BLOOD PROTEIN POLYMORPHISMS OF NATIVE AND JUNGLE FOWLS IN INDONESIA

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Summary

In an attempt to reveal the interrelationship between fowls of jungle and native origin, their gene constitutions were compared using gene frequencies at the 16 loci controlling blood protein variations. Of the 16 loci analysed by electrophoresis, polymorphism was detected at following seven loci: *Es-1, Amy-1, Akp-akp, Akp-2, Alb, Tf* and *6-PGD*. The other nine loci: *Amy-3, Es-D, PGM, PHI, MDH, To, LDH, Hb-1* and *Hb-2*, were noted to be monomorphic. Genetic distance between pairs of native fowl and jungle fowls was estimated by a numerical taxonomic method. The Indonesian native fowl was genetically close to the Indonesian red jungle fowl, and the grey jungle fowl was genetically similar to the Ceylonese jungle fowl. It was also suggested that the green jungle fowl was genetically remote from the other jungle fowls and from the Indonesian native fowl. The proportion of polymorphic loci (*Ppoly*), the expected average heterozygosity per individual *H*, and the effective number of alleles per locus (*Ne*) were calculated to evaluate the genetic variabilities in the native and jungle fowls. The Indonesian native fowl exhibited slightly higher the proportion of polymorphic loci than the jungle fowls.

(**Key Words:** Protein Polymorphism, Native Fowl, Jungle Fowl, Indonesia, Genetic Distance, Genetic Variability)

Introduction

There are two theories as to whether the jungle fowl is the ancestor of the domestic fowl, namely the monophyletic origin theory which suggests the red jungle fowl (*Gallus gallus*) as the ancestor, and the polyphyletic origin theory regarding the grey jungle fowl (*Gallus sonneratii*), the Ceylonese jungle fowl (*Gallus lafayettii*) and the green jungle fowl (*Gallus varius*) other than the red jungle fowl as the ancestors (Darwin, 1890; Hutt, 1949). Two species, the red and green jungle fowls, still occur in the wild throughout Indonesia. The habitat of the red jungle fowl is limited to the deep forest, while the green jungle fowl even lives in bush near cultivated fields as well as in the forest (Nishida et al., 1980).

This study songht to clarify the relationship between native and jungle fowls from a phylogenetic point of view. The gene frequencies controlling the blood protein variations of these various species were compared. The genetic distance between pairs of native and jungle fowls was estimated, and the degree of genetic variability within populations quantitatively analysed.

Materials and Methods

The types of fowls surveyed in this work are shown in table 1. Blood samples from a total of 284 Indonesian native fowls collected during the first (1977), the second (1978) and the fifth (1981) investigations in Indonesia were examined. A blood sample from a hybrid between native and jungle fowls was also analysed. This hybrid had been raised at Ragunan Zoo in Jakarta and was reported to be a hybrid between a female native fowl and a male green jungle fowl. Green jungle fowls have a green or reddish purple comb and a red, yellow or blue-green wattle. Unlike

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TABLE 1. BREEDS OF FOWLS SURVEYED

Breeds or species	Breeding places	No. of birds
Indonesian native fowl (No. 1)[ab]	Indonesia	40
Indonesian native fowl (No. 2)[ac]	Indonesia	138
Indonesian native fowl (No. 3)[ad]	Indonesia	106
Indonesian native fowl (Total)	Indonesia	284
Red jungle fowl (Indonesia)[ad]	Indonesia	12
Red jungle fowl (Philippine)	Kagoshima Univ.	6
Red jungle fowl (Thailand)	Kagoshima Univ.	6
Green jungle fowl[ad]	Indonesia	15
Ceylonese jungle fowl	Kagoshima Univ.	4
Grey jungle fowl	Kagoshima Univ.	12
Indonesian native fowl[ad] × Green jungle fowl	Indonesia	1

[a] The blood samples were taken from fowls by the member of the Society for Researches on Native Livestock, Japan.
[b] First investigation (1977).
[c] Second investigation (1978).
[d] Fifth investigation (1981).

the other three species of jungle fowl, green jungle fowls have only one median wattle and a comb with no serration. As shown in figure 1, the hybrid of a green jungle fowl and a native fowl has a reddish comb with slight serration. Also, this hybrid has a pair of small wattles derived from the maternal native fowl, in addition to one wattle derived from the paternal green jungle fowl. A white vertical band is present on the posterior side of the wattle, along the earlobe beginning immediately below the ear. The other part of the wattle is red.

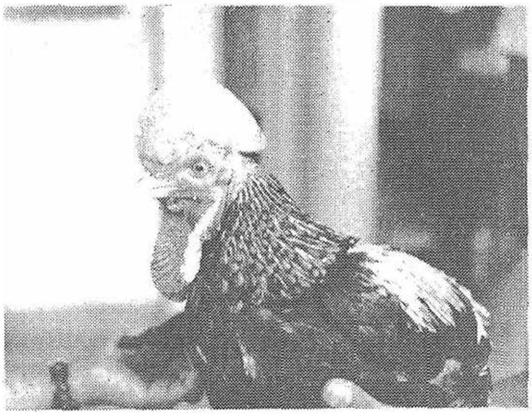

Figure 1. A male hybrid between native hen and green jungle cock called Ayam Bekisar (Ragunan Zoo).

Blood samples were separated into plasma and erythrocyte fractions, and stored at −40℃. Later, sixteen genetic loci controlling the structure of 13 kinds of enzymatic and non-enzymatic blood proteins were examined by electrophoresis as listed in table 2.

The genetic variabilities (Nozawa et al., 1976) within populations were estimated by measuring the following items: the proportion of polymorphic loci or *Ppoly* (the criterion of polymorphism was the frequency of the commonest allele < 0.99); the expected proportion of heterozygosity per individual ($\overline{H} = 1 - \overline{\sum_i q_i^2}$), where q_i was the frequency of i-th allele at a locus and the average fixed was over all the gene loci including loci without variation; and the effective number of alleles per locus ($Ne = \overline{1/\sum_i q_i^2}$).

Genetic distance between pairs of native and jungle fowls was estimated by the numerical taxonomic method (Nei, 1972). That is, the given distance between the j-th and k-th populations, D_{jk} was defined as

$$D_{jk} = -\log_e [\overline{\sum_i q_{ij} \cdot q_{ik}}/(\overline{\sum_i q^2_{ij}} \cdot \overline{\sum_i q^2_{ik}})^{1/2}],$$

TABLE 2. LIST OF BLOOD PROTEINS EXAMINED

Symbol of locus	Name of blood protein	Type of electrophoresis	Cited from
Es-1	Plasma esterase	Thin layer agar gel	Hashiguchi et al. (1976)
Amy-1	Plasma amylase	Thin layer agar gel	Hashiguchi et al. (1970)
Amy-3	Plasma amylase	Thin layer agar gel	Hashiguchi et al. (1970)
Akp-akp	Plasma alkaline phosphatase	Starch gel	Tanabe et al. (1977)
Akp-2	Plasma alkaline phosphatase	Starch gel	Kimura et al. (1979)
Alb	Plasma albumin	Starch gel	Stratil (1968)
Tf	Plasma transferin	Starch gel	Stratil (1968)
LDH	Erythrocyte lactate dehydrogenase	Starch gel	Manwell and Baker (1969)
6-PGD	Erythrocyte 6-phosphogluconate dehydrogenase	Starch gel	Bengtsson and Sandberg (1973)
PGM	Erythrocyte phosphoglucomutase	Starch gel	Bengtsson and Sandberg (1973)
PHI	Erythrocyte phosphohexose isomerase	Starch gel	Bengtsson and Sandberg (1973)
To	Erythrocyte tetrazolium oxidase	Starch gel	Baur and Schorr (1969)
MDH	Erythrocyte maltate dehydrogenase	Starch gel	Davidson and Cortner (1967)
Es-D	Erythrocyte esterase	Starch gel	Watanabe et al. (1977)
Hb-1	Hemoglobin	Cellulose acetate	Washburn (1968)
Hb-2	Hemoglobin	Cellulose acetate	Washburn (1968)

where the averages were fixed over all the gene loci examined, including the loci without variation. From the matrices of the genetic distance values, the dendrograms were drawn using the unweighted pairgroup method (Sokal and Sneath, 1972) of clustering in numerical taxonomy.

Results and Discussion

Gene constitutions of the Indonesian native fowl and the four species of jungle fowls were compared using gene frequencies at the 16 loci controlling blood protein type. Of the 16 loci analysed by electrophoresis, polymorphisms were detected at seven loci: plasma esterase (*Es 1*), plasma amylase (*Amy-1*), plasma alkaline phosphatase (*Akp-akp, Akp-2*), plasma albumin (*Alb*), plasma transferrin (*Tf*), and erythrocyte 6-phosphogluconate dehydrogenase (*6-PGD*). The remaining nine loci, *Amy-3, LDH, PGM, PHI, To, MDH, Es D, Hb 1* and *Hb-2*, were monomorphic. With the limited number of samples of the jungle fowls used, it was confirmed that the phenotypes in their various protein types appeared entirely the same as in those of the domestic fowls.

Plasma esterase isozyme (Es-1) :

The results of analyses on plasma esterase isozymes are shown in table 3. Indonesian native fowl possessed $Es\text{-}1^B$ (0.530), $Es\text{-}1^A$ (0.436) and $Es\text{-}1^C$ (0.034). The existence of $Es\text{-}1^C$ was not observed in any of the four jungle fowl species. Indonesian and Philippian red jungle fowls showed higher $Es\text{-}1^B$ (0.571~0.583) than $Es\text{-}1^A$ (0.417 ~0.429). On the contrary, red jungle fowl from Thailand possessed higher $Es\text{-}1^A$ (0.883) these $Es\text{-}1^B$ (0.167). The frequency of $Es\text{-}1^B$ (0.625 and 0.583) was higher than that of $Es\text{-}1^A$ (0.375 and 0.417) in the Ceylonese jungle fowl and grey jungle fowl, respectively. The green jungle fowl showed frequencies of 0.250 for $Es\text{-}1^A$ and 0.542 for $Es\text{-}1^B$, and had $Es\text{-}1^D$ (0.208). The only green jungle fowl possessed this BD type of phenotype. The plasma esterase isozyme *Es-1* of the fowl is controlled by the four autosomal codominant alleles, $Es\text{-}1^A$, $Es\text{-}1^B$, $Es\text{-}1^C$ (Grunder, 1968) and $Es\ 1^D$ (Watanabe, 1982). BD type was also detected in the hybrid between the Indonesian

TABLE 3. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF PLASMA ESTERASE ISOZYME (*ES-1*) IN NATIVE AND JUNGLE FOWLS

Breeds or species	No. of birds	Phenotypes							Gene frequencies			
		AA	AB	AC	BB	BC	CC	BD	*Es-1*^{A}	*Es-1*^{B}	*Es-1*^{C}	*Es-1*^{D}
Indonesian native fowl	220	46	98	2	63	9	2		0.436	0.530	0.034	
Red jungle fowl (Indonesia)	7	2	2			3			0.429	0.571		
Red jungle fowl (Philippine)	6	1	3			2			0.417	0.583		
Red jungle fowl (Thailand)	6	4	2						0.833	0.167		
Green jungle fowl	12	3				4		5	0.250	0.542		0.208
Ceylonese jungle fowl	4	1	1			2			0.375	0.625		
Grey jungle fowl	12	4	2		6				0.417	0.583		
Indonesian native fowl × Green jungle fowl	1							1				

native fowl and the green jungle fowl.

Plasma amylase isozyme (*Amy-1*):

In the Indonesian native fowl, the frequency of *Amy-1*^{A} (0.816) was higher than that of *Amy-1*^{B} (0.184). Only *Amy-1*^{A} was detected in the Philippian red, Thailand red, Ceylonese, and grey jungle fowls. Indonesian red and green jungle fowls, had *Amy-1*^{A} and *Amy-1*^{B}, as well as *Amy-1*^{C}. The frequencies of *Amy-1*^{A} and *Amy-1*^{B} were 0.375, and that of *Amy-1*^{C} was 0.250. In green jungle fowl, *Amy-1*^{C} had the highest frequency (0.678), followed by *Amy-1*^{A} (0.286) and *Amy-1*^{B} (0.036). The hybrid between Indonesian native fowl and green jungle fowl exhibited the presence of CC type. *Amy-1*^{C} has been detected in some breeds of domestic fowls. Watanabe (1982) reported the existence of *Amy-1*^{C} in the red and grey jungle fowls, and detected only *Amy-1*^{D} in the Ceylonese jungle fowl. However, *Amy-1*^{D} was not detected in the Ceylonese jungle fowls in this study.

Plasma alkaline phosphatase isozyme (*Akp-akp*, *Akp-2*):

All native and jungle fowls tested, except Thailand red jungle fowl, showed higher frequencies of *akp* than *Akp*. At the locus for *Akp-2*, green jungle fowl showed higher frequencies for *Akp-2*^{a} (0.756) than that for *Akp-2*^{b} (0.244),

TABLE 4. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF PLASMA AMYLASE ISOZYME (*Amy-1*) IN NATIVE AND JUNGLE FOWLS

Breeds or species	No. of birds	Phenotypes						Gene frequencies		
		AA	AB	AC	BB	BC	CC	*Amy-1*^{A}	*Amy-1*^{B}	*Amy-1*^{C}
Indonesian native fowl	280	204	49		27			0.816	0.184	
Red jungle fowl (Indonesia)	12		7	2		2	1	0.375	0.375	0.250
Red jungle fowl (Philippine)	6	6						1.000		
Red jungle fowl (Thailand)	6	6						1.000		
Green jungle fowl	14	3	1	1			9	0.286	0.036	0.678
Ceylonese jungle fowl	3	3						1.000		
Grey jungle fowl	9	9						1.000		
Indonesian native fowl × Green jungle fowl	1						1			

TABLE 5. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF PLASMA ALKALINE PHOSPHATASE ISOZYME (*Akp-akp*, *Akp-2*) IN NATIVE AND JUNGLE FOWLS

Breeds or species	No. of birds	Phenotypes		Gene frequencies		Phenotypes		Gene frequencies	
		F	S	*Akp*	*akp*	+	−	$Akp\text{-}2^a$	$Akp\text{-}2^b$
Indonesian native fowl	284	67	217	0.126	0.874	30	254	0.325	0.675
Red jungle fowl (Indonesia)	12	3	9	0.134	0.866	2	10	0.408	0.592
Red jungle fowl (Philippine)	5	2	3	0.225	0.775		5		1.000
Red jungle fowl (Thailand)	6	5	1	0.592	0.408		6		1.000
Green jungle fowl	14	5	9	0.198	0.802	8	6	0.756	0.244
Ceylonese jungle fowl	3	1	2	0.184	0.816		3		1.000
Grey jungle fowl	9	3	6	0.184	0.816		9		1.000
Indonesian native fowl × Green jungle fowl	1	1				1			

TABLE 6. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF PLASMA ALBUMIN (*Alb*) IN NATIVE AND JUNGLE FOWLS

Breeds or species	No. of birds	AA	AB	AC	AD	BB	BC	BD	CC	CD	DD	Alb^A	Alb^B	Alb^C	Alb^D
Indonesian native fowl	283					275	7		1				0.984	0.016	
Red jungle fowl (Indonesia)	12					11	1						0.958	0.042	
Red jungle fowl (Philippine)	6					6							1.000		
Red jungle fowl (Thailand)	6					6							1.000		
Green jungle fowl	14					1		1			12		0.107		0.893
Ceylonese jungle fowl	3					2	1						0.833	0.167	
Grey jungle fowl	12					8	4						0.833	0.167	
Indonesian native fowl × Green jungle fowl	1							1							

while all other types showed higher $Akp\text{-}2^b$ frequencies than $Akp\text{-}2^a$. The other jungle fowls except Indonesian red jungle fowl had only $Akp\text{-}2^b$.. In the hybrid between native fowl and green jungle fowl, the F type was at the *Akp-akp* locus, and the + type was at the *Akp-2* locus.

Plasma albumin (*Alb*):

Alb^A was not detected in the Indonesian native fowl or the four species of jungle fowls. The frequency of Alb^B was greater than that of Alb^C, in the native fowl and Indonesian red, Ceylonese, and grey jungle fowls. The Philippian and Thailand red jungle fowls possessed only Alb^B.

In the present study, BD and DD types were detected in the green jungle fowl. Although the mode of genetic control of these D bands is unknown, their gene frequencies were estimated on the assumption that they are probably controlled by Alb^D, which is in a codominant to Alb^A, Alb^B and Alb^C genes (Stratil, 1968). In case of green jungle fowl the frequency of Alb^D (0.893) was higher than Alb^B (0.107), and no Alb^C was detected. In the hybrid between native fowl and green jungle fowl, the phenotype BD was observed. Although Watanabe (1968) had recently detected Alb^D in Ceylonese jungle fowl, it was not confirmed in the present study.

Plasma transferrin (*Tf*):

In the native fowls, frequency of Tf^B (0.995) was much higher than those of Tf^A (0.002) and Tf^C (0.003) (table 7). Only Tf^B was detected in the red jungle fowls (Indonesian, Philippian and Thailand), the Ceylonese and the grey jungle fowls, but not in the green jungle fowls. In the green jungle fowl, Tf^C was observed at a high frequency (0.821) and Tf^B was present. The hybrid fowl showed the phenotype CC.

Erythrocyte 6-phosphogluconate dehydrogenase isozyme (*6-PGD*):

The Indonesian native fowls exhibited polymorphism for *6-PGD*. Three phenotypes, fast, slow and an intermediate were designated as AA, BB and AB, respectively. When the erythrocyte

TABLE 7. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF PLASMA TRANSFERRIN (*Tf*) IN NATIVE AND JUNGLE FOWLS

Breeds or species	No. of birds	Phenotypes						Gene frequencies		
		AA	AB	AC	BB	BC	CC	Tf^A	Tf^B	Tf^C
Indonesian native fowl	282		1		279	2		0.002	0.995	0.003
Red jungle fowl (Indonesia)	12				12				1.000	
Red jungle fowl (Philippine)	6				6				1.000	
Red jungle fowl (Thailand)	6				6				1.000	
Green jungle fowl	14				2	1	11		0.179	0.821
Ceylonese jungle fowl	4				4				1.000	
Grey jungle fowl	9				9				1.000	
Indonesian native fowl × Green jungle fowl	1						1			

TABLE 8. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF ERYTHROCYTE 6-PHOSPHOGLUCONATE DEHYDROGENASE ISOZYME (*6-PGD*) IN NATIVE AND JUNGLE FOWLS

Breeds or species	No. of birds	Phenotypes			Gene frequencies	
		AA	AB	BB	$6\text{-}PGD^A$	$6\text{-}PGD^B$
Indonesian native fowl	278	3	11	264	0.031	0.969
Red jungle fowl (Indonesia)	12			12		1.000
Red jungle fowl (Philippine)	6			6		1.000
Red jungle fowl (Thailand)	6			6		1.000
Green jungle fowl	15			15		1.000
Ceylonese jungle fowl	3			3		1.000
Grey jungle fowl	9			9		1.000
Indonesian native fowl × Green jungle fowl	1			1		

of the AA type was mixed with the same volume of that of the BB type, the band for AA and BB were independently observed at some unchanged positions. Therefore, the mode of genetic control on *6-PGD* is unknown at present. However, it appears that as with Japanese quail (Leung and Haley, 1974; Manwell and Baker, 1969) and pig (Oshima and Tanaka, 1974; Saison, 1968) the *6-PGD* in the native fowl may be composed of a dimer of two subunits. Assuming that the genes controlling *6-PGD* are $6\text{-}PGD^A$ and $6\text{-}PGD^B$, the frequency of $6\text{-}PGD^A$ and $6\text{-}PGD^B$ may be estimated as 0.031 and 0.969, respectively. The four jungle fowls possessed $6\text{-}PGD^B$. Commercial chickens available in Japan including various native breeds, showed only $6\text{-}PGD^B$, but not $6\text{-}PGD^A$. In case of the hybrid (Indonesian native fowl × green jungle fowl), BB type was observed. $6\text{-}PGD^A$ was detected only in Indonesian native fowls at low frequencies. As shown in table 9, $6\text{-}PGD^A$ was found in the native fowls on Sumatra, Sumbawa, Lombok and Bali islands.

Genetic variability in fowl:

Electrophoretically detected variations in the primary structure of blood proteins were assumed to be the samples extracted randomly from total gene pool and genetic variability in each population was assayed. The proportion of polymorphic loci (*Ppoly*), the expected average heterozygosity per individual $\overline{H}$ and the effective number of alleles per locus (*Ne*) were used as indices (table 10). The Indonesian native fowl exhibited slightly higher the proportion of polymorphic loci than the jungle fowls. Regional analyses showed that only the native fowl from Sumatra island had higher genetic variability, while the native fowls in other areas in Indonesia showed the same variability as the four jungle fowls. (table 11). Genetic variabilities have been investigated also in cattle [(Abe et al., 1980), Japanese cattle: $Ppoly = 0.576 \sim 0.692$, $\overline{H} = 0.124 \sim 0.192$], horse [(Nozawa et al., 1976), Japanese

TABLE 9. DISTRIBUTION OF PHENOTYPES AND GENE FREQUENCIES OF (*6-PGD*) IN INDONESIAN NATIVE FOWLS

Locality	No. of birds	Phenotypes			Gene frequencies	
		AA	AB	BB	$6\text{-}PGD^A$	$6\text{-}PGD^B$
Sumatra	79		2	77	0.013	0.987
Madura	25			25		1.000
Sulawesi	49			49		1.000
Sumbawa	25	2	2	21	0.120	0.880
Lombok	20		1	19	0.025	0.975
Bali	80	1	6	73	0.050	0.950
Total	278	3	11	264	0.031	0.969

TABLE 10. QUANTIFICATION OF GENETIC VARIABILITY IN INDONESIAN NATIVE AND JUNGLE FOWLS

Breeds of species	$Ppoly \pm$ S.E.	$\overline{H} = 1 - \overline{\sum_i q^2_i}$	$Ne = 1/\overline{\sum_i q^2_i}$
Indonesian native fowl	0.4375 ± 0.1240	0.0993	1.10
Red jungle fowl (Indonesia)	0.3125 ± 0.1159	0.1223	1.14
Red jungle fowl (Philippine)	0.1250 ± 0.0827	0.0552	1.06
Red jungle fowl (Thailand)	0.1250 ± 0.0827	0.0476	1.04
Green jungle fowl	0.3750 ± 0.1210	0.1393	1.16
Ceylonese jungle fowl	0.1857 ± 0.0976	0.0655	1.07
Grey jungle fowl	0.1857 ± 0.0976	0.0655	1.07

TABLE 11. QUANTIFICATION OF GENETIC VARIABILITY IN INDONESIAN NATIVE FOWLS

Locality	$Ppoly \pm$ S.E.	$\bar{H} = 1 - \sum_i q_i^2$	$Ne = 1/\sum_i q_i^2$
Sumatra	0.4375 ± 0.1240	0.1065	1.12
Madura	0.1875 ± 0.0976	0.0609	1.06
Sulawesi	0.3125 ± 0.1159	0.0886	1.10
Sumbawa	0.2500 ± 0.1082	0.0721	1.08
Bali	0.3750 ± 0.1210	0.0995	1.11

TABLE 12. MATRICES OF GENETIC DISTANCE BETWEEN THE RESPECTIVE PAIR OF 7 FOWL BREEDS, USED ON 16 LOCI, CALCULATED BY NEI'S EQUATION

	1	2	3	4	5	6	7
1 Indonesian native fowl	0						
2 Red jungle fowl (Philippine)	0.0101	0					
3 Red jungle fowl (Thailand)	0.0341	0.0204	0				
4 Red jungle fowl (Indonesia)	0.0110	0.0322	0.0581	0			
5 Ceylonese jungle fowl	0.0117	0.0021	0.0271	0.0335	0		
6 Green jungle fowl	0.1581	0.1940	0.2257	0.1345	0.1854	0	
7 Grey jungle fowl	0.0114	0.0019	0.0246	0.0338	0.0001	0.1858	0

native horse: $Ppoly = 0.1428 \sim 0.4000$, $\bar{H} = 0.0349 \sim 0.1210$; Thoroughbred: $Ppoly = 0.333$, $\bar{H} = 0.1277$; Arab: $Ppoly = 0.4285$, $\bar{H} = 0.1501$], goat [(Nozawa et al., 1976), Shiba goat: $Ppoly = 0.0370 \sim 0.1851$, $\bar{H} = 0.0018 \sim 0.0178$; Japanese Saanen: $Ppoly = 0.1481$, $\bar{H} = 0.0510$], Asian native fowl [(Hashiguchi et al., 1986, 1988), $Ppoly = 0.278 \sim 0.500$, $\bar{H} = 0.080 \sim 0.134$], Japanese native fowl [(Hashiguchi et al., 1981), $Ppoly = 0.111 \sim 0.278$, $\bar{H} = 0.046 \sim 0.087$], commercial chickens [(Hashiguchi et al., 1981), $Ppoly = 0.222$, $\bar{H} = 0.034 \sim 0.109$], and Japanese quail [(Kimura et al., 1980), $Ppoly = 0.516$, $\bar{H} = 0.167$]. The genetic variabilities obtained for fowls in the present study are similar to these livestock and poultry.

Genetic distance between Indonesian native fowl and jungle fowls:

Gene frequencies were estimated for the total of 16 loci made of seven loci showing polymorphism and nine loci showing monomorphic. Genetic distance between the pair of the two different breeds or species (table 12), was then calculated, using Nei's method (Nei, 1972). A

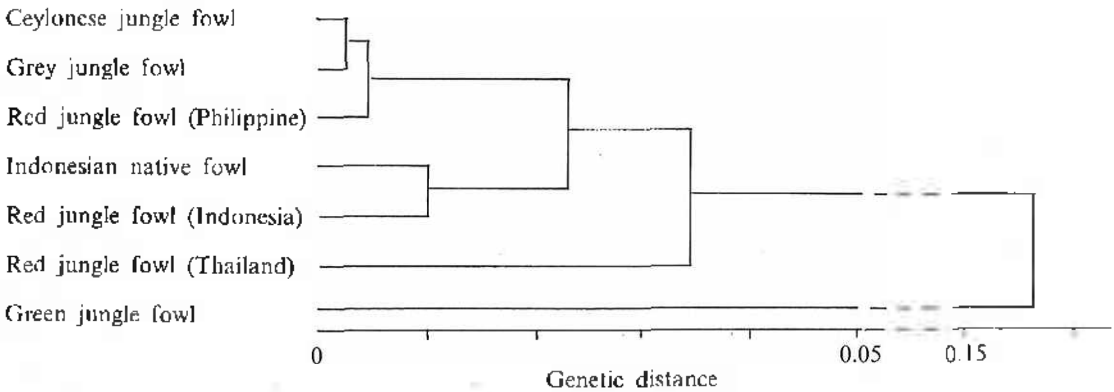

Figure 2. Dendrogram showing genetic similarities among the Indonesian native and jungle fowls, estimated from 16 loci.

dendrogram was prepared from the data, by means of the unweighted pair-group method (Sokal and Sneath, 1972) As summarized in figure 2, the results indicated that grey jungle fowl are genetically similar to Ceylonese jungle fowl, and Indonesian native fowl are genetically close to the Indonesian red jungle fowl. We also suggest that green jungle fowl is genetically remote from other jungle fowls and Indonesian native fowl.

Literature Cited

Abe, T., M. Komatsu, T. Oishi, T. Amano, M. Shiomi, S. Tsuji and T. Fukushima. 1980. Genetic variabilities in two population of Japanese Black cattle estimated from blood groups and blood protein polymorphism. Jpn. J. Zootech. Sci. 51:311-318.

Baur, E. W. and R. T. Schorr. 1969. Genetic polymorphism of tetrazolium oxidase in dogs. Science 166:1524-1525.

Bengtsson, S. and K. Sandberg. 1973. A method for simultaneous electrophoresis of four horse red cell enzyme systems. Anim. Blood Grps. Biochem. Genet. 4:83-87.

Darwin, C. 1890. The variation of animals and plants under domestication. 2d ed. D. Appleton & Company. New York.

Davidson, R. G. and J. A. Cortner. 1967. Genetic variant of human erythrocyte malate dehydrogenase. Nature. 215:761-762.

Grunder, A. A. 1968. Inheritance of electrophoretic variants of serum esterase in domestic fowl. Can. J. Genet. Cytol. 10:961-967.

Hashiguchi, T., M. Yamagida, Y. Maeda and M. Taketomi. 1970. Genetical studies on serum amylase isozyme in fowls. Japan J. Genet. 45:341-349.

Hashiguchi, T., S. B. Loh, Y. Maeda and M. Taketomi. 1976. Genetic variation of pancreatic esterase isozyme in Japanese quail. Anim. Blood Grps. Biochem. Genet. 7:65-72.

Hashiguchi, T., M. Tsuneyoshi, T. Nishida, H. Higashiuwatoko and E. Hiraoka. 1981. Phylogenetic relationships determined by the blood protein types of fowls. Jpn. J. Zootech. Sci. 52:713-729.

Hashiguchi, T., S. Okamoto, T. Nishida, Y. Hayashi, H. Goto and H. W. Cyril. 1986. Blood protein variations of the Ceylon jungle fowl and native fowl in Sri Lanka. Rep. Soc. Res. Native Livestock. 11:192-207.

Hashiguchi, T., T. Nishida, Y. Maeda, S. Okamoto and I. Okada. 1988. Phylogenetic studies on the jungle fowls and native fowls in south and southeast Asia. Proc. Ⅷ World Poultry Congress. 538-539.

Hutt, F. B. 1949. Origin of the fowl. In "Genetic of the fowl" pp. 9-12. McGraw-Hill Book Company. New York.

Kimura, M., Y. Goda and I. Isogai. 1979. Alkaline phosphatase isozyme system. *Akp-2*, in the chicken Japan. Poult. Sci. 16:266-270.

Kimura, M., M. Ishiguro, S. Ito and I. Isogai. 1980. Protein polymorphism and genetic variation in a population of the Japanese quail. Japan. Poult. Sci. 17:312-322.

Leung, E. S., and L. E. Haley. 1974. The ontogeny of phosphogluconate dehydrogenase and glucose 6-phosphate dehydrogenase in Japanese quails and chicken-quail hybrids. Biochem. Genetic. 11:221-230.

Manwell, C. and C. M. A. Baker. 1969. Hybrid proteins, heterosis and the origin of species-1. Unusual variation of polychaete Hyalinoecia "nothing dehydrogenases" and of quail Coturnix erythrocyte enzymes. Comp. Biochem. Phsiol. 28:1007-1028.

Nei, M. 1972. Genetic distance between populations. Amer. Nat. 106:283-292.

Nishida, T., Y. Hayashi and K. Kondo. 1980. Ecological and morphological studies on the red jungle fowl and the green jungle fowl in Indonesia. In The Origin and Phylogeny of Indonesian Native Livestok (report by Grant-in-Aid for Overseas Scientific Survey, No. 404315). 71-81. The Research Group of Overseas Scientific Survey.

Nozawa, K., T. Shotake and Y. Ohkura. 1976. Blood protein variations within and between the east Asian European horse populations. Z. Tierzüchtg. Züchgsbiol. 93:60-74.

Nozawa, K., Y. Kano, T. Sawasaki, T. Nishida, T. Abe, T. Shotake and Y. Matsuda. 1978. Gene constitution of miniature "Shiba" goats. Exp. Anim. 27:413-422.

Oshima, H. and K. Tanaka. 1974. 6 phosphogluconate dehydrogenase variants in pigs. Jpn. J. Zootech. Sci. 45:129-132.

Saison, R. 1968. Serum and red cell enzyme systems in pigs. Proc. XIth Eur. Conf. Blood Grps and Biochem. Polymorphism. 321-328.

Sokal, R. R. and P. H. A. Sneath. 1972. Principles of Numerical Taxonomy. Freeman. San Fransisco.

Stratil, A. 1968. Transferrin and albumin loci in chickens. Gallus L. Comp. Biochem. Physiol. 24:113-121.

Tanabe, Y., S. Sugiura and K. Ito. 1977. Studies on the phylogenetic relationships of the Japanese native fowl breeds. I. genetic polymorphism of plasma albumins, esterase and alkaline phosphatases. Japan. Poult. Sci. 14:19-26.

Washburn, K. W. 1968. Inheritance of an abnormal hemoglobin in a randombred population of domestic fowl. Poultry. Sci. 47:561-564.

Watanabe, S., T. Shibata and T. Kawahara. 1977. Esterase-D isozymes in Japanese quail. Poultry. Sci. 14:66-70.

Watanabe, S. 1982. Studies on the polymorphism of protein and isozyme in the three species of jungle fowls. Report by Grant-in-Aid for Co-operative Research (No. 504162, N. 5604355) from the Ministry of Education, Science and Culture of Japan. 9-20.