CHANGE OF POPULATION STRUCTURE OF A COMPLETELY CLOSED SUB–POPULATION IN JAPANESE BLACK CATTLE

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SUMMARY

Change of population structure of a completely closed sub–population in Japanese Black Cattle was surveyed using population genetic parameters. Diversity of sires decreased and variance of progeny number per sire increased dramatically during 1960 to 1988. The average coefficient of inbreeding increased in 3 % or more by each decade. Effective population size was only 8 in 1988, that value is about one over thirty three in 1960. From these results, it is concluded that intensive use of a few sires due to the spread of artificial insemination with frozen semen had resulted in loss of diversity of sires and dramatically reduced effective population size.

INTRODUCTION

The population structure of Japanese Black Cattle is characterized by separation in more than twenty prefectural sub–populations and existence of the functional stratification with a few prefectural sub–populations as its top. The sub–populations are classified into two types, *i.e.*, breeders' prefecture and multipliers' prefecture (Nomura and Sasaki,1986).

Hyogo Prefecture has been well recognized to be the most famous breeders' prefecture in Japan. The population of Hyogo Prefecture is quite important as breeding stock for improving meat quality of Japanese Black Cattle. The population in Hyogo Prefecture has been maintained as a closed population for over 70 years.

A dramatic changes of the breeding structure of Japanese Black Cattle occurred in the last three decades resulted from wide use of artificial insemination (AI) with frozen semen and from an alteration of breeding objective from drafting purpose to beef purpose. It is interesting enough to see how such changes affected to the population structure of a closed sub–population.

The objective of this study is to analyze the changes of population structure of breeding heifers in Hyogo Prefecture from 1960, when AI with frozen semen became available, to today.

MATERIALS AND METHODS

From heifers of Japanese Black Cattle born in 1960, 1970, 1980 and 1988, and registered in Hyogo Prefecture, two hundreds heifers were randomly chosen for each year. Animals born around 1940 were assumed as base population and the pedigree of heifer were traced back to the base population. The following population genetic parameters were calculated.

1) Diversity of sires (D)

Diversity of sires is defined as the probability that two heifers randomly selected were produced from the same sire (Simpson,1963). The formula is as follows:

$$D = \frac{\sum_i n_i(n_i - 1)}{\sum_i n_i(\sum_i n_i - 1)}$$

where, n_i is number of heifers produced from the ith sire.

2) F-statistics:

F_{IT} is the average coefficient of inbreeding for heifers; F_{ST} is the average coefficient of inbreeding, that would be expected if parents of heifers were randomly mated and F_{IS} is the coefficient of inbreeding due to consanguine mating, calculating from the formula (Wright,1965),
$F_{IS} = (F_{IT} - F_{ST})/(1 - F_{ST})$.

3) Index of subdivision(I)

The index of subdivision is calculated from the following formula (Lush,1946),
I=F_{IT}/F_{ST}.

4) Effective population size(N_e)

Effective population size is calculated from the following formula;
$N_e = 1/(2\Delta F_{ST})$,

where ΔF_{ST} means the increment F_{ST} per generation and is calculated from dividing F_{ST} by average generation number among two sampling years (Wright,1965).

RESULTS

Diversity of sires and its standard error (S.E.), and variance of progeny number per sire are shown in Table 1. The diversity decreased substantially during 1960 to 1988. Consequently the variance of progeny number per sire was increased dramatically. Only two sires produced 49.5% of heifers among thirteen sires used as a whole in 1988, compared to sixty six sires used in 1960.

Table 1. Diversity of sires and its standard error and
the variance of progeny numbers per sire

Year	Diversity of sires		S.E.	Variance of progeny No.
1960	0.022	±	0.0026	7.01
1970	0.047	±	0.0050	27.53
1980	0.061	±	0.0057	43.86
1988	0.174	±	0.0121	336.76

F–statistics and index of subdivision are shown in Table 2. The average coefficient of inbreeding (F_{IT}) increased in 3% or more by each decade from 1960 to 1988. On the other hand, both F_{IS} and index of subdivision decreased. F_{IS} became negative value and index of subdivision became smaller than one after 1980.

Table 2. F–statistics (F_{IT}, F_{ST} F_{IS}) and index of subdivision

Year	F_{IT}	F_{ST}	F_{IS}	Index of subdivision
1960	1.60	0.69	0.92	2.34
1970	4.06	3.64	0.44	1.12
1980	7.02	7.61	-0.64	0.92
1988	11.08	12.38	-1.48	0.89

Average generation number between sampling years, amount of increment of F_{ST} per generation (ΔF_{ST} (%)) and effective population size are shown in Table 3. ΔF_{ST} substantially increased term by term and effective population size dramatically decreased. In the last eight years, effective population size was only 8, compared to one over thirty three in 1960.

Table 3. Average generation number between sampling year, amount of increment of F_{ST} per generation (ΔF_{ST} (%)) and effective population size (N_e)

Term	Average generation No	ΔF_{ST} (%)	N_e
Base-1960	3.60	0.19	262
1960-1970	1.45	2.03	25
1970-1980	1.48	2.68	19
1980-1988	0.80	5.93	8

DISCUSSION

A commercial use of AI with frozen semen was introduced in mid 1960's in Japan, and ever since it was widely used in Japanese Black Cattle. Before the introduction of AI technique, several famous strains called "Tsuru" were raised within regions and not moved across the regions even within Hyogo Prefecture. Consequently the diversity of sires were well maintained in Hyogo

Prefecture as a whole at that time. However, the concentrated use of a few popular sires, made possible by the use of AI with frozen semen, occurred in the two decades from 1960 to 1980 resulted in the loss of diversity of sires.

A decline of the index of subdivision during 1960 to 1988 reflected the tendency of homogenization of the entire population of Hyogo Prefecture. This homogenization, however, was not the simple mixture of sub–populations in the entire population, but was rather concentrating a few specific sires across the regions.

Recently, inbreeding depressions and problems resulting from inbreeding were warned, and mating between the relatives with high hereditary relationship has been consciously avoided, reflecting the value of F_{IS} changed from positive to negative in 1980.

It is concluded that the population structure of Japanese Black Cattle in Hyogo Prefecture has remarkably changed during 1960 to 1988 and the effective population size of the sub–population is very small at present.

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