Chicken Breeding with Local Breeds in China - A Review

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ABSTRACT : This paper reviews the meat-type chicken breeding with local breeds in China. The quality chickens are defined as purebred final products of local breeds, and semi-quality chickens as crossbreds of local breeds with specialized broiler (sire or dam) lines from western breeding organizations. The present status of the chicken production and the market in China, in comparison with the western countries, is reviewed, indicating that there is large market demand for (semi-) quality chickens in the present and future China. Breeding for (semi-) quality chickens emphasizes the sensory quality of chicken meat. The present status of breeding for (semi-) quality chickens with the local breeds is illustrated, including breeding goals and the existing breeding programs. The potential role of local breeds in breeding programs in China is discussed in relation to both providing higher quality (than commercial hybrid broilers) of chicken meat for the local market and meeting the objectives of genetic resource conservation. Besides, further research topics on breeding for (semi-) quality chickens are suggested. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 10 : 1482-1498*)

Key Words : Local Breeds, Quality Chickens, Genetic Diversity, Broiler Breeding, China

INTRODUCTION

Chicken raising in China has a long history. There is a large number of local chicken breeds that developed in different circumstances of various regions of the country. In some parts of China, local consumers prefer chicken meat with high sensory quality, a driving force for the breeding for high (sensory) quality meat of broiler. Although the last decade has seen tremendous increase in chicken production in China as a result of the equivalent increase in gross national product (GNP) per capita (Watt Publishing Co., 1997), there is still large potential demand for chicken meat.

The commercial crossbred (white) broilers from breeding organizations in western countries have a worldwide dissemination. The number of independent breeding programs has been reduced sharply, and only a few breeds are used in these programs. In the way that breeding and selection took place, the modern commercial stock of laying hens has lost important genes, which led populations being unable to perform well when returned to the old floor/free range systems (Sørensen, 1997). While the modern commercial meat-type and egg-type stocks are gradually losing their ability of fitness and adaptability, the local and un-industrialized breeds will appear more and more important in future production. The formation and existence of local breeds are closely connected to the ecological, economic and social conditions of the regions. The value of these breeds and their genes is versatile: they can be used in modern breeding programs but they also have historical importance and ethnographic significance (Alderson and Bodó, 1992). For the fact that a considerable proportion of world animal genetic resources is at high risk of being lost, FAO organized the Global Strategy for the Management of Farm Animal Genetic Resources (Hammond, 1998). The large number of local chicken breeds in China provides choices for broiler breeding in future. Therefore, both conserving the local breeds and breeding with these breeds will come to be more important for future China, and for the world.

The aim of this paper is to: (1) review the present status of the chicken production and the market in China, in comparison with the western countries; (2) review the present status of broiler breeding for the local breeds; (3) discuss the potential role of local breeds in breeding programs in China.

CHICKEN PRODUCTION AND CONSUMPTION IN CHINA

1. General feature

China is a big country, not only for its population size, but also for its poultry production and consumption. The unprecedented changes that took place in China for the last twenty years have led to rapid growth in GNP and per capita income. Still, China has big potential to increase its economic status. The striking differences can be found from the comparison with developed countries. Figure 1 shows comparison for human population and GNP between China, USA and The Netherlands. Among these three countries, China has the highest average annual growth (10.8%) of gross domestic product (GDP) for 1991-1998, comparing USA with 2.6% and The

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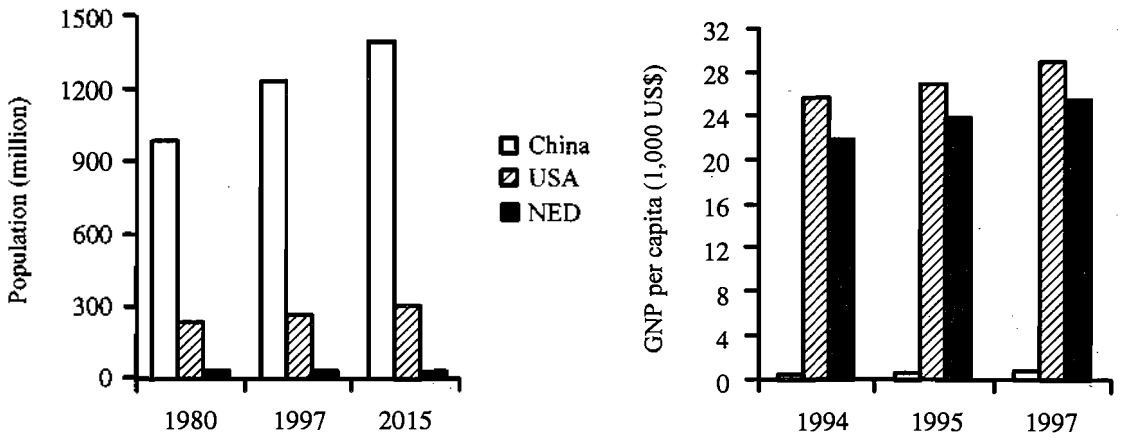

Figure 1. Human population and per capita gross national product (GNP) of China, USA and The Netherlands (NED) (World Bank, 1999)

Netherlands with 2.6% (International Monetary Fund, 1999). Increase in human population size and economic status in China will result in further increased production and consumption of poultry.

The past decades have witnessed the rapid growth of animal production in China, and animal production has become increasingly more important among sectors of agriculture than ever before. In 1949, the output value of animal production was 12% of total agricultural output value; in 1988, it was 20%; in 1993, it was 27% (Ministry of Agriculture of China, 1995).

Comparing 1970 and 1996, per capita food consumption in the U.S. changed markedly, with eggs decreasing by 23%, red meat decreasing by 15%, poultry meat increasing by 90%. In 1997, this trend continued; Americans consumed less red meat, more poultry meat and fish than before (U.S. Department of Agriculture, 1998). The same trend is seen in China. In the total meat production in China, poultry meat accounted for 8% in 1985, 11% in 1990, and 18% in 1995 (Ministry of Agriculture of China, 1996).

Total poultry egg production in China approached USA in 1986, with China in the leading position afterwards (Ministry of Agriculture of China, 1995). According to Watt Publishing Co. (1997), in 1996 the hen egg production in China was 14.00 million tons, with USA (4.51 million tons) ranking second (figure 2, Watt Publishing Co., 1997). Watt Poultry Statistics (Watt Publishing Co., 1997) showed egg consumption in 1994 was 11.31 kg/person for China, 13.36 kg/person for USA, and 14.78 kg for The Netherlands, considering the world average level is 7.06 kg in that year (figure 2). Per capita (poultry) egg consumption has increased largely in the past ten years in China, now being very close to that of the USA.

Poultry meat production was unbalanced for different regions, for example, in 1995, east China accounted for 66.7%, central China 23.2%, and west 10.1% of the total production (Ministry of Agriculture of China, 1996). However, data of per capita meat consumption for different regions within China are not available. Chicken meat is the major part of poultry meat in these three countries. However, China produces more duck meat than USA and The Netherlands, whereas USA and The Netherlands have much higher proportion for turkey meat than China (figure 3).

In poultry meat production, more chickens are slaughtered in the USA than in China (figure 4). Although poultry meat output in China was ranked second in 1996, it is catching up on the USA, that is ranked first. There is a close correlation between the growth in GNP/person and per capita poultry meat consumption. Meat has a high income elasticity, especially in developing countries, so, when income rise, meat consumption increases, replacing grain (Watt Publishing Co., 1997). According to the FAO data, poultry meat consumption per capita in 1994 was 6.7 kg for China, 43.97 kg for USA, and 16.31 for The Netherlands, considering the world average level was 8.87 kg (figure 5). More recent data showed poultry consumption per capita in China in 1998 reached close to 9.0 kg (Ma, 1999). The data of USDA showed broiler meat consumption per capita in 1996 was 3.9 kg for China, 36.4 for USA, and 15.9 for The Netherlands. Prediction showed that in the year 2010, poultry meat consumption per capita in China will reach as much as 18 to 20 kg (Ma, 1998); the expected increase is about 1.5 to 2.0 times the consumption level in 1994 (6.7 kg).

2. Quality chicken production and consumption in China

Worldwide, the white broiler is the most popular meat-type chicken; it accounts for about 70% of the

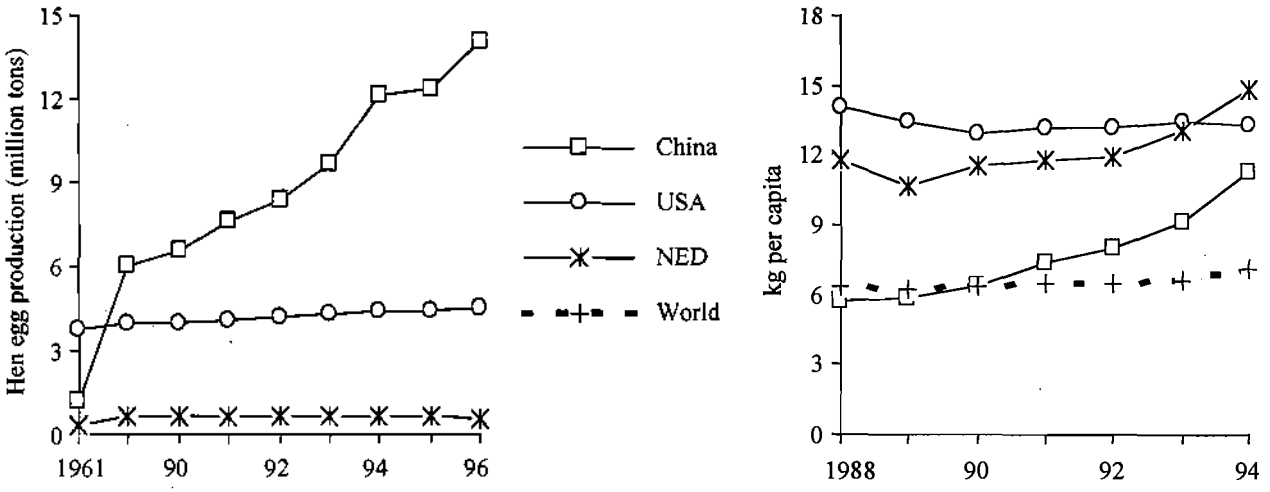

Figure 2. Hen egg production and poultry egg consumption per capita for China, USA and The Netherlands, compared with the world average level (Watt Publishing Co., 1997)

world market (Watt Publishing Co., 1996), and in developed countries it accounts for almost the whole market. However, in other regions of the world, especially in East and South Asia, considerable proportions of chicken meat come from local breeds, e.g., 70% to 75% in India (Mukherjee, 1990). In the past decade in Taiwan, market share of local breeds is about 50% for chicken meat (Taiwan Provincial Department of Agriculture and Forestry, 1996, as cited by Lee et al., 1997a and Lee, 1998). Although the production efficiency for local breeds is lower than that of white broiler chickens, the local breeds are preferred by the consumers due to pigmentation, taste, leanness, and their availability for special dishes (Horst, 1988; Lee et al., 1997a).

According to Nardone and Valfrè (1999), the concept of quality consists of hygienic, compositional, nutritional, sensory and technological aspects. For the (semi-) quality chickens in China, the term meat quality generally refers to sensory quality, i.e., color, flavor, taste, tenderness and juiciness. Meat-type chickens (broiler) in China are classified into three types according to the degree of meat quality:

Type I with the highest quality meat is called Quality chicken, which comes directly from the local breeds that have not been crossbred or industrialized. In Taiwan, it is called "Native Chicken".

Type II with the middle degree of meat quality is regarded as Semi-quality chicken, which comes from the crossbred among local breeds and the imported broiler-type chicken, based on the goal to improve the performance of local breeds. This type of crossbred chickens is also called "Simulated-Native Chicken" in Taiwan (Roan and Hu, 1997).

Type III with the lowest meat quality is the White broiler chicken from western countries, which is crossbred among specialized sire and dam lines; this type of chickens is also regarded as Fast-Big chicken in China, addressing its character of fast growth and big body size. The term not only refers to the white plumage, but also to any imported exotic commercial broiler. Therefore, imported broiler such as Redbro also belongs to this type although the plumage is red or yellow.

The concept of (semi-) quality chickens is somewhat various in different regions in China (Chen and Sun, 1997). For example, in all south provinces, local purebred hens more than one year old are regarded as specially nourishing and the three-yellow (yellow plumage, beak and skin or shanks) is regarded auspicious. Therefore, the stewed chickens are regarded nourishing for people, especially aged people. In Jiangsu, Anhui, Henan and Jiangxi provinces, yellow cockerels of 100 to 150 days old are regarded high quality. In Guangdong province, Hong Kong and Macao, high quality chickens are those pullets which at 100 to 140 days old weighing about 1.6 kg. Another definition is that the (semi-) quality chickens are the pullets with body weight of 1.4 to 1.8 kg, which are close to sexual maturity and with yellow or partridge yellow plumage. A very brief definition is that: the (semi-) quality chickens are either local purebred or its crossbred that can reach 1.2 to 1.5 kg of market body weight at the age of 60 to 90 days (Meng et al., 1999). The black-boned chickens (either silky or normal feathering) also follow this definition although their three-black character is addressed.

There is a grand culture of cuisine in China. Different regions and provinces have their own character of the cuisine. The eight national recognized cuisine styles include Guongdong cuisine, Sichuan cuisine, Beijing cuisine and others. Only in Guangdong cuisine, more than 200 different chicken dishes are listed in the standard menu (Chen, 1997). Each cuisine

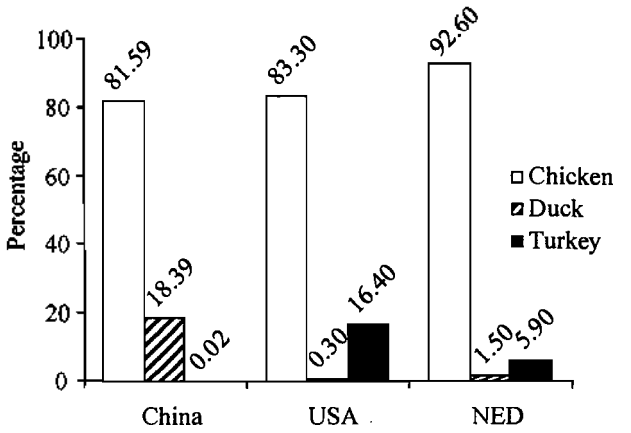

Figure 3. Proportions of chicken, duck and turkey meat to total poultry meat in 1996 for China, USA and The Netherlands (NED) (Watt Publishing Co., 1997)

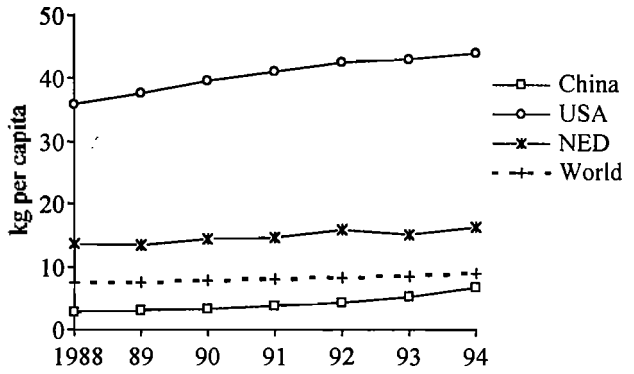

Figure 5. Poultry meat consumption for China, USA and The Netherlands (NED), compared with the world average level (Watt Publishing Co., 1997)

style or even dish has dedicated demand for the meat quality of chickens (e.g., Chen, 1997). For some of (semi-) quality chickens, more detailed classifications of the quality grade are made according to the market demand. For example, concerning the Shiqi chickens in Guangdong province, the detailed classifications are based on the demand of well-recognized dishes (Chen, 1997). Surely, cuisine culture in China is one of the important factors to maintain the chicken breed diversity and to gear the direction of breeding of quality chickens.

Starting in the 1920s, foreign (standard) breeds were gradually imported to China. In the 1950s crossbreeding with these standard imported breeds was carried out aiming to improve the performance of local breeds. By the end of 1970s, specialized laying stocks and broiler stocks from western countries found their way to China. Due to the commercial white broiler chickens and the attached husbandry technology, the meat-type chicken production in China has been changed from backyard to industrialized production, and during the 1980s white broiler production increased tremendously. The increase in chicken meat production in the 1980s was basically due to white broiler production in China. After 1990, the speed of increase in importing white broiler lines slowed down, e.g., in 1993 China imported 269,000 chickens of broiler grandparent stock, which was 11.4% less than the previous year (Li, 1994). This slowing down of the increase in importing white broiler lines is because of, among other reasons, more demand for quality of meat chickens due to the increase in living standard of the Chinese consumers. This tendency is more apparent in south provinces of China, e.g., Guangdong province, than north ones (Mu et al., 1998). This is well illustrated by the market prices. According to Chen and Sun (1997), in the region southeast China, the market prices per kilogram live broiler in 1996, were 16 to 24 Yuan Yuan: Chinese currency. 1.00 Yuan = 0.12 $US, approx. for quality chickens (purebred local breeds), 12 to 16 Yuan for semi-quality chickens (crossbred with local breeds), and 7 to 9 Yuan for white broiler. Concluding, in the past decades the importance of the local breeds in China showed a wave-like pattern: starting as the only source for meat production, then dominated by imported white broiler lines, and then gradually receiving more attention again.

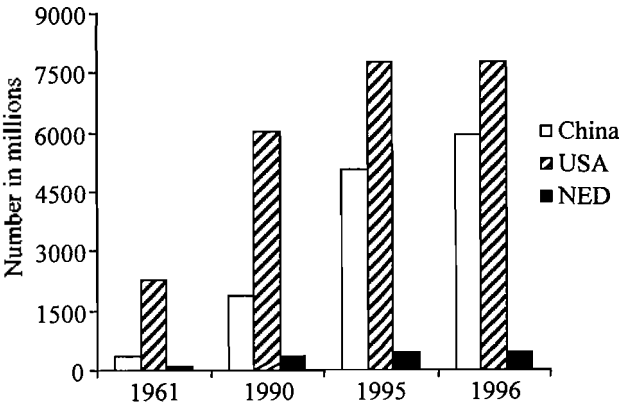

Figure 4. Yearly number of chickens slaughtered for China, USA and The Netherlands (NED) (Watt Publishing Co., 1997).

The importance of appearances of (semi-) quality chickens is well shown in markets in China. Chickens are sold as either live birds or carcass ("whole bird" base) with a few feathers left; further-processed chickens are rarely practiced for (semi-) quality chickens (personal communication with managers of three-yellow chicken breeding farms in Guangdong province). Although crossbred, the semi-quality chicken

also possesses the appearances of quality chickens, and it is therefore difficult to distinguish between the quality chickens and the semi-quality chickens in the market.

The data sources in China (e.g., Ministry of Agriculture of China, 1995; Ministry of Agriculture of China, 1996; State Statistical Bureau of China, 1997) did not distinguish the production and the consumption for different types of broiler at national level. Ministry of Agriculture of China (1995, cited by Ministry of Agriculture, Nature Management and Fisheries of The Netherlands, 1996; Xu, 1999) estimated that in total poultry meat production in China, white broiler accounts for 45.0%, eliminated hens finishing egg production for 22.8%, water fowl for 26.7%, and three-yellow chicken for 5.5%. It is obvious that production with local breeds was not completely accounted for. Li (1994) estimated that in 1993 there were 269,000 birds as imported grandparent stock and 110,000 birds as locally produced grandparent stock for broiler production. Based on this figure, we still can not calculate the production proportions, because it is most likely that the backyard production with the local breeds were not accounted for, as the term "grandparent stock" is not used for this backyard chickens. However, data for production at some regional levels are available.

Yan (1998) estimated that there is a large market in China for (semi-) quality chicken. In 1994, the yearly marketed number of (semi-) quality chickens from chicken farms was about 1,000 millions, and during 1995 and 1997, it was 1,200 millions. Note that these figures excluded the backyard production. According to Mu et al. (1998), in Guangdong province, the broiler breed distribution for three-yellow:white broiler:other type is 82:15:3. Among three-yellow, the distribution for large size yellow:middle size yellow:small size yellow is 30:50:20. There are 840.5 million birds of broiler produced in 1996 in Guangdong. In recent years, the production of three-yellow chickens in Guangdong province increased by 14% annually; in 1998, the number of three-yellow chickens in production was 690 million birds (Chen and Chen, 1999). According to the projection to year 2000 by Wu et al. (1998), production of black-boned chickens is 30 million birds, of three-yellow chickens is 50 million birds, and of Chongren Partridge (a local chicken breed) 50 million birds in Jiangxi province. Also, in provinces in south, east, southeast and southwest China, the administration departments have recognized the importance of production with local breeds as a way to provide higher quality meat, comparing to white broiler. Because of the shrink in market for white broiler, even in the largest white broiler production province, Shandong, three-yellow chicken production has recently started (Wang and Xu, 1999). The market demand for (semi-) quality chickens is also growing in Taiwan (Lee et al., 1997a; Roan and Hu, 1997) and Hong Kong and Macao (Mu et al., 1998). To promote the knowledge in breeding, nutrition, management and marketing of (semi-) quality chickens, a regular symposium on (semi-) quality chickens started from 1989, cooperated by Chinese mainland, Taiwan and Hong Kong (Chen and Huang, 1999). Therefore, production of (semi-) quality chicken is of great importance at present and promising in future China.

QUALITATIVE TRAITS AND THEIR INHERITANCE

Qualitative traits are economically important for most local chicken breeds in China. Consumers' tendency for acceptance or refusal of products from the local breeds, is largely dependent on its appearances. There at least are two aspects. First, consumers have direct preference for some specific characters that are qualitative traits. Second, consumers believe that there is close relationship between the appearance and the inner quality of the products, e.g., three-yellow vs quality meat, black-skin (black-boned chickens) vs both medical and quality meat, and tinted egg shell vs eggs from local breeds, and so on. As a reason for this, whenever developing breeding strategies, the qualitative traits with specific characters must be considered soundly. Understanding the heredity of qualitative traits is a prerequisite for breeding for quality chickens.

1. Black-boned character

In China, so called black-boned chickens represent the chickens with black (or dark) skin, meat and membrane on bone (sometimes also called three-black). This is equivalent to the melanism or fibromelanosis as often referred to in scientific literature. According to Stolle (1968, reviewed by Smith, 1990), fibromelanosis is due to sex-linked id^+ together with a dominant enhancer gene *Fm*; combinations of these genes resulted in different degrees of darkness of connective tissue pigmentation:

Genotype			Phenotype
Enhancer gene	Sex-linked gene		
	Female	Male	
Fm/-	*id*+/W	id^+/ id^+	Darkly pigmented
Fm/-	*Id*/W	*Id*/-	Faintly pigmented
fm^+/ fm^+	id^+/W	id^+/ id^+	Unpigmented
fm^+/ fm^+	*Id*/W	*Id*/-	Unpigmented

As indicated by Smith (1990), considerable variation in the degree of fibromelanotic pigmentation

suggests that a number of other factors can modify the expression of the trait. Some of these factors may also be related to plumage color although fibro-melanotic Silkie chickens exist with white, black, blue and partridge patterns.

The three-black trait was first observed in Silkies (White and Eastick, 1953). In China, black-boned character appears in two types of chickens: Silky-like feathering chickens (e.g., Taihe Silkies) and normal feathering chickens. According to the observation of three-black trait in a black-boned population with normal feather, Du et al. (1996) concluded that the three-black trait is heritable in the normal feathering population. On the basis of the observations of black skin in a black feather Silkies population, Huang et al. (1993) indicated that the inheritance of black skin followed the genetic pattern by Stolle (1968, reviewed by Smith 1990). However, Huang et al. (1993) did not experimentally prove this. Based on segregation analysis, Chen et al. (1998) found that the skin fibromelanosis was due to polygenic effects, and the estimated heritability was 0.41, implying that it is effective to select for the trait directly. In fact, in establishing the black-boned chicken population, direct selection has been done by institutions in China, although they did not reveal the inheritance of three-black trait in advance.

2. Three-yellow character

Few reports are found from local research on the inheritance of yellow (buff) plumage for specific local breeds in China.

Although the number of genes for buff color is unknown, it is known that the buff birds carry allele *s*, for gold color on a sex-linked locus, and the Buff Orpingtons have the same type of restricted black gene (*e*) as Rhode Island Red and Columbians (Hutt, 1949). Therefore, the genotype for buff males is *e/e s/s*, and for buff females *e/e s/W*. However, these same alleles are found in Rhode Island Red. The genes that make buffs different in color from Rhode Island Reds have yet to be discovered. The black commonly found in the neck, wings, and tail of buff birds supports the contention that most of them are genetically black fowls with the *ee* type of restriction. As explained by Smith (1990), although both melanins and carotenoid pigments contribute to the feather color of certain avian species, the melanins determines the plumage color and patterns of the domestic fowls. Brumbaugh and Hollander (1966) indicated that buff plumage was not a single mutant, but that it is determined by four or five loci. The genotypes for buff plumage are:

The yellow coloration of the skin, shanks, beak, body fat, and egg yolk, is dependent on the carotenoid pigment. Yellow skin color is a breed characteristic of many standard breeds (Smith, 1990). The genetic basis for shank and foot color is complex, depending on the cumulative and interactive effects of several major genes, plus unidentified modifiers. The genotypes for different shank and foot colorings are as fellows (according to the review by Smith, 1990):

Genotype	Phenotype
e^b/e^b *Co/Co* db^+/db^+ mh^+/mh^+	Buff or Light Brahma
e^y *or* $e^{bc}/?$ *Co/Co* db^+/db^+ *Mh/Mh Di/Di*	Buff Minorca

Genotype	Phenotype
w/w Id/Id e^+/e^+	Yellow shanks and feet
w/w id^+/id^+ e^+/e^+	Green shanks with yellow soles
W^{+}/W^{+} id^+/id^+ e^+/e^+	Blue shank with white soles
w/w id^+/id^+ *E/E*	Black shanks with yellow soles
W^+/W^+ id^+/id^+ *E/E*	Black shanks with white soles
W^+/W^+ *Id/Id* e^+/e^+	White shanks and feet
W^+/W^+ *Id/Id E/E*	Near-black with white soles
w/w Id/Id E/E	Near-black with yellow soles

Apart from yellow shanks, character of blue shanks is also regarded as a symbol of local breeds in some markets in China (Chen, 1998).

3. Blue eggshell

There are two countries in the world that have chickens laying blue shelled eggs: China and Chile. The blue eggshell is rarely seen in chickens, and was first reported in the native south American breed known as Araucana (Punnett, 1933). In 1983, it was also found in the local chicken breed Black Jiuyuan, in east Sichuan, China. It was claimed that in the Black Jiuyuan chicken population, 5% of the hens give eggs with blue shell. In Shaanxi province (neighbouring province of Sichuan), a local breed named Lushi chickens was also claimed to have about 3% hens laying blue shelled eggs. In Jiangxi province, a small sized breed named Changxi also lays blue shelled eggs (Huang et al., 1999). Both areas (Chile and China) are far remote from each other geographically. Concerning the origin of Araucana, Stromberg (1996) wrote "The Secretary of the Araucanas Club in England wrote that there is a claim that tribes from Peking migrated to South America bringing the Araucanas. This might be a possibility since some chickens did originate in China. However, I know of no chicken in China with the genes to lay colored eggs". It is remarkably controversy that seven pages after this statement in the same book, it reads "(Chinese) Black Jiuyuan chickens are known for laying blue shelled eggs".

Inheritance of blue shell is due to the presence of

an autosomal dominant gene (*O*), which was first shown by Punnett (1933) with Araucana chickens. For the trait of blue shell in Jiuyuan chicken, Jiang and Luo (1991) and Jiang et al. (1991) revealed the same inheritance. According to Jiang and Luo (1991), the *O* gene on the multigenetic background for white shell color (crossbred between Jiuyuan and White Leghorn) resulted in a blue shell color, the same as the original blue shelled eggs from Jiuyuan chickens, while the *O* gene on the multigenetic background for brown shell color (crossbred between Jiuyuan and Rhode Island Red) resulted in a lighter blue shell color, similar to the olive drab color as described by Punnett (1933). According to the review by Bitgood and Somes (1990), the locus of blue shell was mapped in Group III, on the short arm of chromosome 1, linked to pea comb locus (*P*); the linear order was centromere - *P* - *O*. The linkage distance between *P* and *O* was 4 map units.

The value of blue shelled eggs is that they are regarded as "health eggs" in the native area of Jiuyuan county. People there believe there is a link between blue eggshell and the nutritive and healthy values of the eggs, but they do not know the physiological background. In Shaanxi province, blue shelled eggs from Lushi chickens are also called "Medicine eggs" by the local people (Sheng et al., 1999). It is interesting that the same claim existed for Aruacanas, which was stated by Hickman (1974; cited by Somes et al., 1977), among others, that the eggs were found "no cholesterol, 20% more protein, and 20% more iron". To verify the alleged attributes of Araucana eggs, several studies in North America were carried out. In comparisons between Araucana eggs with eggs of white or brown shell, Cunningham (1977) reported that there was no difference in the kind or amount of yolk or albumen protein, or percent solids, but 4.0% higher cholesterol content than white shelled eggs (from Leghorn) while brown shelled eggs (from Plymouth Rock) were intermediate. Somes et al. (1977) found blue shelled Araucana eggs to be lower in protein but higher in cholesterol contents than either white or brown eggs. Sadjadi et al. (1983) found no difference in the yolk cholesterol of blue and white eggs. Simmons and Somes (1985) indicated significantly more total cholesterol (27%), yolk cholesterol (7%), yolk protein (11%), zinc (10%), iron (3%) and total egg protein (5%) in eggs from Araucanas than eggs from White Leghorns. These studies did not determine the contents of amino acids of the eggs. All these studies, at least, revealed the fact that the cholesterol content of blue shelled Araucana eggs is not lower than white or brown eggs.

Luo et al. (1990) determined the composition of blue shelled eggs from Chinese Black Jiuyuan chicken, with regard to both chemical composition and contents of amino acids. Comparisons were made among blue shelled eggs from Jiuyuan chicken, both blue shelled and white shelled eggs from crossbred of White Leghorn × Black Jiuyuan, and brown shelled eggs from Rhode Island Red. Chickens for the experiment were hatched together in the same incubator, and then were reared in the same house with same diet. Determination was carried out at the 40 weeks of age. The results indicated that protein content was the highest for blue shelled egg of Jiuyuan (13.2%), lowest for brown egg of RIR (12.3%), and blue egg of White Leghorn Black Jiuyuan was in the intermediate (12.9%). Blue eggs also contented more ash (1.0%) than the brown eggs (0.9%). However, these differences were not statistically significant. The same is true for the comparisons of the contents of 17 amino acids; although there were some differences among eggs with different shell colors, striking characters were not found.

The studies in both North America and China did not prove the eggs with blue shell to be "health eggs". Nevertheless, in some markets blue eggs are welcomed with high price, e.g., in North America (Stromberg, 1996). The same is true in the native area of Black Jiuyuan chicken in China. Even in The Netherlands, the Araucana blue shelled eggs can be seen in supermarkets with price 2.5 times as much as brown or white shelled eggs.

Another alleged attribute of blue Araucana eggs was "shells harder to break" (Somes et al., 1977). Cunningham (1977) found Araucana eggs had slightly but nonsignificantly thicker shell than white or brown eggs. Using Araucana chickens, Sadjadi et al. (1983) indicated there was no difference between white and blue eggs for shell strength as measured by Instron measures and Marius deformation. This study was based on the same genetic background, that is, the difference between genotypes within a crossbred originates only from the *O/o* alleles.

For Jiuyuan chickens, while compared based on different genetic backgrounds, Chen and Wang (1986) and Yang and Jiang (1989) found significantly higher breaking strength and shell thickness in blue eggs from Jiuyuan than brown eggs from Rhode Island Red. To reveal whether or not the *O* gene had the pleiotropic effect on eggshell quality, Jiang et al. (1992) made the comparisons based on the same genetic background. The results are summarized in table 1. The results suggested the *O* allele had effects on shell quality, resulting in significantly higher breaking strength. As shell strength is an important character for chicken industry, it should be noted that the *O* gene in Jiuyuan chickens may contribute to laying chicken breeding (Jiang, 1992).

GENETIC PARAMETERS FOR PERFORMANCE TRAITS

When searching through the literature, it appears that there are only a few reports on the estimation of genetic parameters for local Chinese chicken breeds. Lou et al. (1991) estimated heritabilities (male and female separately) and genetic correlations of traits (both production and reproduction) for Wuding chickens. For each of the seven generations in a selected dam line for meat-type chickens, genetic parameters were estimated, and in total eight traits for male and 13 traits for female were included. Heritabilities ranged from 0.25 to 0.44, and from 0.28 to 0.43 for male body weight at 60 and 90 days of age, respectively; from 0.30 to 0.62 and from 0.31 to 0.65 for female body weight at 60 and 90 days of age, respectively. Heritability was 0.10 to 0.25 for egg production and 0.20 to 0.53 for egg size at 300 days of age. Genetic correlations of egg size at 300 days of age with days at first egg (0.13) and egg size at 500 days of age (0.31) were positive. Negative genetic correlations were found between days at first egg and egg production at 300 or 500 days of age (between -0.15 and -0.50), and between egg size at 300 or 500 days of age and egg production at 300 or 500 days of age (ranging from -0.01 to -0.46). Li et al. (1998) estimated heritabilities and genetic correlations of eight traits of laying performance for Yugan black-boned chickens, again based on sire variance. Heritability for egg number was 0.38 for either 300 days or 500 days of age. Heritability for egg size was again relatively high, ranging from 0.34 to 0.76 with different ages. With a new line Jinshui silkie chickens (selected for four generations, based on Taihe Silkies), Pi et al. (1999) estimated heritabilities and genetic correlation among three traits for laying performance. Comparing estimated heritabilities with those by Li et al. (1998), lower heritabilities for egg number at 40 weeks of age (0.13), egg size at 40 weeks of age (0.58), and age of first egg (0.41) were found in Jinshui relative to Yugan. Pi et al. (1999) concluded that one of the reasons might be that although both breeds are characterized by black-boned, their origination and appearances are different, e.g., Yugan with normal feathering vs Jinshui with silky feathering. It is worth notifying that results from the abovementioned reports on genetic parameters were within the range of the parameters as reviewed by Chambers (1990) and Fairfull and Gowe (1990).

Table 1. Averages of breaking strength and shell thickness of crossbreds with Black Jiuyuan chickens and two commercial lines (L = White Leghorn; RRI = Rhode Island Red)*

Crossbred	Genotype	Shell color	Breaking strength (kg/cm^2)	Shell thickness (micron)
RRI × Jiuyuan	*Oo*	blue	4.83	358.1
	oo	brown	4.35	331.4
L × (LJiuyuan)	*Oo*	blue	3.96	327.9
	oo	white	3.55	346.0

* Source: Jiang et al. (1992).

BREEDING FOR BROILER WITH THE LOCAL BREEDS

Nowadays, the commercial broiler and layer stocks have a worldwide dissemination. The commercial chicken breeding programs are under operation by just a few large organizations. For example, only the two largest breeding groups account 75% laying breeders market share in the world (Flock, 1998). For this reason, there is a significant probability of losing genetic variability in commercial chickens (Siegel et al., 1992). Although in China there is a considerable number of local chicken breeds, protecting the local breeds is of great importance today because of the vast use of commercial crossbred lines in industry and also the change of husbandry system (e.g., from backyard to housing). The direct use of the imported crossbred lines in industry of China, and the fact of not paying enough attention to the conservation of genetic resources while practicing crossbreeding between local breeds and commercial crossbred lines, has made some of the local breeds endangered or shrunk the size of population (Li, 1998; Shen, 1996) and has been destroying the diversity of chicken genetic resources in China. However, according to FAO (FAO, 1998), utilization is the most efficient form of genetic conservation. Therefore, the goal of breeding with local breeds is twofold: economically using genetic resources and efficiently conserving these resources. The common shortcoming of the local breed is lower performance for production and reproduction traits. Therefore, to make more use of local breeds, it is very important to improve their performance, and meanwhile maintaining their superiority in meat quality. To meet these two demands in the same time is not an easy job, as there probably is genetic conflict between these two aspects. However, for the past two decades, much work has been done in China.

In breeding for (semi-) quality chickens it can be seen from the above description that breeding goal has to be set differently from those of white broiler. Although there is no systematic definition of breeding goals for (semi-) quality chickens, clues can be found in papers by Chen (1997), Chen and Sun (1997), Mu et al. (1998), Li (1998), Wu (1998) and Meng et al. (1999), among others. Accordingly, the general goal of breeding for (semi-) quality chickens is to get the

chickens weighing around 1.5 kg at the age of 70 to 80 days with accepted "color and flavor". More detailed description includes the following aspects:

Plumage color: In China, generally speaking, white color is regarded as un-auspicious, and almost all local chicken breeds are with colored plumage. Yellow plumage is a symbol of local breed in most regions. In breeding for (semi-) quality chickens, yellow plumage (with a few black feathers on neck and wings) and yellow partridge plumage are the favorite pattern for most regions of China. However, in some regions, black plumage is also favored by consumers. One exception is the Taihe Silkies with white silky plumage, but more other types of black-boned chickens are with black plumage.

Sexual maturity: Chickens near to sexual maturity are with reddish faces and complete plumage, and this appearance is favored by consumers in Guangdong and Hong Kong, and other regions. Most chemical constitutions of animal muscle other than moisture increase with age (Lawrie, 1985). At sexual maturity there is considerable amount of vitamins, amino acids, minerals and (intramuscular) fat in bird body, therefore, meat from chickens close to sexual maturity is especially nourishing and nutritive, and has good taste and flavor (Chen and Sun, 1997). Selection for earlier sexual maturity would favor production efficiency and also marketing values of the chickens.

Conformation and carcass appearance: The (semi-) quality chickens are middle body size, shaped rectangle, plumy breast but less fat than white broiler. Yellow and fine skin is favorable in market. Fat under skin is not thick, and fat in yellow color will markedly increase the appearance quality of the carcass.

Reproductive performance: It is a marked shortcoming that local breeds have low reproductive performance. Selection for reproduction traits is relevant.

Body weight at given age: For (semi-) quality chickens, growth and body weight are intermediate optimum, due to that the market does not accept large sized chickens and also growth rate is negatively correlated with meat taste and flavor (Lee et al., 1997b; Chen and Sun, 1997).

Meat Quality: Sensory quality (meat color, flavor, taste, tenderness, and juiciness etc.) is stressed by the Chinese market. Systematic method for the evaluation of sensory quality is available in China (e.g., Chen, 1993; Yu and He, 1993).

Production efficiency: For (semi-) quality chickens production, the improvement in production efficiency could not be obtained by the usual way applied in white broiler, i.e., the increased growth rate and feed efficiency. Presently, the practiced way is selection for earlier sexual maturity. This is being practiced in the Chinese Mainland (Chen and Sun, 1997) and Taiwan (Lee et al., 1997b; Lee, 1998). To decrease the cost price of day-old chicks, the imported recessive white Rock, especially the dwarf line, is used as dam line for cross (e.g., Li and Li, 1995; Wei et al., 1995; Liu et al., 1997). The dwarf line is also developed in local breed population (e.g., Liu et al., 1998).

It is worthy to note that the breeding goals are different in regions within China, and choices are always made according to market demand.

The breeding for (semi-) quality chickens for commercial perspective started 20 years ago, as a goal to meet the market demand in south part of China. Up to now, there are more than 20 commercially developed stocks of (semi-) quality chickens, and more are under development, due to the booming market demand for it (Chen and Sun, 1997; Meng et al., 1999). At first the breeding and production of (semi-) quality chickens originated from Guangdong province, for providing the Hong Kong and Macao markets. Chickens named Shiqi were the first three-yellow quality chicken exported to Hong Kong and Macao. As Shiqi chickens played an important role in the development of (semi-) quality chicken breeding, the history of Shiqi chickens is regarded a well reflection of the history of (semi-) quality chicken breeding in China. Shiqi chickens originate from Xiaonan town of Shiqi city in Guangdong province, south China. The first name of Shiqi chickens is the ancient Jiaozi chickens that could date back to about 2,000 years ago. According to Chen and Huang (1999), in the process of formation of Shiqi chickens, the red jungle fowl was used in the breeding. Besides, the formation of Shiqi was largely dependent on the rich natural resources, advanced agriculture, and especially, the cuisine in its native area. As the cuisine disseminated through the Guangdong province, and then to Hong Kong and Macao, more demand for Shiqi chickens was a driving force for the improvement of the breed to a higher meat quality. In the 1960s, for improving the productive performance, breeders in Hong Kong used western broiler, including Redbro and Tegel, to cross the Shiqi chickens, and in this way, a new line was named Shiqi-Za (Za means hybrid). In the 1980s, Kabir broiler from Israel was also used to cross Shiqi-Za. These Shiqi-Za chickens were imported back to Guangdong in 1980's (Mu et al, 1998; Zhao, 1993). However, the crossbreeding made Shiqi-Za chickens grow faster, but with less taste and flavor. As a reason of this, original Shiqi chickens from Xiaonan town were again recognized (Chen and Huang, 1999), and a new line of Shiqi chickens was developed (Chen, 1993, 1995). Shiqi has been used to develop commercial brand labeled semi-quality chickens for commercial production (Zhao, 1993).

The usual way of breeding and production for

(semi-) quality chickens in China is as follows:

(1) Pureline selection and production. Selection is carried out within local breed and the purebred is directly used for producing final products. Breeding for black-boned chickens follows this way (e.g., Liu et al., 1995; Zhang et al., 1997), and so does breeding for some three-yellow chickens (e.g., Qingyuan Partridge chickens, Chen and Chen, 1999). This system can also follow the broiler production system as described by Groen et al. (1998), but the stage of multiplier may be un-necessary and the purebred final products are produced at commercial grower stage. The advantage of this breeding and production structure is that the final products directly come from purebred local breed; the products belong to quality chickens, thus with high market price. The disadvantage is that this system is with relatively low production efficiency due to low performance in growth and reproduction traits. Therefore, the existence of this system must rely on the high market prices when adopted by intensive commercial producers. In the backyard raising condition with low-input and low-output, this breeding structure is quite adequate. More recently, a modification of this system is being carried out. Selection for specialized sire and dam lines within breed is being practiced, e.g., using Taihe Silkies. The main goal is to improve the reproduction performance in the dam lines and to increase the uniformity of the final products by crossing sire and dam lines, apart from maintaining the meat quality.

(2) Crossbreeding between local breeds. This way is in favor of meat quality and livability, but the growth rate is not improved significantly (Wu, 1998). Considering that heterosis is in favor of the traits with low heritabilities, such as reproduction and livability traits, this system is quite practical for improving reproduction and maintaining meat quality, as there is variety of local breeds in China. It is suggested here that, e.g., for two-way cross, selection for specialized sire and dam lines should be carried out within local breeds. Sire lines could come from meat-type local breed with stress on its growth performance, and dam lines from egg-type or general-purpose-type local breed with stress on its reproduction performance. The striking advantage of this breeding and production system is that either sire or dam line is purebred local breed with quality meat, therefore the final product is quality chickens. In addition, when three-way or four-way cross is adopted, heterosis for reproduction performance could be utilized. In choosing the breeds for the crossbreeding system, the result of genetic distance between breeds is useful, particularly while aiming at using heterosis. The third advantage of this system is that the final product (commercial grower) uniformity is improved by crossbreeding which is welcomed by intensive commercial producers. The authors feel that this system would be very promising in quality chicken production in China, as long as growth rate is improved adequately to meet the requirements of intensive production but not at the expense of meat quality. Besides, the commercial chicks can also be used in backyard condition.

(3) Breeding of synthetic strain using a local breed with one or more imported white broiler, but the local breed contributed most part of the genes to the line. For example, a synthetic strain named New Shiqi chickens is composed of 1/8 genes from recessive White Rock chickens (Chen, 1993, 1995). The synthetic strain is used either for direct production of final products or as a sire line to take part in crossbreeding. The new shiqi chickens were developed by using Shiqi chickens and a imported broiler line (Kabir). Grading mating was applied (figure 6). The grading resulted in the second back-cross generation (BC_2) carried 7/8 of the inheritance of Shiqi chickens and 1/8 of Kabir chickens. The new line was improved in growth rate, feed conversion and reproductive traits, but maintained the three-yellow character and meat quality of the original Shiqi chickens (Chen, 1995). It is obvious that the goal of breeding of a synthetic strain is to improve the production and reproduction performance, and in the same time to maintain the meat quality. While the detected Quantitative Trait Loci (QTLs) for the required characters are available, use of marker-assisted introgression of QTLs will be more efficient (see Hospital and Charcosset, 1997).

(4) Single cross between a local breed and an imported broiler, and the resulting F1 is directly used to produce the final products. This way is practiced in Jiangsu province, Shanghai and other regions, either for meat production (Chen and Sun, 1997; Liu et al., 1999) or for egg production (Zhang et al., 1995a, b). In general, to produce the final products with three-yellow character, the imported line used in this crossbreeding is with red or yellow plumage, e.g.,

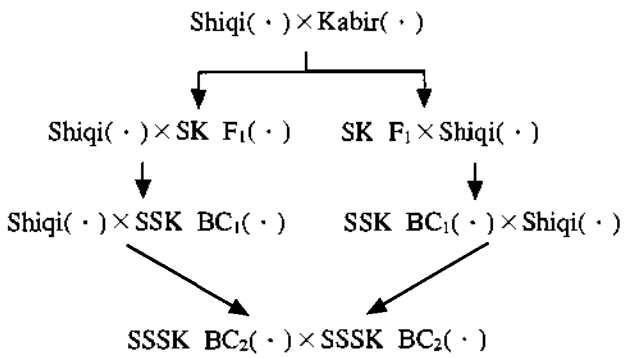

Figure 6. The development of a synthetic line, example of New Shiqi (source: Chen, 1995)

Redbro. The imported broiler line can be used as either sire line or dam line. The F1 chickens weigh about 1.5 kg at the age of 70 days (Chen and Sun, 1997). This crossbreeding is particularly used for backyard production of semi- quality chickens.

(5) Crossbreeding by using local breeds and imported lines with recessive white plumage genes. The final products are crossbreds of local breed and an imported white broiler with recessive white plumage genes (Chen and Sun, 1997). There are different ways to produce semi-quality chickens different in growth rate (so-called "high quality type" and "middle growth rate type"). For producing the "high quality type" chickens, the male parent is purebred local breed, and female parent is a cross between local breed (male) and the recessive white plumage chickens (female). The growers reach 1.6 to 1.9 kg at the age of 90 to 120 days, close to sexual maturity. For producing the middle growth rate type chickens, the male parent is either a synthetic strain like Shiqi-Za chickens, or a cross between local breed and an imported broiler line, and the female parent comes from a cross between local breed (male) and the recessive white plumage chickens (female). The growers reach 1.5 to 1.6 kg at the age of 70 days. Chen (1998) described three-way crossbreeding to produce the three-yellow chickens with blue shanks, in which a local breed (e.g., Gushi chickens), a synthetic strain (e.g., Shiqi-Za), and the recessive white plumage chickens. Breeding for (semi-) quality chickens in the form of *PeiTaoXi* (a complete set of specialized lines for cross in form of either two-, three- or four-ways) is also practiced by, e.g., Fu and Hua (1995, 1997), Liu et al. (1997), Lou et al. (1991) ,Tong (1997), Wang et al. (1997), Yang et al. (1995), and Zhao et al. (1997). This form of crossbreeding is used mainly for intensive commercial production, where the production efficiency is stressed, apart from meat quality. The breeding and production structure is quite similar to that as described by Groen et al. (1998). Selection for dam lines emphasizes on the reproduction traits. To maximize genetic response on reproduction traits, it is suggested that the method of combined crossbred and purebred selection (see Jiang and Groen, 1999) could be applied when performance records from crossbred are available.

Some broiler breeding companies outside China, for example, Kabir Chicks Ltd. from Israel, have a well understanding for the market diversity in the world (see Katz, 1995). Aiming at the market in China (particularly in south China), Kabir proposed a basic breeding and production structure for three-way and four-way crosses, in which the dam line is fixed but with alternating the other two or three lines different types of final products are obtained. For example, with a specialized dam line D (named K2700, recessive white plumage, genotype *i/i k/k s/s e/e* for male and *i/i k/- s/- e/e* for female), five different forms of three-way crosses are proposed by using Chinese local breeds as sire lines, to produce the three-yellow chickens as final products, and in this way grandparent stocks of line D are sold to the local breeding farms in China (personal communication with Katz). The advantage is more choices left for clients (e.g., multiplier). This is different from the crossbreeding structure, where the lines for the crosses are supposed fixed because they have been decided based on the combining ability tests, and the advantage is, of course, the production efficiency is optimized (or maximized).

In animal breeding, meat quality is a complex traits, referring to the compositional, visual and sensory traits of a carcass, or its retail cuts (Thompson, 1998). Up to now, eating quality is stressed by consumers, which refers to the sensory attributes of cooked product, i.e., tenderness, flavor, juiciness and color. As the consumers have always played a major role in the definition of the given meat quality (Nardone and Valfrè, 1999), it is reasonable to put the sensory quality as one of the goals in breeding for quality chickens.

There are many factors related to the meat quality (e.g., by the point of view in biochemical aspects). Dikeman (1994) concluded the reasons for the difficulties in improving meat quality. Progress in improving meat quality through genetic selection has been greatly hindered by the fact that the most meat quality traits cannot be evaluated, or at least not evaluated accurately, in breeding animals. This is especially true for traits that relate to consumer acceptance (meat color, fat color) and eating quality (tenderness, flavor, juiciness). Progeny testing has been the only accurate method in selecting for these traits, but it is slow, expensive and often impractical. Sensory evaluation for meat palatability rarely is used in any breeding program, primarily because it is too expensive and time consuming. Secondly, the relative economic importance of meat quality is less than that of growth rate, and especially less than that of reproduction. Thirdly, there is genetic antagonism between some meat quality traits and carcass composition. For example, there is genetic antagonism between meat quality and growth rate in selection for quality chickens (Lee et al., 1997b). However, to include meat quality traits in selection programs, estimates of the genetic variance are required, and some of them (e.g., eating quality and fatty acid composition) are under study or already available (Thompson, 1998). As stated by Thompson (1998), molecular techniques in the form of candidate genes and QTLs can be used to improve the rate of genetic progress in meat quality traits. Although the nature of

meat quality of local chickens is not known now in China, there is a practical way to consider that character in the breeding program, that is, the choice of breeding materials (Zhang and Yang, 1998). The success of breeding for quality chickens is to large extent judged by the market, especially breeding for the *PeiTaoXi* by breeding companies. However, sounder breeding programs need to be made based on a systematic method, especially the definition of breeding goals (see Jiang et al., 1998, 1999).

In the process of breeding for (semi-) quality chickens, genes for qualitative traits were also applied either to develop auto sexing lines (e.g., feathering speed: Xiong et al., 1995; Zhang et al., 1998) or to improve the productive efficiency of dam lines (e.g., dwarf gene: Huang et al., 1998b; Jiang and Wang, 1993; Li and Li, 1995; Li et al., 1991; Liu et al., 1997; Liu et al., 1998; Wei et al., 1995; Zhou et al., 1997). Disease resistance is also getting attention (e.g., Li et al., 1993).

DISCUSSION AND CONCLUSION

Many breeds and commercial crossbred lines (34 in chicken, 10 in duck, and two in goose) have been imported in China from North America and Europe (Li, 1994). The vast increase in poultry meat production in China in the past two decades is largely due to this importation of western broiler crossbred stocks (white broiler) in conjunction with improved nutrition and management technologies. Production of white broiler has made considerable contribution for providing the protein food for human population of China. As stated by Mercier (1997, cited by Nardone and Valfrè, 1999), when countries became able to cover their needs for quantity, the next step was to obtain products of high quality to satisfy the consumers who ask for "safe and tasty" products. Besides, the culture and cuisine style defined the specific character of the products. For these two reasons, presently meat quality is the most important factor in the breeding goal for local breeds in China. Chicken meat quality is defined by several aspects, such as sensory, hygienic, compositional, nutritional and technological quality (Nardone and Valfrè, 1999). The term meat quality has a different definition among countries and among producers, processors, retailers and consumers (Dikeman, 1994). The needs of consumers for meat quality is dependent on the culture background (for example, three-yellow character is equal to (semi-) quality chickens), traditionally nutritional and medical beliefs (e.g., the black-boned chickens), and cuisine style. Also in western countries, the social request for animal welfare corresponds to the diffuse feeling that animals reared under "natural" conditions give "better" products. Although this is not always true, this feeling must be considered as a positive factor, as it is helpful for both the economic and market development (Nardone and Valfrè, 1999). As genetic improvements in (white) broilers has led to improved weight gain, but at the same time to a reduction in meat quality. Therefore, the un-industrialized local breeds in China can make considerable contributions to meet the demands on meet quality.

Politiek (1962, cited by Groen, 1989) defined the general goal of animal breeding is: obtaining a new generation of animals that will produce the desired products more efficiently under future farm economic and social circumstances than the present generation of animals. Based on this definition of breeding goal, two items are emphasized: "desired product" and "efficiency". As there is large market demand for quality chickens in both present and future China, breeding for chickens with quality meat is of great importance. Concerning the breeding goals for sustainable production system for the local chicken breeds in China, firstly a definition of sustainable production is desired. Following Olesen et al. (1999), considering animal breeding in view of its impact on genetic diversity, environment and society is a prerequisite for being able to find and carry out significant actions towards animal breeding for sustainable production systems. Amer et al. (1998) defined breeding goals for sustainable production systems. They defined production systems in developing countries as subsistence production systems or commercial production systems. For the subsistence production systems, attention should be given to maintaining and enhancing adaptive characteristics of local breeds while at the same time improving productivity. For intensive commercial production, the breeding goals should stress the increase in production and the improvement of the animals' capacity for efficient use of feed. For extensive commercial production systems, the goal should be to improve survival and productivity in the relevant environment. For the local chicken breeds in China, there are also two production systems (subsistence and commercial). In the countryside of China, almost every family tends to keep chickens either for family needs or for both family needs and commercial. A common way is that the family keeps the pullets for laying eggs and markets the cockerels. Although this production system is less efficient, it provides a way to conserve the genetic resources of chicken breeds and to provide the market with high quality chickens (based on its purebred and natural rearing conditions). Better marketing conditions for backyard chickens (e.g., in Sichuan province) is a driving force for the small holders to produce local purebred chickens more commercially than before.

According to Hammond (1998), about 30% of the world animal genetic resources at the breed level are at high risk of loss. He argued that the general approach to genetic development of domestic animals resulted in a very small number of breeds for producing a single product under high input production conditions. This situation is especially true in poultry sector in the world (See Sørensen, 1997; Delany and Pisenti, 1998; Flock, 1998) and in China (Shen, 1996; Li, 1998). Since the beginning of this century, China has been engaged in an intense effort to assimilate modern western science. In making such an effort, many things were perhaps adopted without sufficient critical reflection (Chai, 1993). The fast dissemination of the western broilers in China for the past two decades is one of the examples, with the annual number of marketed white broilers increasing from almost zero to more than 3,000 millions (Huang, 1997). The positive effect of this importation has been reflected in the fast increase in poultry meat production, and has been well appraised in the national press (e.g., Huang, 1997; Ma, 1998). However, negative effects are also attached. First, if this dissemination continues, what will happen in the future? Domestic animal diversity will be destroyed further. The existence of a local breed is dependent upon its adaptation to the local environment, and its economic values for the local (and outside) market. Second, is the present approach of the use of local chicken breeds in south China an adequate way to meet both demand of consumers market and genetic resources conservation? In conserving the genetic resources, both *in situ* and *ex situ* conservation is suggested. The breeding programs in the local breeding companies perform the way of *ex situ* conservation, but the backyard production is a way of *in situ* conservation. To facilitate this role of *in situ* conservation, it is necessary to maintain and possibly improve the existing backyard production systems.

Definition of quality chicken should be in terms of a series of criteria on hygienic, compositional, nutritional, sensory and technological aspects. Strong scientific findings on the physiological and biochemical basis are needed for breeding of quality chickens. Nutrition requirements of (semi-) quality chickens are different from that of white broilers. Although there is research on the nutrition requirement of local breeds, standard nutrition requirement is still not available (Xu, 1997). Therefore, more research is asked for this field, as it is related to the quality of the chickens. Husbandry systems for the production of (semi-) quality chickens should be addressed. Huang et al. (1998a) observed that husbandry systems are also in relation to the darkness of color in three-yellow chickens, and they suggested that the complete housing system has made a lighter color of the three-yellow chickens. The cohesiveness and elasticity of meat are very important to the Chinese cuisine. The market classifies chickens based not only on their genetic background but also on their rearing environment, i.e. production systems, marketing age, and feeds and feeding. More research should be carried out to look for genotype by environment interaction on the character of three-yellow. Besides, it is possible to use the breeds with blue eggshell in form of backyard production to produce the so-called natural table eggs, and to use the gene O in commercial intensive production system to improve the eggshell quality.

It is very important for the (semi-) quality chicken breeding organizations in China that any improvement in production efficiency should not be at expense of product quality. Otherwise, the breeding for quality chickens would be back to the same way of breeding for white broiler as practiced in western countries, and all the significance of quality chicken breeding and production would then disappear. Based on the above description and discussion, the authors strongly feel that it is necessary to combine the two aspects together, that is, quality from local breeds in China and production efficiency from western countries. The genetic resources belong to and can contribute to mankind all over the world. The worldwide research on the reproduction characteristics of Chinese Meishan pigs is a good example that poultry scientific institutions and breeding organizations may follow. It is suggested that a cooperation between western and Chinese chicken breeding companies in the use of Chinese local chicken breeds should aim at economic and sustainable use of the local chicken breeds. If this is successful, it seems that China will be able to maintain the diversity in breeds for quite a long time.

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REFERENCES

Alderson, L. and I. Bodó. 1992. Genetic conservation of domestic livestock. Vol. 2. C.A.B International, Wallingford, UK.

Amer, P. R., N. Mpofu and O. Bondoc. 1998. Definition of breeding objectives for sustainable production systems. In: Proceedings of the Sixth World Congress on Genetics Applied to Livestock Production. Armidale, NSW, Australia. Vol 28. pp. 97-104.

Bitgood, J. J. and R. G. Somes, Jr. 1990. Linkage relationships and gene mapping. In: Poultry Breeding and Genetics (Ed. R. D. Crawford). Elsevier, Amsterdam, The Netherlands. pp. 469-495.

Brumbaugh, J. A. and W. F. Hollander. 1966. Genetics of buff and related color patterns in the fowl. Poult. Sci. 45:451-457.

Chai, C. K. 1993. Developing the native pig breeds of China. Pig News and Information. 14(1): 27N-30N.

Chambers, J. R. 1990. Genetics of growth and meat production in chickens. In: Poultry Breeding and Genetics (Ed. R. D. Crawford). Elsevier, Amsterdam, The Netherlands. pp. 599-643.

Chen, J. and B. Wang. 1986. Comparison of eggshell quality between blue eggs from Black Jiuyuan and brown eggs from Rhode Island Red chickens. J. Sichuan Animal Sciences and Veterinary, Issue No. 3 (in Chinese).

Chen, K. 1998. Breeding for meat-type chickens with blue shanks. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 9-11 (in Chinese).

Chen, K. and Y. Sun. 1997. The present and the future of (semi-) quality chickens in China. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 142-145 (in Chinese).

Chen, Q. 1993. A new line of Shiqi three-yellow chickens. In: Proceedings of the Sixth Conference of Chinese Poultry Science Association. Beihai, China. pp. 214-216 (in Chinese).

Chen, Q. 1995. The development of a new line of Shiqi chickens and its crosses. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 134-136 (in Chinese).

Chen, Q. 1997. The judgment, management and marketing of Shiqi three-yellow chickens. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 146-148 (in Chinese).

Chen, Q. and D. Huang. 1999. The history of Shiqi chickens. China Poultry. 21(1):22-24 (in Chinese).

Chen, T. and P. Chen. 1999. Qingyuan Partridge chicken entered markets of Guangzhou. Guangzhou Daily, 28 July, Guangzhou, China (in Chinese).

Chen, Z., L. L. G. Janss, Y. He, S. Li and Y. Li. 1998. Segregation analysis of black skin pigmentation in Silkies. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 49-51 (in Chinese).

Cunningham, F. E. 1977. Composition of Araucana eggs. Poult. Sci. 56:463-467.

Delany, M. E. and J. M. Pisenti. 1998. Conservation of poultry genetic research resources: consideration of the past, present and future. Poultry and Avian Biology Review. 9(1):25-42.

Dikeman, M. E. 1994. Genetics of meat quality. In: Proceedings of the Fifth World Congress on Genetics Applied to Livestock Production. Guelph, Ontario, Canada. Vol 19. pp. 437-449.

Du, X., Q. Zhu and Z. Yang. 1996. Heredity of plumage and skin colors of Sichuan Mountain black-boned chickens. J. Sichuan Agricultural University. 14(1):32-35 (in Chinese).

FAO. 1998. Primary guidelines for development of national farm animal genetic resources management plans:domestic animal diversity information system. FAO, Rome, Italy.

Fairfull, R. W. and R. S. Gowe. 1990. Genetics of egg production in chickens. In Poultry Breeding and Genetics (Ed. R. D. Crawford). Elsevier, Amsterdam, The Netherlands. pp. 705-759.

Flock, D. 1998. Genetic improvement of laying performance. Guide to Chinese Poultry. 15(3):11-12 (Chinese version translated by Y. Zhang).

Fu, Z. and S. Hua. 1995. Reproductive performance of hens of Qianhuang three-yellow chickens. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 162-163 (in Chinese).

Fu, Z. and S. Hua. 1997. A further report on productive performance of Qianhuang three-yellow chickens. In Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 157-159 (in Chinese).

Groen, A. F. 1989. Cattle Breeding Goals and Production Circumstances. Ph.D. Thesis, Department of Animal Breeding, Wageningen Agricultural University, Wageningen, The Netherlands.

Groen, A. F., X. Jiang, D. A. Emmerson and A. Vereijken. 1998. A deterministic model for the evaluation of broiler production systems. Poult. Sci. 77:925-933.

Hammond, K. 1998. Development of the global strategy for the management of farm animal genetic resources. In Proceedings of the Sixth World Congress on Genetics Applied to Livestock Production. Armidale, NSW, Australia. Vol 28. pp. 43-50.

Horst, P. 1988. Native fowls as reservoir for genomes and major genes with direct and indirect effects on productive adaptability. In: Proceedings of 18th World's Poultry Congress. Nagoya, Japan. pp. 99-104.

Hospital, F. and A. Charcosset. 1997. Marker-assisted introgression of quantitative trait loci. Genetics, 147:1469-1485.

Huang, S. 1997. The past, present and future of poultry industry in China. Poultry Industry Science and Technology 13(10):4-8 (in Chinese).

Huang, F., H. Wu, X. Zhou and S. Lin. 1999. A breed with blue eggshell: Changxi chickens. China Poultry. 21(4):45-46 (in Chinese).

Huang, F., X. Zhang and Q. Zhou. 1993. Inheritance of feathering and skin color in a Silkie chicken population of black plumage. In: Proceedings of the Sixth Conference of Chinese Poultry Science Association. Beihai, China. pp. 134-135 (in Chinese).

Huang, D., J. Xu, G. Ying and J. Zhou. 1998a. Thinkings about breeding and production of three-yellow chickens. China Poultry. 20(9):27-28 (in Chinese).

Huang, Q., J. Li, Z. Zhou, Q. Tai, Z. Gu and H. Ji. 1998b. Breeding of dwarf line for three-yellow chickens. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 77-82 (in Chinese).

Hutt, F. B. 1949. Genetics of the fowl. McGraw-Hill Book Company, Inc., New York, USA.

International Monetary Fund, 1999. World economic outlook. Issue: May. Washington, DC, USA.

Jiang, Y. and H. Wang. 1993. The dwarf gene (dw) applied in crossbreeding with Taihe Silkies. In: Proceedings of the Sixth Conference of Chinese Poultry Science Association, Beihai, China. pp. 180-183 (in Chinese).

Jiang, X. 1992. Studies on the blue eggshell in chickens, a review. China Livestock and Wildlife Magazine (Taiwan).

24(10):23-26 (in Chinese).

Jiang, X., H. Du and C. Yang. 1991. Genetic study on blue eggshell in Jiuyuan chickens. In: Proceedings of the Fifth Conference of Chinese Poultry Science Association, Chengdu, China. pp. 23-24 (in Chinese).

Jiang, X., H. Du and C. Yang. 1992. Effect of blue eggshell allele with different paternal origin on egg shell quality of crossbred chickens. In Proceedings of the 19th Worlds Poultry Congress. Amsterdam, The Netherlands. Vol 3. p. 121.

Jiang, X. and A. F. Groen. 1999. Combined crossbred and purebred selection for reproduction traits in a broiler dam line. J. Anim. Breed. Genet. 116:111-125.

Jiang, X., A. F. Groen and E. W. Brascamp. 1998. Economic values in broiler breeding. Poult. Sci. 77:934-943.

Jiang, X., A. F. Groen and E. W. Brascamp. 1999. Discounted expressions of traits in broiler breeding programs. Poult. Sci. 78:307-316.

Jiang, X. and C. Luo. 1991. Inheritance of blue eggshell in Jiuyuan chickens. China Poultry. 11(2):35-36 (in Chinese).

Katz, Z. 1995. Breeders have to take nature into account. World Poultry. Vol. 11, No. 4.

Lawrie, R. A., 1985. Meat science. Pergamon Press. Oxford, U.K.

Lee, Y. -P. 1998. Preservation and utilization of poultry genetic resources in Taiwan. In: Proceedings of the 6th Asian Pacific Poultry Congress, Nagoya, Japan. pp. 36-41.

Lee, Y. -P., P. -L. Chiang and H.-H. Huang. 1997a. A study on the optimal marketing age of Taiwan country chicken. J. Chin. Soc. Anim. Sci. 26(3): 285-296 (in Chinese).

Lee, Y. -P., L. -T. Yeh and H. -H. Huang. 1997b. A study on the production system of Taiwan Country chicken: growth traits of three-strain cross country chickens. J. Chin. Soc. Anim. Sci. 26(3):271-284 (in Chinese).

Li, D. 1998. On crossbreeding with local chicken breeds of China. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 16-19 (in Chinese).

Li, D. and X. Li. 1995. Breeding of a dwarf line of Rock chickens. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 187-190 (in Chinese).

Li, D., L. Luu, M. Huang and X. Li. 1991. Selection for ecological adaptation in a broiler dwarf line. In: Proceedings of the Fifth Conference of Chinese Poultry Science Association. Chengdu, China. pp. 113-115 (in Chinese).

Li, F., J. Xie and D. Jiang. 1998. Estimation of genetic parameters of traits for Yugan black- boned chickens. China Poultry. 20(3):4-6 (in Chinese).

Li, K., P. Wei, M. Liang, Z. Zeng, Q. Fan, S. He and C. Li. 1993. Breeding for Mareks disease resistance in Xiayan chickens. In Proceedings of the Sixth Conference of Chinese Poultry Science Association. Beihai, China. pp. 202-207 (in Chinese).

Li, W. 1994. Breeding stock in China. Poultry International. 33(12):30-34.

Liu, H., H. Zhao, Z. Chen, K. Chen, H. Lin and D. Zhang. 1997. Breeding of a dwarf line for Kangdaer three-yellow chickens. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 154-156 (in Chinese).

Liu, J., X. Du, F. Wang, F. Shao and Z. Chen. 1995. The inheritance of some traits of Chishui black-boned chickens with black plumage. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association, Hangzhou, China. pp. 172-173 (in Chinese).

Liu, J., F. Shao, X. Du, Z. Chen and Q. Tian. 1998. Breeding for dwarf Chishui black-boned chickens with black plumage. China Poultry. 20(1):8-9 (in Chinese).

Liu, Y., Z. Yang and Q. Zhu. 1999. The performance of cross between Sichuan Mountain black-boned chickens and a broiler line. China Poultry. 21(4):13-15.

Lou, Y., P. Xie, M. Yu, J. Huang and L. Song. 1991. Breeding of a dam line in Wuding Chickens. In: Proceedings of the Fifth Conference of Chinese Poultry Science Association. Chengdu, China. pp. 33-41 (in Chinese).

Luo, C., X. Jiang, C. Yang, J. Chen and B. Wang. 1990. Egg production and chemical compositions of eggs in Jiuyuan chickens. J. Sichuan Animal Sciences and Veterinary. Issue No. 3 (in Chinese).

Ma, C. 1998. Prediction for poultry meat production and consumption in China in year 2010. Guide to Chinese poultry. Vol. 15, No. 1 (in Chinese).

Ma, M., 1999. The dilemma and rethinking for poultry industry in China. Guide to Chinese Poultry. Vol 16, No. 16 (in Chinese).

Meng, Q., K. Xiang and X. Wu. 1999. The poultry genetic resources and the poultry breeding in China. China Poultry. 21(3):12-15 (in Chinese).

Ministry of Agriculture of China, 1995. Agriculture yearbook of China. Agricultural Publishing House of China, Beijing, China (in Chinese).

Ministry of Agriculture of China. 1996. Report for the development of agriculture in China. Agricultural Publishing House of China, Beijing, China (in Chinese).

Ministry of Agriculture, Nature Management and Fisheries of The Netherlands (1996), De Chinese pluimveesector. Den Haag, The Netherlands.

Mu, D., S. Huang and Z. Xiao. 1998. Studies on the strategy for development of poultry industry in Guangdong province. Project report, <http://www.poultryinfo.com.cn/gdzlyj/>, Guangdong, China (in Chinese).

Mukherjee, T. K. 1990. Breeding and selection programs in developing countries. In: Poultry Breeding and Genetics (Ed. R. D. Crawford). Elsevier, Amsterdam, The Netherlands. pp. 1049-1060

Nei, M. and A. K. Roychoudhury. 1974. Sampling variances of heterozygosity and genetic distance. Genetics. 76:379-390.

Nardone, A. and F. Vafrè. 1999. Effects of changing production methods on quality of meat, milk and eggs. Livest. Prod. Sci. 59:165-182.

Olesen, I., A. F. Groen and B. Gjerde. 2000. Definition of animal breeding goals for sustainable production systems. J. Anim. Sci. 78:570-582.

Pi, J., J. Du, J. Sheng, Z. Fu and Z. Liang. 1999. Genetic analysis on egg production traits of Jinshui Silky fowl.

China Poultry. 21(2):6-7 (in Chinese).

Punnett, R. C. 1933. Genetic studies in poultry, IX. The blue egg. J. Genetics. 27:465-470.

Roan, S. -W. and C. -L. Hu. 1997. Growth performance and carcass characteristics of Taiwan simulated native chickens. J. Chin. Soc. Anim. Sci. 26(2):163-176.

Sadjadi, M., J. A. Renden, F. H. Benoff and J. A. Harper. 1983. Effects of the blue shell allele (O) on egg quality and other economic traits in the chicken. Poult. Sci. 62:1717-1720.

Shen, C. 1996. Diversity of animal genetic resources and sustainable development of animal production in China. Animal Genetic Resources Information. Vol. 20:3-8. FAO, Rome, Italy.

Sheng, X., H. Han and X. Chen. 1999. Lushi chickens. China Poultry. 21(3):47 (in Chinese).

Siegel, P. B., A. Haberfeld, T. K. Mukherjee, L. C. Stallard, H. L. Marhs, N. B. Anthony and E. A. Dunnington. 1992. Jungle fowldomestic fowl relationships: a use of DNA fingerprinting. Worlds Poult. Sci. J. 48:147-155.

Simmons, R. W. III and R. G. Somes, Jr. 1985. Chemical characteristics of Araucana chicken eggs. Poult. Sci. 64:1264-1268.

Smith, J. R., Jr. 1990. Genetics of plumage, skin and eye pigmentation in chickens. In: Poultry Breeding and Genetics (Ed. R. D. Crawford). Elsevier, Amsterdam, The Netherlands. pp. 109-167.

Somes, R. G., Jr., P. V. Francis and J. T. Tlustohowicz. 1977. Protein and cholesterol contents of Araucana chicken eggs. Poult. Sci. 56:1636-1640.

Sørensen, P. 1997. The population of laying hens loses important genes: a case history. Animal Genetic Resources Information. FAO, Rome, Italy. Vol. 22:71-78.

State Statistical Bureau of China. 1997. China statistical yearbook. China Statistical Publishing House, Beijing, China.

Stromberg, S. 1996. Poultry of the World. Silvio Mattacchione & Co., Ontario, Canada.

Thompson, J. M. 1998. Meat quality. Vol. 25, In Proceedings of the Sixth World Congress on Genetics Applied to Livestock Production. Armidale, NSW, Australia. pp. 147-148

Tong, H., K. Wang and K. Chen. 1997. The use of Xianju and Buff Baier chickens in breeding for high quality three-yellow meat-type chickens. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 170-173 (in Chinese).

U.S. Department of Agriculture. 1998. Agriculture fact book. Washington, USA.

Wang, B. and D. Xu. 1999. Chicken production in future China. China Poultry. 21(1):1-2 (in Chinese).

Wang, K., H. Tong, S. Li and K. Chen. 1997. The use of egg-type line in the crossbred of three-yellow chickens. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China, pp. 165-169 (in Chinese).

Watt Publishing Co. 1996. Watt poultry statistics yearbook 1996. Poultry International, Mt Morris, IL, USA.

Watt Publishing Co., 1997. Watt poultry statistics yearbook 1997. Poultry International, Mt Morris, IL, USA.

Wei, F., X. Huang, D. Li, Y. Liao, Z. Yang and M. Liu. 1995. Selection of a dwarf line from Rock chickens. In Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China, pp. 137-140 (in Chinese).

White, R. F. and H. L. Eastlick. 1953. The development of melanophores in the down feathers and skin of the Silkie fowl. Poult. Sci. 32:235-247.

Wu, C. 1998. On heterosis in crossbreeding for quality chickens. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 1-4 (in Chinese).

Xiong, Y., B. Wen, C. Yang and K. Bao. 1995. The production performance of a new line of auto-sexing by feathering speed from Lingnan three-yellow chickens. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 123-125 (in Chinese).

Xu, A. 1997. Studies on the nutrition requirements of native chickens. Poultry Industry Science and Technology. 13(7):11-13 (in Chinese).

Yan, H. 1998. The present and future of quality chicken industry in China. China Poultry. 20(8):3-5 (in Chinese).

Yang, C. and X. Jiang. 1989. The measurement of blue eggshell quality in Juiyuang chickens. China Poultry. 9(2):16-17 (in Chinese).

Yang, C., B. Wen, K. Guo, D. Su and G. Hu. 1995. The growth performance of different crosses with Lingnan three-yellow chickens. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 118-120 (in Chinese).

Yu, W. and Y. He. 1993. A method to quantify the meat quality of three-yellow chickens. In: Proceedings of the Sixth Conference of Chinese Poultry Science Association. Beihai, China. pp. 97-101 (in Chinese).

Zhang, T., Y. Tang, Y. Zhou, S. Wu and H. Guan. 1991. Characteristics of Chahua chickens. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 121-123 (in Chinese).

Zhang, T., Y. Tang, Y. Zhou and Q. Feng. 1995a. The performance of crosses with Wuding Chickens. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 166-168 (in Chinese).

Zhang, X., F. Huang and Y. Su. 1995b. Crosses using Xianju and Gushi chickens with imported lines. In: Proceedings of the Seventh Conference of Chinese Poultry Science Association. Hangzhou, China. pp. 176-178 (in Chinese).

Zhang, X., F. Huang, Y. Su and D. Zhao. 1998. The genetic pattern of feathering speed in some local chicken breeds in China. In: Proceedings of the Fifth Conference on Improvement and Production for Quality Chicken in China (Ed. Y. Feng and G. Wang). Wuyishan, Fujian, China. pp. 45-48 (in Chinese).

Zhang, X., F. Huang, Y. Su, K. Chen and S. Li. 1997. The productive performance of black-boned chickens with black plumage. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 187-190 (in Chinese).

Zhang, D. and S. Yang. 1998. On meat quality in breeding for quality chickens in China. China Poultry. 20(9):1-2

(in Chinese).
Zhao, H. 1993. The present and the perspective of Shiqi-Za chickens in Guangdong province. In: Proceedings of the Sixth Conference of Chinese Poultry Science Association. Beihai, China. pp. 87-89 (in Chinese).
Zhao, H., H. Zeng, X. Ou and Q. Chen. 1997. Breeding for Kangdaer three-yellow chickens. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 149-151 (in Chinese).
Zhou, Z., D. Su, K. Guo, C. Yang and Y. Xiong. 1997. Measurement of shank length of three-yellow chickens. In: Proceedings of the Eighth Conference of Chinese Poultry Science Association. Suzhou, China. pp. 123-125 (in Chinese).