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Current state of knowledge on indigenous chicken genetic resources of the tropics: domestication, distribution and documentation of information on the genetic resources

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This paper covers the domestication and distribution of chickens in different parts of the world and describes the global data bases containing information on chicken genetic resources. The review shows the dispersion of chickens from the putative centres of domestication to different parts of the world, although introduction of the domesticated chicken into Africa is poorly documented. Currently, there are three globally accessible data bases containing information on chickens; however none of these provide a comprehensive system for systematically classifying domestic chickens in developing countries in terms of their present-day uses, potential for the future and distribution within and across countries. Such a system should be developed to include indigenous chicken genetic resources at the same level of detail as for other farm animals. The data management systems should incorporate all available information at the molecular level. Such information is important not only for discerning the existing diversity but also for making decisions on conservation priorities. Addressing the gaps in information on indigenous chicken genetic resources should primarily be the focus on the Domestic Animal Genetic Resources Information System (DAGRIS). DAGRIS, as a virtual library of indigenous animal genetic resources in developing countries, could play a leading role in delivering systematic information on the diversity, distribution and classification of domestic chicken in the tropics.

Keywords: domestication; distribution; chicken; genetic resources; tropics; DAGRIS

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Introduction

The world chicken population has been estimated to be about 17 billion; approximately half of which are in Asia and another quarter in Latin America and the Caribbean. Europe and the Caucasus hold a further 13% of the world's flock, followed by Africa with 7%. Chicken breeds make up a large majority of the total number of avian breeds in the world. Among avian species, chickens have by far the highest number of breeds at risk on a world scale. This is partly related to the large number of breeds in the world, but the proportion of breeds at risk is high in chickens (33%) (FAO, 2007). Chicken production in developing countries is based on traditional scavenging systems using indigenous breeds/ecotypes. The share of family poultry to total poultry population in developing countries (in general and in Africa in particular) is not well documented, but estimated to be between 70 to 80%.

Chicken farming in the tropics is undergoing dramatic changes as large-scale production expands in response to surging demand for chicken meat and eggs. A wide portfolio of breeds/ecotypes is crucial to adapting and developing the different production systems. Climate change and the emergence of new and virulent animal diseases underline the need to retain this adaptive capability of breeds. Systematic documentation of animal genetic resources and understanding their domestication and distribution history is important due to the growing concern over the conservation and sustainable utilisation of the genetic diversity worldwide. Information on the extent and use of existing diversity in indigenous farm animal genetic resources (FAnGR) is the basis for their present as well as future sustainability. Such information is generally lacking in Africa. The aim of this review is to present the domestication history and dispersal of chickens to different parts of the world and particularly to developing countries. It highlights the limited genetic base of the commercial industry, indicating the potential risks involved in the present fast replacement of indigenous stocks in developing countries by a few modern breeds. Finally, existing classification schemes and data bases were reviewed to assess their suitability and limitations in addressing indigenous chicken genetic resources.

Domestication of the chicken

The domestic chicken is believed to have been originated as the tropical jungle fowl of genus *Gallus*. The four recognized wild species of genus *Gallu*s, which may have contributed to today's domesticated fowl are the red jungle fowl *(G. gallu*s), the grey jungle fowl *(G. sonnerrati),* the Ceylon jungle fowl *(G. lafayettei)* and the green jungle fowl *(G. varius*). Whereas no subspecies were recognised for the grey, Ceylon or green jungle fowls, the red jungle fowl, *G. gallu*s, includes five subspecies: G. *g. gallus*, G. *g. spadiceus*, G. *g. bankiva,* G. *g. murghi*, and G. *g. Jabouillei (*Crawford, 1990; Horst, 1989*)*.

Whether chickens were domesticated from one or all of these species remains an open question. Taking into account the geographic range of the species (Crawford, 1990), archaeological discoveries (West and Zhou, 1988), protein polymorphisms and morphological characteristics (Moiseyeva *et al.*, 2003), it has been suggested that domestic chickens were derived predominantly from the red jungle fowl. However, questions still linger on whether only one or the five sub-species of red jungle fowl contributed to the genetics of domestic chickens. In a series of studies that analysed 400 base pairs of the mtDNA D-loop region of four species of genus Gallus (*G. gallus, G. varius, G. lafayettei and G. sonnerati*), three sub-species of *G. gallus* (*G. g. gallus, G. g.*

spadiceus and G. g. bankiva), nine domestic breeds of chicken from South Asia, South East Asia, Japan and Europe, Akishinonomiya *et al.* (1994, 1996) presented evidence which suggested that domestic chickens are derived from a single continental population of *G. g. gallus*. However in a separate study, Liu *et al.* (2006) demonstrated that besides *G. g. gallus*, several other sub-species of the red jungle fowl were also involved in the genesis of modern chickens.

Besides the red jungle fowl other wild species of jungle fowl might also have contributed to the genetics of modern chickens. A study by Nishibori *et al.* (2005) revealed genetic evidence for hybridisation of species in the genus *Gallus* which suggests multiple species origins of domestic fowls. Erikson *et al.* (2008), by examining the origins of skin colour variations in domestic chickens, revealed that although the white skin allele in modern chickens is derived from the red jungle fowl, the most likely origin of the yellow skin gene is the grey jungle fowl (*G. sonnerati*). Another debate is whether the process of chicken domestication was a single event at a specific time or took place in several geographic locations at different time periods. Crawford (1990) proposed that the domestication of chickens took place in the Indus valley around 2500 – 2100 BC. However, archaeological discoveries in 16 Neolithic sites along the Huang He (Yellow River valley) in Northeast China indicated that domestication of chickens may have taken place as early as 6000 BC (West and Zhou, 1988). Based on the fact that the conditions around the 16 Chinese Neolithic sites are not typical of the natural environment for jungle fowls, West and Zhou (1988) proposed that domestication may have taken place in Southeast Asia, and birds taken to China by humans. In their study, Akishinonomiya *et al.* (1994, 1996) gave support to Southeast Asia (Thailand and its neighbouring regions) as the cradle of domestic chickens. Liu *et al.* (2006), on the other hand, found evidence implicating multiple maternal origins of chicken centred around South and Southeast Asia. All these results indicate that our current knowledge of chicken domestication and genetic diversity remains far from complete.

Evolution of chicken domestication

The domestication of plants and animals is very important anthropologically and is often associated with the progression and development of human culture. Archaeological and historical records show that domestic chickens were first used in religion, decorative art and entertainment and much later as a source of human food (Crawford, 1990). Since their domestication, chickens have played an important role in the development of human culture in many parts of the world.

Skinner (1974) and Crawford (1984; 1990) proposed that the process of chicken domestication followed four distinct stages. The first evolutionary stage involved use of these animals for religious, cultural and traditional purposes, which resulted in active selection for morphological features, such as particular plumage colour. This is unlike the case with other animals, which were domesticated from the beginning as sources of food and/or primarily served as work animals. The second stage is characterised by the dispersal of chickens from centres of domestication to adjacent countries, and continents with different environments and cultures. These are believed to have led to gradual genetic differentiation of the chicken populations in different parts of the world. According to Clutton-Brock (1999), the current genetically diverse populations are the result of this long-term evolutionary process, which have lead to adaptations to different environmental conditions and to a wide range of human needs. In each case, the primary factors contributing to today's populations were complex and included founder effects,

migration, mutation, natural selection and selection by humans. The third stage was epitomised by the 'hen craze' of the 19th century when most of the indigenous pure breeds and varieties in Europe and the USA were developed. The fourth stage involved the period in the 20th century when the modern chicken meat and egg industry was developed (Crawford, 1990).

Worldwide pattern of dispersion of the domestic chicken

West and Zhou (1988) proposed that chickens were taken from Southeast Asia by man and became well established at Neolithic sites in Northern China and, later, in India at about 2000 BC. Japanese chickens were thought to have been introduced via similar Southeast Asian regions (Komiyama *et al.*, 2004). Many routes have been proposed to explain the distribution of domestic chickens to Europe. A review by Shahbazi *et al.* (2007) indicated that chickens were introduced to Iran from the Indus valley around 2500-2000 BC from where they spread to Europe. Another proposal is that chickens were taken from Iran to Greece and Italy across the Aegean Sea or directly to central Europe through Scythia and Southern Russia. Other possible routes include dispersion through Iran to the Mediterranean and, through China and Russia to Europe (Crawford, 1995). West and Zhou (1988) suggested that North European chickens were introduced from China through Russia, and not from the Indus Valley. Based on the fact that chickens in the Mediterranean were morphologically different from those found in Northern Europe, West and Zhou (1988) shared the opinion that Mediterranean chickens could have been introduced through Iran.

The introduction of the domesticated chicken into Africa is not well documented. Clutton-Brock (1993) summarised the archaeological findings on the domestic fowl in Africa: the earliest evidence being a sketch of a cockerel on an ostracon from the tomb of Ramses IX (1156-1148 BC). Chickens were not common in Egypt until the Ptolemaic period (332-330 BC). In West Africa they have been excavated from the Iron Age site of Jenne-jalo in Mali, dating from 500-800 AD. In East Africa they have been found in two Iron Age sites in Mozambique, and other sites in South Africa from the eighth century. Plug (1996) confirmed that they were found in early Iron Age sites, but apparently not very common. Chicken and other poultry species play significant roles in the cultural life of rural people. In Africa, the cultural, social and religious functions of indigenous chicken types are important in many areas (Sonaiya, 1999). The association of the chicken to an African culture can be so strong that, for instance, in the Congo a girl must eat a whole chicken without breaking a single bone to demonstrate to her family that she is ready to get married (Minilek Magazine, July 2001, page 21). Important features with socio-cultural significance are the colour, sex and comb type of the bird, and these are often related to the spirituality of their owners (Tadelle, 1996; Sonaiya, 1999).

As suggested by MacDonald (1992), it is likely that chickens were present in Africa well before the earliest date yet determined by archaeological findings. Williamson (2000) concluded that there is a basic conflict between archaeological findings to date and the apparently deep embedding of chicken in many African cultures as well as the linguistic and ethnographic evidence which suggest presence of chicken in Africa at much earlier dates. As was the case with other livestock species, the domesticated chicken could have been introduced into Africa through the Isthmus of Suez, the horn of Africa and through direct sea trading between Asiatic countries and coastal eastern Africa. There is no evidence for or against these theories.

Classification of domesticated chicken

The first scheme of classification of world chicken stocks was outlined by the FAO (1973) and later by Crawford (1984). The classifications were based on breeding systems, peculiar genetic attributes as well as the type of ownership and utilisation of chicken. Accordingly, chicken stocks of the world have been classified into four broad categories; industrial, middle-level, indigenous or native, and feral. This scheme lacks consistency in structure and content. Furthermore, it does not relate different stocks to any centres of domestication and distribution.

Skinner (1974; 2000) developed another scheme of classification based on the evolutionary process of domestication in certain geographical regions of the developed world. It places purebred chicken into classes, breeds, varieties and strains. This scheme pays little attention to the indigenous chicken breeds/ecotypes/strains of Africa, Asia and Latin America.

The Society for the Preservation of Poultry Antiquities (SPPA) developed another scheme of classification based on the major purpose of keeping chicken. It divided chicken stocks of the World into seven categories; Industrial, Traditional Agricultural, Historical, Games, Ornamental, Exhibition and Experimental. Details are presented in the following website of the SPPA: http://www.feathersite.com/Poultry/SPPA/SPPA.html. Again, this classification has considerable overlaps between the categories, lacks clarity and focuses only on chicken stocks of developed countries. Origin and distribution of the chicken in developing countries are not considered in this classification scheme.

Based on the strength and weaknesses of these classification schemes, there is a need to develop a scheme that addresses the indigenous chicken breeds/ecotypes/strains of Africa, Asia and Latin America.

The modern chicken industry and its impact on genetic diversity

Commercial chickens are the result of modern production practices, which comprises the egg industry; where the majority of the chickens are reared on deep litter and then housed in cages in large commercial units, and the meat industry; where broilers are raised entirely on deep litter in large sheds.

Most of the modern breeds found today in Europe and North America were developed during the late 19th century by breeding for exhibition traits using local and imported stock (Crawford, 1995). From the 1950s, some of the most productive breeds and varieties that were developed by fanciers were subjected to intensive selection for quantitative traits giving rise to the breeds currently used in the broiler and layer industry. The industry has been very quick to adopt new advances in genetics and breeding. This progress concentrated on a limited set of chicken breeds, with the results that the number of breeds, varieties and strains used in commercial egg and broiler production have declined to the very few which still dominate the industry. The intense selection for traits of commercial interest without regard to maintenance of the original genetic base meant that, in the last 50 years, this was further reduced to only few breeds currently in use in the system. For example, nearly 100% of the commercial chicken broilers in most parts of the world are descendants of White Plymouth Rock females; the sire side in this case is a synthetic breed, combining genetic material from the Cornish, New Hampshire and Barred Plymouth Rock varieties (Hawes, 1986). Similarly, the commercial egg layers are comprised either of light, medium or heavy cross breeds. The light breeds and medium sized breeds mainly

consist of the White Leghorn line crosses or crosses with other breeds to produce white and tinted-shelled eggs, while the heavier crossbreds utilise the New Hampshire and Rhode Island Red breeds to produce brown shelled eggs (Glatz *et al.*, 1996).

The loss and potential loss of genetic variability in chickens may be a cause for concern in the industry due to the disproportionate concentration of breeding materials and programs under the control of just a few large companies (Ponsuksili *et al.*, 1996). A review by Al-Nasser *et al.* (2007) reported that concerns of reduced genetic diversity are evident in highly selected commercial populations specifically categorised as meat or egg type. This could give cause for concern, especially when coupled with the increasing loss of indigenous breeds in developing countries as reservoirs of useful gene pools that could be utilised in future genetic improvement programs throughout the world.

According to an FAO report (FAO, 2000), the total proportion of avian breeds at risk of being lost in the developing world increased dramatically from 1995 to 1999: from 20 to 34% in Africa, from 32 to 37% in Asia and Pacific regions and from 5 to 45% in Latin America. Among avian species, chickens have by far the highest number of breeds denoted as 'at risk' on a world scale. This is partly related to the large number of chicken breeds in the world, but also the proportion of breeds at risk is high in chickens (33%). Forty breeds have already been lost (FAO, 2007). According to the same document, the regions with the highest proportion of their breeds classified as at risk are Europe and the Caucasus (49%), and North America (79%). These regions have the most highly intensive and specialised livestock industries, in which production is dominated by a small number of breeds. In absolute terms, Europe and the Caucasus have by far the highest number of 'at risk' breeds. Despite the apparent dominance of these two regions, problems in other regions may be obscured by the large number of breeds with unknown risk status. In Latin America and the Caribbean, for example, 81% of avian breeds are classified as being of unknown risk status, while the estimate for Africa is 60%. The indigenous stocks in these regions are being rapidly replaced by a small number of commercial breeds in the attempt to improve productivity in the traditional poultry sector. Therefore it is important to understand and document the status of chicken breeds in developing countries and design appropriate conservation strategies in order to preserve the present and future value of the attributes of locally adapted breeds. Preserving the gene pools of indigenous stocks also provides opportunities to commercial chicken industries as reservoirs of genes of special utility in their breeding programs.

Globally accessible databases on chicken genetic resources

Presently there are three public domain electronic databases on animal genetic resources delivering information on the chicken in addition to other domestic animals. The first one is Domestic Animal Diversity Information System (DAD-IS) developed and managed by FAO global databank on animal genetic resources (AnGR); the second is the database of Oklahoma State University on breeds of livestock of the World (Breeds of Livestock of the World, 2005) and the third one is Domestic Animal Genetic Resources Information System (DAGRIS) which is developed and managed by ILRI.

DAD-IS

The Domestic Animal Diversity Information System (DAD-IS) is the first globally accessible database on AnGR developed by FAO. It was initiated as a key communication and information tool for implementing the Global Strategy for the Management of Farm AnGR, mainly to assist countries and country networks in their

respective country programs (FAO, 1999). Currently DAD-IS maintains information on 5,300 breeds in 35 species from 180 countries regarding origin, population, risk status etc. This information has been used to prepare the World Watch List for Domestic Animal Diversity (WWL-DAD-3). The total number of breed records in the Global Databank has increased greatly since the publication of the WWL–DAD:3 (FAO, 2000). The total number of entries rose from 6379 in 1999 to 14017 in 2006. According to FAO (2007), the increase was particularly marked in the case of avian breed populations including chicken, whereby the number of records increased from 1049 to 3505 - which is an encouraging trend. A key feature of DAD-IS is that it provides country-secure information storage and communication tool for use by the countries with individual countries deciding when and what breed data are released through the officially delegated contact person (DAD-IS, 2005).

BREEDS OF LIVESTOCK OF THE WORLD

This database has been developed and administered by the Department of Animal Science at Oklahoma State University. This site is intended as an educational and informational resource on breeds of livestock throughout the world. As of January 2005, the database included animal breed entries for 11 species (buffalo, cattle, goat, sheep, poultry, horse, donkey, swine, camel, llama and yak) from every inhabited continent in the World. The database displays breed level information on origin, development, population size, performance, photographs, distribution and bibliographic sources of information on the breed.

DAGRIS

Domestic Animal Genetic Resources Information System (DAGRIS) is a public-domain and web-based electronic database that is designed to cater for the needs of researchers, policy makers, development practitioners, teachers, students and farmers in developing countries (Tadelle *et al.*, 2005). This virtual library has been developed and managed by the International Livestock Research Institute (ILRI) to facilitate the compilation, organisation and dissemination of information on the origin, distribution, diversity, present use and status of indigenous farm animal genetic resources from past and present research results.

DAGRIS is being expanded to include indigenous chickens of developing countries of Africa and Asia. However, because of the very limited published information on indigenous chicken in developing countries, the structure and content of information in the database is slightly different from the other two databases, as it focuses on breed level characterisation. For example, in chickens of developing countries, the words 'breed', 'strain' and 'ecotype' are often used interchangeably. From published information to date it is not possible to find any grouping of chicken breeds/strains or ecotypes into higher hierarchies, like breed group or sub-group. These groupings would have some leading information on the origin and development of the different chicken breeds/strains/ecotypes, and thus would reveal evolutionary associations between chicken ecotypes across regions and countries.

Apart from any published information, DAGRIS uses research from unpublished literature from academic and research institutions. Currently, 127 chicken breeds/ ecotypes/strains from Africa and some selected Asian countries have been entered into the database, with trait records for about 100 of these. The available information in the web site provides general breed level information (breed name/variety/ecotype, common name/synonym, origin, main location, habitat and special characteristics), image, present main use, risk status and breed level trait data. Breed level data and other information in

database are linked to the sources of information and details about each breed /ecotype/ strain can be obtained in the database.

Conclusions

The existing reports are not able to provide sufficient information for describing the origin and distribution of domestic chicken within and across continents and countries. There is very limited published information at the molecular level for indigenous chickens of the tropics compared to commercial strains. Information at this level is important not only for discerning the diversity of indigenous chickens but also for making decisions on conservation strategies and priorities. Clearly further research into the molecular characterisation of indigenous chickens is strongly recommended. At the same time the available information should be incorporated into existing database management systems.

The current database schemes do not provide a comprehensive system for systematically classifying domestic chicken from developing countries in terms of their present-day uses, potential for the future and distribution within and across countries. Such a system should be developed to treat indigenous genetic resources with the same level of detail as other farm animals. Addressing the gaps in information on indigenous chicken genetic resources should primarily be the focus of DAGRIS, which was initiated to serve as a virtual library on indigenous animal genetic resources of developing countries. DAGRIS did not yet complete gathering comprehensive lists of indigenous chicken ecotypes/breeds in the tropics. This requires concerted efforts of national, regional and international research and development institutions. However, the information made available so far can be used to show the gaps in information and serve as a tool for systematic characterisation of the indigenous chicken genetic resources of the tropics.

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