology tracing becomes very important because of the discovery of so many breeds livestock found today, especially horses and chickens. Data based on production records or morphological characteristics becomes difficult to use in an effort to determine the species hierarchy of horses and chickens, especially in population studies that are mostly carried out in livestock studies. Through molecular studies, variations in the genetic diversity of horses and chickens will be easier to understand. The domestication of chickens is believed to be the result of several domestication events, most notably the red jungle fowl (Gallus gallus) and may also involve Gallus sonnerattii and possibly Gallus lafayettii. Horses were domesticated in broad areas of Eurasia steppe. It is thought that mares underwent the domestication process many times, but few stallions contributed to the genetic formation of domesticated horses.

Keywords: Genetic Diversity, Horses, Chickens, Domestication, Livestock genetic database

ABSTRAK


Kata kunci: Keanekaragaman genetis, Kuda, Ayam, Domestikasi, Database genetis ternak
INTRODUCTION

Domestication of animals is an important breakthrough in the development of human demography and culture. Over the course of livestock history, the evolutionary forces of processes of mutation, selective breeding, adaptation, isolation and genetic drift have created tremendous diversity of local populations, so that local species are replaced by highly productive breeds. This interesting fact about the productivity of livestock species raises concerns about the erosion of genetic resources (United Nations Food and Agriculture Organization, FAO 2007b). Existing livestock traits, however, derive from the genetic diversity of local breeds. Such conditions should be anticipated through the conservation of germplasm of local breeds. According to FAO, 20% of the approximately 7600 breeds reported worldwide, including 18 species of mammals and 16 species of birds, are at risk of extinction, and there have been 62 breeds that have become completely extinct in the first 6 years of this century (FAO 2007b).

An understanding of breed characteristics, including data on population size and structure, geographic distribution, production environment, and genetic diversity within and between breeds is essential in efforts to manage livestock genetic resources. The importance of a comprehensive and integrated understanding of all the above factors has been one of the four Strategic Priorities of the Global Plan of Action for Animal Genetic Resources adopted by 109 countries at the first International Conference on Animal Genetic Resources held in Interlaken, Switzerland in 2007, and endorsed by the FAO Conference (FAO 2007a).

It is recognized that detailed molecular data both between and within breeds are essential for effective management of livestock genetic resources. The mechanisms controlling biodiversity are not yet fully understood. However, data on the environment in which the breed is raised may provide informative data. Based on the various information previously mentioned, the discussion in this paper will begin with the demographic characterization and production environment, followed by a review of the breed description database. The main part is the section on genetic characterization in livestock focuses on the domestication process and genetic diversity of major livestock such as horses and chickens.

Technological advances in the field of molecular genetics have contributed significantly to a detailed understanding of species diversity. Blood grouping, enzyme polymorphisms, transplant antigens, and RFLP have been complemented by molecular observations such as mtDNA haplotypes, Y chromosomes, and autosomal microsatellite. For all domestic species, mtDNA data have allowed explanation of their relationship to their wild ancestral species, and for most species these data have also been informative at the intercontinental level.

DISCUSSION

Demographic Features

Assessment of the risk status of a breed requires accurate data on demographic characterization. The risk status of a breed depends on several factors, but the main one is population size and structure (FAO 1992; Gandini et al., 2004). The value of Ne is very important to determine the inbreeding that occurs in livestock populations, which in turn will be able to assess the loss of genetic diversity in the population. Local breeds is given to species that are only found in a certain area/country. Conversely, species found in more than one country is referred to as transboundary breeds or cross breed (FAO 2007b). In 2008, there were recorded in the FAO Domestic Animal Diversity Information System (DAD-IS; http://www.fao.org/dad-is/) as many as 7040 breeds categorized as local, 500 breeds as regional transboundary...
breeds, and 551 internationally transboundary breeds (FAO, 2009).

Data on the geographic distribution of breed populations are lacking and limited to a few central databases. However, efforts have been made more intensively to provide more reliable information. Key challenges for the future include developing methods for sampling animal populations, in addition to the lack of measures that cover the negative effects of crossbreeding (FAO, 2007b). Molecular characterization studies are an alternative to help reveal this kind of phenomenon.

Breed Database
Conservation and utilization of genetic resources is an important basis for basic information to create a good database. Various websites try to provide valid information.

The “Convention on Biological Diversity” adopted at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 inspired national-scale sites with complete coverage of breeds. Two examples created after the conference were the German Center of Animal Genetic Resources Documentation (TGRDEU; http://www.tgrdeugenres.de/) and the French Bureau des Ressources Genetiques (BGR; http://www.brg.prd.fr).

Meanwhile at the international level, the Breeds of Livestock website managed by the University of Oklahoma (http://www.ansi.okstate.edu/breeds/) provides data on the number of livestock breeds, including horses and poultry, with different levels of detail. Meanwhile, the EAAP (European Association for Animal Production) database which was started in the 1980s is considered to provide factual data on breeds from all over Europe. This database was later redesigned to become FABISnet, a global network consisting of databases that accommodate national and regional data (Groeneveld et al., 2006).

The FABISnet database is considered the most comprehensive dataset, covering data from 198 countries and territories for more than 14,000 populations of 37 species, including descriptions of morphology, performance, reproduction and demographic data. FABISnet is now better because it provides information on breed descriptions, conservation, and utilization.

Livestock Genetic Characteristics

Horse

More than 100 equine mtDNA haplotypes have been analyzed to focus on horse domestication process. Combined analysis of horse mtDNA revealed an unrooted structure (Jansen et al., 2002; Kavar and Dovc, 2008). Involving wild horses from 12,000 to 28,000 years ago, unexpectedly high genetic divergence between horse clades was found (Vila et al., 2001). Analysis of DNA taken from 3rd century BC horses in China (China Tombs) (Keyser-Tracqui et al., 2005) and from the Bronze Age (Lei et al., 2009) showed that mtDNA diversity was detected prior to domestication, which is thought to have occurred about 6000 years ago in the vast plains of Eurasia. DNA analysis succeeded in tracing the domestication process of horses which indicated that it was not limited to a certain area but was widespread and very complex. It was further proved by Ludwig et al. (2009) who analysed based on fossil remains that the domestication of horses from 5000 years ago onwards was followed by the spread of mutations that produced various coat colours.

Based on AMOVA analysis of 72 horse populations from Europe, Southwest Asia, East Asia and Africa, it is evident that there has been a non-random distribution of diversity between populations. In addition the data show that, although weak, there has been geographic partitioning based on variations in mtDNA (McGahern et al., 2006). The mtDNA data also indicate that the Iberian horse haplotype reproduces with high frequency (Luis et al., 2006), which is in agreement with historical evidence for the origin of the American horse. Meanwhile,
Yang et al. (2002) identified the Mongolian haplotype in the Korean Cheju breed.

Analysis of non-coding Y chromosome data by Lindgren et al. (2004) along 14.3 kb of 52 stallions from 15 different breeds failed to identify a separate group. These results at least conclude that the stallion’s genetic contribution to the domestication process is lacking.

DNA studies on horses so far still has many problems because of the sensitivity of the horse breeding business of each breeder group. However, using microsatellite data, proteins, and various markers, consistently, supports various morphological appearances of different breeds. Aberle et al. (2004) using microsatellites succeeded in obtaining three clusters between breeds (1. Riding breeds of Arabian and Hanoverian; 2. primitive breeds [Exmoor and Sorraia]; and 3. German Cold-Blooded). Furthermore, there is a distinct separation by 12 markers to cluster Thoroughbred and Anglo-Arabian breed and of of Haflinger, Italian heavy draught and Bardigiano (Bigi et al., 2007). Another study using 17 proteins and 12 microsatellite markers succeeded in classifying eight breed clusters among 33 breeds, specifically four groups formed a clear cluster, namely:

1. Andalusia with Lusitano; 2. Friesian with two ponies; 3. Morgan, standardbred, Rocky Mountain and American Saddlebred; 4. Irish Draught, Hanoverian, Holsteiner and Thoroughbred (Luis et al., 2007). The origin of the horse has also been identified by microsatellite analysis, such as that conducted by Kakoi et al. (2007) who found evidence of Mongolian ancestry in Japanese breed horses.

**Chicken**

The ancestors of today’s domesticated chickens are believed to have come from the red jungle fowl (Gallus gallus). Distribution of this chicken occurs widely in East Asia, from Pakistan through China, East India, Burma, most of Indo-China, and on the islands of Sumatra, Java and Bali (Crawford, 1990). Variations in mtDNA sequences, particularly in highly polymorphic regions, have been used to study the domestication process of chickens. From the results of DNA observations using four wild Gallus species, local chickens from Indonesia and two commercial breeds, concluded that the domestication of chickens only comes from one species, namely Gallus gallus, and a single domestication center is very likely to occur in Thailand and the surrounding areas (Fumihioto et al., 1996). Other studies using the entire mtDNA sequence and two core markers revealed that Gallus sonneratii and Gallus lafayettii may also contribute to the genetic makeup of contemporary domesticated chickens, albeit to a lesser extent (Nishibori et al., 2005). Research conducted by Eriksson et al. (2008) using sequence variations of the BCDO2 gene showed that domestic chickens and wild species are quite closely related. The use of BCDO2 (encodes beta-carotene dioxygenase 2 which has the function of breaking down feather-colouring carotenoids into colourless apocarotenoids) is necessary because the yellow skin color, a common feature of many domestic chicken breeds, does not originate from the red jungle fowl (Gallus gallus) gene, but most likely derived from the grey jungle fowl (Gallus sonneratii), a wild type of chicken related to the domestic chicken in India. Another study involving African domestic chickens revealed that there were two female offspring among the Zimbabwean, Sudanese and Malawian chickens, one from Southeast Asia, and the other possibly from India (Muchadeyi et al., 2008). The mtDNA analysis also proved that the descendants of modern Chilean chickens did not originate from Polynesia (pre-Columbian), but from Indo-Europe and Asia. The study results of ancient mtDNA haplotypes found in chickens in the pre-Columbian archaeological era support the theory of Polynesian/Pacific chicken transportation. This haplotype apparently never arrived in South America, or may have been replaced by new introductions (Gongora et al., 2008).
As one of the main sources of protein for humans, chicken is widely distributed to various countries, continents and cultures. As a result of years of adaptation and breeding, various types of broilers were found today. Various treatments of breeders and hobbyists have changed the original chicken breeds. As a result, more and more local chicken breeds are under threat of extinction (Blackburn, 2006).

Overall, the results of studies using microsatellite markers indicate that the jungle fowl population as the origin of current chickens and unselected traditional breeds is a broadly heterogeneous population, accounting for most of the total genetic diversity. In commercial chickens, broiler lines are slightly more polymorphic than layers. Meanwhile, between layers, the white layer is less polymorphic than the brown layer. In recent years, there has been concern about reduced genetic variability in commercial egg white layers derived from a single breed, the Single Comb White Leghorn.

A large-scale analysis of 2000 individuals from 65 populations representing different chicken breeds from various geographic areas was carried out by Hillel et al. (2007) used 29 microsatellite loci showing that the population was grouped according to geographic origin and cultivation history, namely Asia, Europe and Africa. Using the same dataset, Granevitze et al. (2007) showed that the degree of polymorphism varied between groups. Relatively low genetic diversity was observed in indigenous European ancestry. In contrast, indigenous populations from Africa and Asia have high genetic diversity and do not exhibit a distinctive population structure. Differentiation is only observed between populations originating from two locations and countries that are far apart. Furthermore, small-scale studies analyzing only a few Italian or Japanese fancy breeds have shown these two breeds might be and generally exhibits low genetic diversity (Tadano et al., 2007; Zanetti et al., 2007).

Research using SNP markers can identify a loss of 50% or more of the genetic diversity of commercial chickens. Only a small part of this loss can be recovered by combining all commercial poultry stocks. However, modern breeding is not the only cause of allele loss in chickens, as many alleles loss were also recorded before that.

An assessment of the level of Linkage disequilibrium (LD) which is an indicator of the consistency of a population has been carried out in nine commercial broiler breeding populations based on the analysis of genotype data for 959 and 398 SNPs on chromosomes 1 and 4, respectively (Andreescu et al., 2007). The results of this study indicate that this LD level does not exceed the limit of about 0.5 cM, which is shorter than previously reported for other livestock species. However, this value is likely to be much greater in the case of White Leghorn based breeds. If the LD value is within 1 cM, the population tends to be consistent across related populations.

CONCLUSION

Domestication of livestock, directly or indirectly, affects genetic variation in livestock. The data presented based on molecular biology tracking are very important considering the many discoveries of livestock breeds found today, especially horses and chickens.

The domestication of chickens is thought to be the result of several domestication events, most notably the red jungle fowl (Gallus gallus) in Southeast Asia and may also involve Gallus sonneratii and possibly Gallus lafayettii. Horses were domesticated in broad areas of Eurasia steppe. It is thought that mares underwent the domestication process many times, but few stallions contributed to the genetic formation of domesticated horses.

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