Historical Look at the Genetic Improvement in Korean Cattle[a] - Review -

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ABSTRACT : The Korean cattle industry is important to farming households, the national economy, and the security of foodstuffs in Korea. Since Korean cattle have had inferior ability to produce meat, the Korean cattle industry aimed to improve the meat production ability and to increase numbers to meet the demand from the growing beef cattle market in Korea. This paper reviews the history of the Korean cattle industry and surveys the efforts devoted to improve genetic abilities of the Korean cattle. Discussed are current situations of the Korean cattle industry, projects related to improvement of Korean cattle, Korean cattle's genetic characteristics of economic traits, and some issues to deal with. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 10 : 1467-1481)*

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INTRODUCTION

Based on historical records, Korean cattle are known to have been around for at least 2000 years in the Korean Peninsula. Since then the Korean cattle have maintained stable traits through pure breeding. Currently, the blood lineage is considered very valuable and is spread out only in the northeast Chinese region and in some Japanese areas. Korean cattle are well adapted to the Korean climate because they have been raised there for a long time. They have served as working animals because they are strong and obedient. Before the 1960s, they were important as draught animals and as suppliers of organic fertilizer. However as mechanization of agricultural methods as well as domestic consumption of beef cattle were rapidly increasing, the Korean cattle became more important as beef cattle rather than working cattle.

The Korean cattle are known to have an inferior ability to produce meat because of a low milking capacity and a low growth rate, while having a relatively superior ability to reproduce. Thus, the Korean cattle industry aimed to improve the meat production ability and to increase numbers to meet the demand from the growing beef cattle market in Korea.

In this paper, we will deal with the current situation of the Korean cattle industry, methods and results employed to improve Korean cattle, and Korean cattle's genetic characteristics related to beef production ability and economic traits.

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CURRENT SITUATION OF THE KOREAN CATTLE INDUSTRY AND A SHORT HISTORY OF KOREAN CATTLE IMPROVEMENT

When in 1962 the Korean government set up a 5 year plan for advancing animal agriculture, the number of Korean cattle was 1,254,000, the number of farming households was 1,092,000, and the beef consumption per person was only 0.6 kg. Since the plan became effective, the Korean Cattle Improvement Committee has generated discussions about directions and specific plans to improve Korean cattle. It made a suggestion that Korean cattle be used primarily for meat and labor, this dependent on purebred breeding, while crossbreeding be allowed in limited areas. Selection of sires and performance testing were included in the plan.

In 1962, the Center for Livestock Artificial Insemination was opened, and it became a stepping stone to advancement of Korean cattle. In 1969, a special committee at the Korean Animal Improvement Federation formulated goals to enhance beef production ability, milking ability, weight, and the homogeneity of general traits. Specifically, they discussed issues of maintaining merits of Korean cattle such as vigilance, convenience in management, and reproduction rate, and issues of inferior shape, milking ability, and lack of trait homogeneity.

The first Korean Cattle Fair was held in 1969, and in the following year, the government started a registration program for Korean cattle; 379 cattle were registered to collect basic data in 1970, and 100,843 cattle were registered by 1998 (Korea Animal Improvement Association, 1999). The first performance test was done at the Koryungji Experimental Site in

1972, and it provided the base of the present performance test and progeny test.

Crossbreeding with other beef cattle was performed from late 1960, and it was intended for practical use. In 1966, 52 Aberdeen Angus and 5 Santa Gertrudis were imported from the United States (Ministry of Agriculture and Forestry, 1997). The Santa Gertrudis were used to produce crossbreds in the Cheju region, and the Aberdeen Angus was used in the Southern part of Korea. But the crossbred with Aberdeen Angus perished soon because the shape was not appropriate for labor, and farmers did not like the color of the crossbred, black. Also as artificial insemination became popular, the utility of male Angus was reduced. In 1969, 5 Charolais from the USA were imported to produce a new synthetic breed that had a genetic structure of Korean cattle 3/8 : Charolais 5/8. It was part of Kanghwado Beef Cattle project.

The consumption of beef kept on rising as the national economy continued booming from the mid 70s. Foreign beef cattle were imported to meet the market demand. From late 1970, a need to preserve the purity of Korean cattle arose as beef cattle were imported. The government designated 8 areas to produce pure Korean Cattle; crossbreeding with foreign cattle was prohibited in these areas. The government also imported a large quantity of cattle as income sources to farming households, but the farmers avoided raising them because Koreans preferred Korean cattle, they did not like black cattle, their body shape was not appropriate for labor, and the price of these cattle were too low to make profit. In addition, it turned out to be difficult for foreign cattle to adapt to the Korean climate and to types of Korean barns and feedstuff, so they perished without maintaining their crossbred or the purebred.

With continuous effort, the amount and the number of Korean cattle has been increasing. In 1985, 1,047 thousand animal farms managed 2,553 thousand cattle. Recently, the total number of farming households that raise Korean cattle has been reduced but the number of Korean cattle per animal farm has been increased.

Table 1 shows several statistics on the Korean cattle industry in 1990s. The number of Korean cattle per animal farm in 1990 was 2.6 and in 1997 was 5.6, which is more than a two times increase. However, the numbers seem to be decreasing since 1998. It may be the impact of the national economy crisis Korea has been facing. Recently the number of animal farms that had given up on raising Korean cattle is on the rise. The fact that the rate of slaughtering female cattle has been increasing intensifies the trend. The total number of Korean cattle raised by animal farms has been also decreasing since 1996.

Domestic production of beef ranged from 43.9% to 63% of total supply before the IMF economic crisis, but in 1998, it had increased to 75.1% due to lack of financial resources to import foreign beef. Until now the Korean government maintained a quota system for beef imports because it was concerned about collapse of the domestic Korean cattle industry. However, a free trade system on foreign beef and live cattle is expected in 2001. More aggressive efforts to maintain a stable rate of self-supplied beef should be made.

PROJECTS RELATED TO IMPROVEMENT OF KOREAN CATTLE

Artificial insemination

The first artificial insemination (AI) was performed when the animal AI center was set up in 1962. Since 1,275 cows received AI in 1965, the number has dramatically increased; 106,000 cattle received AI in 1975 and 1,436,000 in 1996.

The use of semen frozen by liquid nitrogen made it easier to store and transfer semen, and with the frozen semen system, the rate of AI in Korea increased to a world class level. The Korean farms have relatively small space to raise cattle and thus it was rather handy to perform AI as well as to detect estrous signs.

Sires that provided semen have decreased from 198 in 1984 to 49 in 1998. In table 2, sires are divided in two kinds: registered sire and proven sire. Registered sires are selected only from appearance test and semen test. Proven sires are selected from performance test and progeny test. The AI industry only kept proven sires since 1994, but the number has been decreasing. Also the amount of supplied semen has decreased since 1996. It shows that the amount of semen per sire is increasing. Also more intensive selection of sires is expected.

Another thing the table shows is that the number of animal farms practising AI has decreased. Since 1997, the number of cattle that can get pregnant exceeded that with AI treatment. This may suggest that animal farms avoid reproduction or they might prefer natural mating to AI. Reasons for changing the reproductive methods are: (1) The conception rate is higher with natural mating; (2) AI costs more; (3) Farmers can't get the AI professionals on time due to isolated location of farms (Yang, 1999). Considering these problems, natural mating will be more popular to farmers. Although government agencies have been trying to train farmers so that they can perform AI, the conception rate has not been improved. As of 1998, there are 1870 places for AI, and the number of AI professionals is about 1956 (Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative

Federation, 1999a). These professionals should

Table 1. Summary of recent Korean cattle (KC) industry

	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99. 3
Nos. of KC raised (unit: 1000)	1,622	1,773	2,019	2,260	2,393	2,594	2,844	2,735	2,383	2.198
Number of KC farms (unit: 1000)	620	601	585	570	540	519	513	465	427	413
Nos. of KC per farm	2.6	2.95	3.45	3.96	4.43	5.00	5.54	5.88	5.58	5.32
Total no. of slaughtered KC (unit: 1000)	320	312	355	505	591	591	657	912	1,048	-
-Heads of slaughtered female KC (unit: 1000)	134	112	133	201	275	238	260	482	522	-
-Rate of slaughter of female KC (%)	41.9	35.9	37.4	39.7	46.5	40.4	39.6	52.8	49.8	-
Nos. of calves born (unit: 1000)	453	529	708	743	726	860	977	960	807	-
Amount of beef consumption (1000M/T)	177	223	227	233	270	301	323	362	346	-
-Domestic beef (1000M/T)	95	98	100	130	147	155	174	228	260	-
-Imported beef (1000M/T)	82	125	127	103	123	146	149	134	86	-
-Rate of self-supplied beef (%)	53.7	43.9	44.1	55.8	54.4	51.5	53.9	63.0	75.1	-
-Beef consumption per person (kg)	4.1	5.2	5.2	5.3	6.1	6.7	7.1	7.9	7.4	-

(Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative Federation, 1999b; National Livestock Cooperative Federation, 1999b).

broaden their capabilities such as training farmers with new technology on reproduction.

Livestock fair

Starting in 1969, the Ministry of Agriculture have held an annual quality contest for livestock (Korean Rural Economics Institute and Korea Animal Improvement Association, 1989). The contest selected and awarded superior male cattle by semen test and appearance test. It motivated farmers to raise quality livestock. Also the fair selected most of the sires for AI and young sires. Now that a sire selection system via performance test has been completely set up, less importance is given to quality contest but such contests should be continued as a farmers' festival.

Examinations on the Korean cattle improvement trends

Improvement trends examinations were conducted by the National Livestock Cooperative Federation to find out the nature and extent of Korean cattle improvement. Since 1974, Korean cattle available in the national cattle market were categorized by gender and year, and based on these two categories, weights and body measurements of 11 other body parts were measured in every third year. Table 3 presents specific data by category. With weight, the increment for male cattle was higher than that of females. Both male and female cattle showed more weight increment after 12 months. With physique, increment for male cattle exceeded that of females. The increment of rump width for both males and females was larger than other physique traits. However, it is hard to tell whether the increment over 24 years can be attributed to genetic improvement, or to determine the degree of improvement. The problem with the data is that the ages of cattle were not accurate. However, Won (1999) maintained that the increments may be combined results of general improvement of management of Korean cattle and utilization of selected sires. The data were used in the establishment of Korean cattle improvement bases to raise superior female cattle.

Management of Korean Cattle improvement bases

As a large number of foreign beef cattle were imported, a need to preserve the purity of Korean cattle arose. The Korean government designated 8 areas to establish bases to increase and improve pure Korean Cattle. Thus in these regions, pure breeding was practised with selected superior Korean cattle. Also planned breeding with dams was practised in these areas. These regions were to promote efforts of improvement of Korean beef cattle. Cattle for reproduction were selected from each region and these cattle became representatives of Korean cattle. After examining abilities and body shapes of these cattle, they were supplied with semen of selected sires. Female calves that passed necessary tests were considered as dams. Inferior female calves were sold

Table 2. Summary of recent artificial insemination industry

Year	Number of cows older than 18 months	Amount of fertilization	Amount of suppled semen (1000 straw)	Sire			Efficiency of sire[1]
				Registered sire	Proven sire	Total	
1983	-	-	-	-	-	-	-
1984	1,154	925	1,393	198	-	198	7.04
1985	1,200	982	1,504	189	-	189	7.96
1986	1,030	835	1,024	179	-	179	5.72
1987	872	784	1,029	142	18	160	6.43
1988	728	760	1,046	98	29	127	8.24
1989	729	768	1,067	75	47	122	8.75
1990	761	840	1,277	46	65	111	11.50
1991	855	967	1,583	26	82	108	14.66
1992	965	1,105	1,911	23	78	101	18.92
1993	1,066	1,166	2,020	16	91	107	18.88
1994	1,099	1,218	2,095	-	100	100	20.95
1995	1,217	1,330	2,360	-	98	98	24.08
1996	1,339	1,436	2,445	-	90	90	27.17
1997	1,219	1,178	1,838	-	69	69	26.64
1998	1,061	866	1,244	-	49	49	25.39

[1] Efficiency of sire=amount of supplied semen (1000 straw)/total number of sires.
(Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative Federation, 1999a).

for fattening. Male calves that pased tests were supplied for performance tests, or selling for fattening. Such measures aimed to improve beef production ability and attempt total improvement of Korean cattle as a whole. The Korea Animal Improvement Association established Korean cattle standard body shapes that surveyed sex, birth information, weight, shape of cattle, and recorded pedigree information from 1977 to 1988 in these 8 Korean cattle improvement bases. The data were used to identify common weaknesses of Korean cattle in these bases. Once common weaknesses or defects were identified, sires that could reduce such weaknesses were designated. With these sires, planned breeding was practised.

As of 1998, 115,000 registered cattle are managed at 250 improvement bases nationwide, and they produced 46,000 calves in the same year. These improvement bases will provide a foundation for performance testing projects and will play a major role in producing male calves used for performance tests. Also valuable data that enable researchers to evaluate genetic abilities will be provided through such facilities.

Projects for performance test

In the 1980s, performance testing became more systematic and now the testing consist of two parts:

Table 3. Body weight (kg) by ages and years

Year	Male						Female					
	N	3 Mo.	6	12	18	36	N	3 Mo.	6	12	18	36
1974	2,989	87.9	133.1	214.2	289.2	404.2	2,855	83.2	127.8	190.7	245.9	313.4
1975	2,990	88.4	138.0	218.8	305.7	413.9	2,834	83.1	130.8	194.0	250.8	323.2
1980	2,954	92.0	147.1	244.1	331.4	439.8	2,604	85.5	138.2	203.1	265.2	334.3
1983	2,830	94.9	157.4	259.7	361.5	463.6	2247	88.9	144.3	214.0	274.5	353.4
1986	2384	97.5	166.2	283.1	376.8	464.6	1,819	88.5	146.0	219.7	272.2	347.0
1989	2,770	103.7	183.8	399.0	419.2	419.2	1,755	86.3	143.8	240.4	294.7	370.2
1992	2,734	103.6	178.9	366.1	477.0	-	1295	89.2	144.2	242.3	308.7	384.5
1995	4,321	103.0	183.2	368.4	491.3	-	2,134	86.4	145.0	247.0	314.2	404.4
1998	5,011	102.4	176.4	368.3	505.0	-	3,093	84.4	138.4	240.1	315.3	396.6
Inc*		116.5	132.5	171.9	174.6	-		101.4	108.3	125.9	128.2	126.5

* Increment: (weight in 1974/that in 1998) × 100.
(Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative Federation, 1999a).

Table 4. Body sizes at 18 month by years (Unit : cm)

Year	Male					Female				
	Body height	Body length	Chest depth	Rump width	Chest girth	Body height	Body length	Chest depth	Rump width	Chest girth
1974	117.5	128.0	60.0	36.1	157.8	112.4	122.2	56.4	35.4	149.9
1975	117.7	129.4	61.5	37.1	161.7	113.1	122.6	57.7	36.0	150.9
1980	119.7	131.9	63.0	38.7	165.7	114.6	124.3	58.7	37.2	153.3
1983	121.0	133.4	64.5	39.2	169.6	115.3	124.8	58.9	37.3	155.8
1986	122.0	135.1	64.5	39.5	171.3	115.3	125.1	59.3	37.7	155.8
1989	122.6	137.6	65.3	42.0	177.0	115.8	127.6	59.6	38.1	158.0
1992	124.8	142.6	67.8	44.4	188.4	115.3	129.5	59.9	38.0	159.9
1995	125.3	145.2	68.3	45.5	189.0	115.5	129.7	59.7	38.1	160.0
1998	126.5	144.1	70.1	46.4	191.2	116.6	130.1	60.2	38.7	159.5
Inc*	107.7	112.6	116.8	128.5	121.2	103.7	106.5	106.7	109.3	106.4

*Increment: (size in 1974/that in 1998)×100.
(Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative Federation, 1999a).

Table 5. Standard body shape

Month of age	Body weight (kg)	Body height (cm)	Body length (cm)	Chest depth (cm)	Rump width (cm)	Chest girth (cm)
male						
0	25.21	667.15	57.62	26.68	13.73	68.93
	(26.85~ 24.29)	(68.86~ 65.44)	(59.51~ 55.74)	(27.90~25.47)	(14.58~12.88)	(71.08~ 66.78)
3	111.57	83.60	81.87	38.03	20.23	100.13
	(119.67~ 98.65)	(85.76~ 81.44)	(84.68~ 79.07)	(39.79~36.27)	(21.80~18.67)	(104.74~ 95.53)
6	197.92	101.52	108.80	50.37	28.69	134.04
	(212.49~173.00)	(104.53~ 98.52)	(113.76~103.91)	(53.04~48.27)	(30.84~28.47)	(141.37~126.39)
12	370.64	117.85	132.38	63.08	40.89	171.93
	(398.12~321.72)	(121.56~114.15)	(138.73~126.09)	(66.56~60.29)	(43.85~38.75)	(181.13~162.30)
20	466.06	124.12	141.35	68.79	47.07	190.12
	(531.83~401.14)	(128.06~120.18)	(147.63~135.07)	(72.64~64.74)	(50.62~43.77)	(200.00~180.43)
female						
0	24.73	66.78	57.85	25.47	14.25	68.02
	(25.58~ 23.63)	(68.48~ 65.08)	(59.75~ 55.95)	(26.62~24.31)	(15.14~13.36)	(70.14~ 65.89)
3	72.51	83.53	81.10	35.77	20.60	95.07
	(80.35~ 66.34)	(85.69~ 81.37)	(83.89~ 76.31)	(37.42~34.11)	(22.19~19.01)	(99.42~ 90.71)
6	120.31	96.60	97.36	42.82	25.68	115.59
	(135.12~109.05)	(99.44~ 94.47)	(97.39~ 89.57)	(44.59~41.04)	(26.11~24.01)	(117.29~110.40)
12	214.69	106.93	114.67	51.86	31.51	137.67
	(237.48~187.28)	(109.63~103.60)	(119.44~111.82)	(54.56~49.18)	(34.11~29.46)	(144.51~131.87)
18	278.89	113.22	125.26	57.22	35.38	150.63
	(303.65~234.20)	(116.30~109.19)	(132.08~122.67)	(60.46~54.00)	(38.89~32.93)	(159.53~143.85)
24	314.73	117.05	131.75	60.39	37.94	158.22
	(345.16~263.89)	(120.67~112.61)	(139.75~127.97)	(63.95~56.85)	(41.75~35.13)	(167.81~150.54)
36	345.89	120.79	138.15	63.38	40.77	165.29
	(387.53~294.55)	(125.42~115.98)	(145.83~131.80)	(67.23~59.54)	(44.48~37.43)	(174.90~156.36)
48	355.60	122.18	140.56	64.43	42.02	167.72
	(404.19~306.82)	(127.46~117.24)	(147.96~132.72)	(68.38~60.49)	(45.46~38.37)	(177.06~158.18)

( ) : Range.
(Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative Federation, 1999a).

performance test and progeny testing with male cattle. Performance test is to produce young sires, and the progeny test is to produce proven sires.

Performance test is conducted with male calves produced at the performance test centers and with male calves produced in animal farms within Korean cattle improvement bases. The 6-7 months old calves are monitored for 180 days for performance tests. Based on individual ability, these calves are selected as young sires. The center for progeny test determined proven sires among these young sires by testing male calves produced by these selected young sires and dams for 12 months. The male calves are monitored from 10 months old. In 1987 the first batch of 10 proven sires were selected and so far 235 proven sires have been selected. Only these sires provide semen.

The present performance testing system is as shown in figure 1. Presently, National Livestock Cooperative Federation conducts performance tests to select young sires, and the National Livestock Research Institute deals with progeny tests to select proven sires. Genetically superior 30 proven sires are bred with 1000 dams from the National Livestock Cooperative Federation and 2000 female cattle from the improvement bases. Then 1000 male calves are selected and they receive performance tests. One hundred calves that passed the tests become young sires. Then, these young bulls are mated with 5000 female cattle from animal farms in the improvement bases. Among the male calves from this breeding, the total of 1500 calves (15 calves per sire) are given progeny tests, and 100 young sires are selected in the first round. The goal of this project is to select 30 proven sires out of these 100 young bulls annually.

The performance test includes daily weight gain, yearling weight, feed efficiency, ability of semen production, and appearance. The traits examined for the progeny test are growth, and carcass traits of offspring from young sires. The selection equation for young sires includes standardized values for yearling weight (yw) and average daily gain (dg) during testing periods. The selection equation for proven sires includes standardized values for carcass weight (cw), marbling score (ms), and eye muscle area (ema).

Sire selection indices of Korean cattle:
Index for performance test = EBV(yw) + EBV(dg)
Index for progeny test = EBV(cw) + EBV(ms) + EBV(ema)

** EBVs are standardized expected breeding values

Table 6 shows the average estimates of Korean cattle tested as young sires. At the onset of the performance test, the average age was about 197 days, and their average yearling weight was about 363 kg.

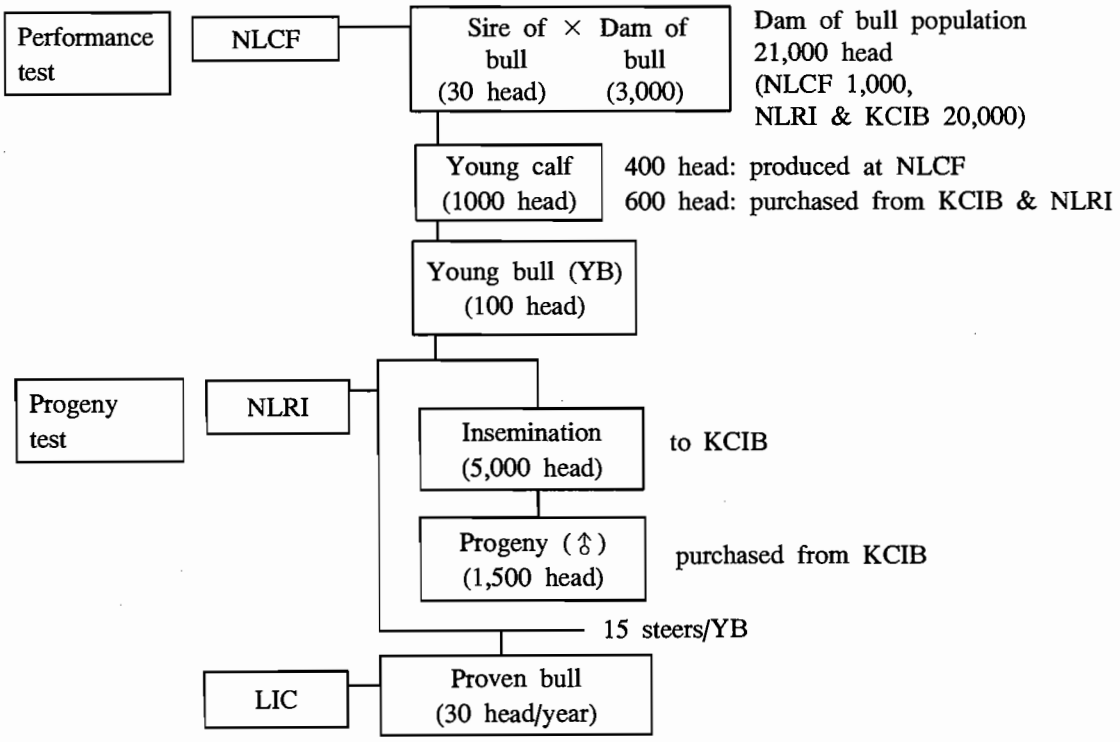

Figure 1. Schematic diagram of performance and progeny test of Hanwoo at station (KCIB: Korean Cattle Improvement Base, KAIA: Korean Animal Improvement Association, LIC: Livestock Improvement Committee, NLCF: National Livestock Cooperative Federation, and NLRI: National Livestock Research Institute) (Won, 1999)

The daily gain during the testing period was 1.13 kg, and the amount of TDN used for weight gain of 1 kg was about 4.51 kg.

Table 7 displays the results of progeny tests since 1995. Up to the first test of 1998, offspring of young bulls were not castrated, but from the second round, they were all castrated. The mean weights of offspring of young sires at the completion of testing were 525.5 kg in 1995, 559.3 kg in 1996, 602.32 kg in 1997, 577.8 kg in the first round in 1998, and 528.3 kg in the second round in 1998. Those of selected proven sires were 528.3 kg, 565.1 kg, 612.86 kg, 585.8 kg and 533.8 kg respectively. The selection differential for marbling degree in the first round in 1998 was 0.01 and that in the second round in 1998 was 0.23. The increase in the selection differential was large, and this was because the test was conducted after castration of young bulls.

Several problems with the current performance testing system have been pointed out:

- Difficulties in systematic selection and planned breeding because a majority of animal farms are small scale.

- It takes too long for selected sires to be put into use and thus results in a large generation gap.

Table 6. Mean values for results from tests on young sires

Item	Mean ± S.D.
Start age (day)	197.9 ± 4.8
BW at 12 months of age (kg)	363.3 ± 38.1
ADG (kg)	1.13 ± 0.16
Feed efficiency (TDN, kg)	4.51 ± 0.67
Body height (cm)	118.88 ± 4.89
Body length (cm)	134.27 ± 7.85
Chest depth (cm)	62.67 ± 2.89
Rump width (cm)	39.15 ± 3.81
Chest girth (cm)	172.92 ± 8.61

(Park, 1999)

- Operation of the current system is costly because of high costs incurred by purchase of male calves (30% higher price than the market price) and transportation, maintenance of testing facilities, and high cost labor. Consequently, the scale of testing has been limited, and the strength and accuracy of selection has been compromised (Won, 1999).

Carcass grading system

The carcass grading system became necessary as

Table 7. Results from progeny test

	'95	'96	'97	'98	
				1st	2nd
<Population>					
o Weight -at birth (kg)	25.3	25.0	24.4	23.5	23.8
- 6 months	144.5	147.6	154.3	149.5	133.0
-22 months	525.5	559.3	602.32	577.8	528.3
o Daily gain (kg)	0.85	0.92	0.92	0.84	0.73
o Carcass					
- Carcass rate (%)	58.60	8.05	59.53	60.2	56.57
- Marbling degree*	1.43	1.28	1.31	1.04	3.47
- Eye muscle area (cm^2)	76.76	82.41	86.70	85.47	73.23
<Selected group>					
o Weight-at birth (kg)	25.6	25.0	24.23	22.9	22.8
- 6 months	143.0	150.3	150.53	140.9	132.3
-22 months	528.3	565.1	612.86	585.8	533.8
o Daily gain (kg)	0.86	0.94	0.94	0.92	0.81
o Carcass					
- Carcass rate (%)	58.6	58.3	59.84	58.57	59.08
- Marbling degree	1.51	1.34	1.40	1.05	3.70
- Eye muscle area (cm^2)	76.93	82.51	88.14	86.97	73.77
<Selection differential>					
- 22 months (kg)	2.80	5.80	10.54	8.00	5.50
- Marbling degree	0.08	0.06	0.09	0.01	0.23
- Eye muscle area (cm^2)	0.17	0.10	1.44	1.50	0.54

* Marbling degree is on the scale of 1 (very low) to 5 (very high)

(Ministry of Agriculture and Forestry, National Livestock Research Institute, and National Livestock Cooperative Federation, 1999a).

consumers prefer high quality meat and because a more specialized meat distribution system has become established. Also, as the beef market was to open in 2001 and as market and distribution situations in the beef industry are changing, the Korean cattle industry is required to set up objective indices to grade carcass to compete in the rapidly changing market environment, and to enhance the quality of domestic meat (Animal Products Grading Service at National Livestock Cooperative Federation, 1999). The carcass grading system was launched at the National Livestock Cooperative Federation's joint market in Seoul in 1992, and now it has expanded its operation nationwide. The grading system has provided an important direction for improvement of Korean cattle because now researchers as well as farmers pay more attention to improving meat quality and to producing high quality meat. The grading procedures are as follows: carcass is stored in refrigeration for 24 hours after slaughter, then weight of cold carcass is measured. The grading system for meat quality is determined based on marbling degree, fat color, meat color, firmness, and maturity. There are 4 grades (1+. 1, 2, and 3) in which 1+ represents the best quality meat and 3 is the worst quality meat. Also grades are given for the amount of meat produced by a cattle. Three grades (A, B, and C) are used to evaluate the meat amount. The grade A represents the carcass having highest percentage of edible meat and C having the lowest percentage of edible meat. The meat amount grade is based on carcass weight, backfat thickness, eye muscle area, and etc.

As most of carcass is distributed after grading in Korea, the grading plays an important role in pricing. If the carcass receives a higher grade, it is sold at a higher price. Animal farms are striving for a better grade for their carcasses. Researchers make more efforts on identifying genetic characteristics of traits that are crucial for better grades such as backfat thickness, eye muscle area, and marbling degree. Table 8 shows the number of graded carcasses by year and sex. The number of graded carcasses was 49,000 in 1994, and the number has been constantly increasing. As of 1998, the number of graded carcass was 947,000. The number of total carcasses was 8.3% in 1994, but it stood at 90.4% in 1998. The graded rate is expected to increase because the grading is being expanded nationwide. Also the percentage of steers has been on the rise. This seems to indicate that animal farms practice fattening more with castration. It is because the fact that marbling degree is higher with castration became widely known to farmers.

Table 9 shows the number of carcasses by grade in 1997 & 1998. The percentage of meat quality 1+ was 0.5% in 1997 and 3.5% in 1998. The first grade meat (Grade 1 & Grade 1+) took only 18.4% in 1997 and 15.4% in 1998. As for the meat quantity, the A grade was only 16.9% in 1997 but increased to 42.7% in 1998.

Farmers became more interested in producing high quality meat and they requested specified standards for marbling score. At this point, the revision of meat quantity grading indices was required because of the increase of carcass weight as well as an increase of castration of male cattle (Animal Products Grading Service at National Livestock Cooperative Federation, 1998). Such matters brought about the new carcass grading standards and they were announced on the first of December, 1997. For example, the portion of A grade in meat quantity was 16.9% in 1997, and increased to 42.7% in 1998. That was due to the revision of meat grading indices in 1997.

Establishment of Goals for improvement

The Korean government determined specific goals to enhance Korean cattle's meat production abilities. A variety of projects have been conducted and the improvement goals have been changed periodically. Table 10 demonstrates the government's improvement goals for Korean cattle. The data were based on those of male cattle. They are as follows: (1) the increase of weight at 6 months and 18 months till 2001; (2)

Table 8. The number of graded carcass by year and sex

	'94		'95		'96		'97		'98	
	Number	%	Number	%	Number	%	Number	%	Number	%
Total	49,304	100.0	130,808	100.0	388,244	100.0	790,302	100.0	947,510	100.0
Female	15,179	30.8	49,985	38.2	153,796	39.6	421,652	53.4	470,765	49.7
Male	33,740	68.4	79,709	60.9	229,011	59.0	354,348	44.8	434,778	46.0
Steer	385	0.8	1,114	0.9	5,437	1.4	14,302	1.8	40,967	4.3
Total of slaughtered cattle (1000)	591		591		657		912		1,048	
Graded rate* (%)	8.3		22.0		59.1		86.6		90.4	

* Graded rate=(the number of graded carcasses/the number of carcasses) × 100.
(National Livestock Cooperative Federation, 1999a).

Table 9. The number of carcasses by grade

Grade		1997 (A)		1998 (B)		difference (B-A)	
		Number	%	Number	%	Number	%
Meat quality	1+	3,770	0.5	32,640	3.5	28,870	3.0
	1	141,731	17.9	112,865	11.9	-28,866	-6.0
	2	237,176	30.0	266,787	28.1	29,611	-1.9
	3	385,917	48.8	511,869	54.0	125,952	5.2
Meat quantity	A	133,773	16.9	404,639	42.7	270,866	25.8
	B	587,576	74.3	474,692	50.1	-112,884	-24.2
	C	47,245	6.0	44,830	4.7	-2,415	-1.3

(National Livestock Cooperative Federation, 1999a).

the increase of carcass rate; (3) the increase of loin area while maintaining backfat thickness; and (4) the increase of the 1 Grade carcass rate.

GENERAL ABILITIES OF KOREAN CATTLE AND ESTIMATES OF GENETIC PARAMETERS

Reproduction abilities of female cattle

Table 11 displays the mean estimates of reproduction traits of Korean female cattle. The data were obtained from female cattle that passed appearance tests (test points over 75) conducted during 24 months to 36 months old. Also these females' lineage were known and they had no genetically inferior traits. They were from 250 improvement bases. These calves stayed with their cows till weaned (3 to 4 months old), and cows were fed mostly with formula feed and rice straw. If necessary, they were fed with supplementary materials. Artificial insemination is performed to cows regardless of reproductive seasons.

The tested cattle were given the first service at around 438 days after birth, and the first calf was born around 25 months old (741 days). It takes an average of 1.41 AI for virgin cattle to produce the first calf. The next insemination after giving birth was on average 79 days later. For the first birth, the gestation length is about 285.6 days, and from the second birth, the period is about 286.8 days. Number of services per conception for multiparous cows is less than that for primiparous cows.

Table 10. Goals for Korean cattle improvement (Male cattle data)

Traits	1992	1997	2001	Yearly improvement
36 month weight (kg)	179	190	200	2.3
18 month weight (kg)	477	515	550	8.1
Carcass rate (%)	57.6	57.7	57.8	0.02
Backfat thickness (cm)	0.75	0.75	0.75-	
Loin area (cm^2)	75.8	76.1	76.4	0.07
1 Grade carcass rate (%)	15	30	60	5.0

(Ministry of Agriculture and Forestry and National Livestock Cooperative Federation, 1995).

Results indicated that the second birth is when cow's age is 1121 days (37.3 months). This means that if the time lag between the birth and the next pregnancy can be decreased, it can be possible that cattle can produce the second calf at 3 years old.

In addition, that fact that Korean cattle are managed in a relatively small place can be an advantage to reproduction efficiency. Research has shown that birth year and birth season were factors influencing Korean cattle's reproduction ability. Generally in recent compared with earlier birth years, cow's first birth has been at a younger age, and the time lapse between the first and the second birth has been shorter (Kim et al., 1997; Lee, 1999). Another influential factor to reproduction ability is the price of cattle in the domestic market. When the price dramatically went down in 1993, the first birth was

Table 11. Average reproductive traits of Korean Cattle with their standard deviations

Traits	Primiparous		Multiparous	
	n	X±SD	n	X±SD
Age at service (days)	27180	438.91±87.89		-
Age at calving (days)	〃	741.78±91.96		-
No. of services per conception	〃	1.41± 0.74	43358	1.36± 0.66
Days to service postpartum	-	-	43358	79.51±41.49
Calving interval (days)	-	-	43358	380.96±49.01
Gestation length (days)	27180	285.83± 5.43	43358	286.86± 5.21

(Kim, 1999)

delayed significantly compared to that in 1992. Also according to Kim et al. (1993), the reproduction abilities of cattle were weakened when the price of cattle was low during a cow price crisis period from 1986 to 1988. It may be that when the price was low, farmers might have shown less interest in reproducing, and resulted in delayed reproduction. Thus establishing stability in cattle price seems a necessary step to improve Korean cattle's reproduction abilities.

Milking abilities of cows

One of the weaknesses of Korean cattle is that the amount of milk produced is small and the milking period is short. Generally, suckling period is about 3-4 months. The insufficient amount of milk leads to low weaning weights of calves, and consequently results in lighter weights when they are sent to market. Thus to improve meat production ability, it is important to increase the amount and continuity of milking. Also considering that the price is determined by the weight of calves, weaning healthy calves should be done to improve profitability of cattle farming households. Research efforts have been made to enhance milking abilities at the Daekwanryeong branch of the National Livestock Research Institute.

Testing cattle give birth calves in spring or fall. In spring the delivery is around April - May, and the fall birth is about October - November. The current method that measures the amount of milk is as follows. The estimation is conducted every two weeks for four months after delivery. The amount of milk is measured twice a day. The 4 nipples are divided into two sides. On one side milking machines are installed and on the other side calves suckle. Calves and cows are separated one day before measuring the amount of milk. After milking, the measured amount of is considered to be half of the daily amount.

Table 12 presents least square means obtained from the average amount of milk daily produced up to 4 months after delivery by 134 cows. The daily average amount of milk ranged from 4.77 kg to 3.88 kg. A difference was found in the amount of milk depending on the season of delivery. Cows with spring delivery produced more milk that those with fall delivery. No significance was found for cow's delivery order. The amount was smaller for the cows with the first offspring than that with the second offspring. The larger amount from the cows with spring delivery may be due to the different state of feeds. In spring cows have grass whereas in fall they eat hay and silage. Also the accuracy of estimation may be an issue here. That is, due to incomplete milking, or cattle management in groups, sometimes other calves can take milk from a cow that is to be measured. In that case, the actual amount of milking is hard to estimate.

Fattening ability of male cattle

There have been many changes in Korean cattle's fattening pattern. In early 1990, the Korean cattle were sent to market at 18 months old. However, as the importance of quality meat is emphasized, the timing has been extended. Now many research reports suggest

Table 12. Least square means of daily milk yield (kg) postpartum at one (X1), two (X2), three (X3), and four (X4) months later by calving year, calving season, parity, and sex of calf (Unit : kg)

		X1	X2	X3	X4
Overall means		4.97±0.14	4.34±0.14	4.34±0.14	3.88±0.17
		**	**	**	**
Year	92	4.36±0.35	3.94±0.35	4.07±0.36	3.95±0.40
	93	5.87±0.30	5.14±0.31	4.94±0.34	4.38±0.45
	94	5.53±0.22	5.62±0.21	4.96±0.25	4.29±0.39
	95	4.12±0.27	4.08±0.26	3.52±0.29	2.84±0.31
	96	3.67±0.29	3.57±0.31	3.12±0.32	2.95±0.33
		NS	NS	NS	NS
Sex	Female	4.69±0.20	4.39±0.20	4.06±0.22	3.57±0.28
	Male	4.73±0.17	4.55±0.18	4.19±0.19	3.80±0.23
		**	**	**	**
Season	Spring	5.13±0.16	5.11±0.16	4.58±0.17	4.28±0.18
	Fall	4.29±0.23	3.83±0.22	3.67±0.24	3.08±0.35
		NS	NS	NS	NS
Parity	1	4.37±0.39	4.20±0.39	3.93±0.44	3.77±0.47
	2	4.64±0.20	4.41±0.20	4.01±0.22	3.77±0.26
	3	4.58±0.24	4.28±0.25	4.41±0.27	3.77±0.31
	4	4.87±0.33	4.47±0.32	4.20±0.35	3.31±0.44
	over 5	5.08±0.31	4.99±0.32	4.07±0.35	4.29±0.48

(Choi et al., 1999)

that it is desirable to send to market after 24 months old.

Daekwanryeong branch of National Livestock Research Institute conducted research to examine the effects of fattening cattle up to 24 months old. Table 13 shows results of fattening 60 head of spring birth and 45 head of fall birth up to 24 months old during the period of 1992-1996. The average age of tested carcasses was 756 days. The frozen carcass was cut between the 13th thoracic vertebra and the 1st lumbar. Backfat thickness and eye muscle area were measured. Marbling degree was divided into 5 grades. The results are given in table 13. The average birth weight was 26.1 kg, and the average weight at 18 months old was 576 kg. The average carcass weight was 410 kg. The average carcass rate was about 59.2%. Especially in case of the cattle born in 1996, the weight at 18 months old was 602 kg, that at 24 months old was 728 kg, the eye muscle area was 105 cm^2, and the carcass rate was 59%. Those estimates exceeded goals of improvement suggested in table 10. Consideration is needed whether non-castrated cattle should be raised till 24 months old. Especially the thickening of backfat may be a reason for poor grading of meat amount.

Fattening ability of castrated cattle

The Korea Animal Improvement Association is holding annual performance contests of Korean cattle in order to promote high quality meat production. Each farm raises a registered cattle in its own ways. The registered cattle should have a known lineage and be castrated at an early age. Also these cattle have to be sent out to market and to be slaughtered at designated places at a certain time.

Table 14 demonstrates results from the 1995 contest; 117 castrated cattle from 39 farms participated in this competition. These testing cattle were castrated on the average 156 days old. They were fed for about 556 days before they were sent to market. According to results of carcass quality grading, 74% of tested carcasses were first Grade, 24% second Grade, and 2% third Grade. In terms of meat quantity grading, A grade consists of 4%, B grade of 82%, C grade of 14%, a relatively high percentage (Lee, 1996).

One of the problems in raising castrated cattle is that an increase in cost due to the longer raising period. A careful decision should be made how long farmers raise cattle based on the economic concern. Lee (1998) has suggested several standards as to the raising period. According to performance testing scores, the means and standard deviations of backfat thickness, eye muscle area, marbling degree, and meat quantity were 1.09 ± 0.50, 78.52 ± 7.83, 12.09 ± 5.10, and 75.48 ± 1.31, respectively. He reported that castrated cattle should be raised at least up to 24 months old to improve marbling degree. It is because marbling degree of cattle younger than 22 months old is low and increases considerably till 24 months old. After that period, the increase of marbling degree was slow.

Performance of carcass traits

Table 15 presents average estimates of carcass traits from 11601 Korean cattle (female 1176, male 9989, steer 436) that had been carcass graded between September, 1995 and March, 1996. Steers had thicker backfat, superior marbling degree, higher carcass rate,

Table 13. Male cattle's fattening abilities

	Birth weight (kg)	18 month (kg)	24 month (kg)	BF[1] (cm)	EMA[2] (cm^2)	CW[3] (kg)	MS[4] (Grade)
Overall means	26.1±0.34	576.1± 4.1	692.0± 5.5	1.12±0.07	92.88±1.29	410.5±3.7	2.81±0.11
Year	NS	*	**	**	**	**	*
92	25.5±0.87	567.3±16.7	691.3±24.7	0.97±0.12	91.19±2.65	376.8±8.9	2.33±0.40
93	26.3±0.78	581.2± 8.4	666.5±11.3	0.83±0.10	84.46±2.38	397.7±8.0	3.42±0.24
94	26.2±0.72	567.4± 7.9	694.8±10.6	0.50±0.10	86.44±2.20	423.8±7.9	2.91±0.22
95	26.4±0.73	587.9± 8.0	715.7±10.7	1.15±0.10	94.84±2.25	423.0±7.5	2.51±0.23
96	27.6±0.90	602.6± 9.8	728.2±13.2	2.05±0.12	105.98±2.76	432.9±9.3	3.21±0.28
Season	NS	*	**	**	NS	NS	*
Spring	26.9±0.52	568.5± 6.2	677.5± 8.6	1.41±0.07	94.81±1.59	406.3±5.4	2.52±0.17
Fall	25.7±0.62	594.1± 7.4	721.2±10.2	0.94±0.08	90.35±1.19	415.4±6.6	3.22±0.20
Parity	**	*	NS	**	NS	NS	NS
1	24.1±0.69	569.0± 8.9	694.2±12.2	0.85±0.09	90.67±2.12	402.5±7.1	2.66±0.22
2	27.0±0.79	575.7± 9.4	703.4±12.7	1.19±0.11	93.34±2.43	414.1±8.1	2.94±0.26
3	26.4±0.81	608.4±10.3	716.7±13.8	1.36±0.11	91.84±2.49	410.9±8.3	2.73±0.28
4	28.3±0.85	575.3± 9.6	689.9±13.6	1.41±0.11	93.45±2.60	414.1±8.7	2.82±0.31
≥5	25.8±0.64	578.1± 8.1	692.6±10.9	1.04±0.09	93.60±1.97	412.6±6.8	3.23±0.23

* [1] Backfat thickness; [2] Eye muscle area; [3] Carcass weight; [4] Marbling score (1 to 5). (Jeon et al., 1999)

Table 14. Statistics of growth and carcass traits for steers

Traits	n	Mean	SD	Minimum	Maximum
WT (kg)	116	566.43	55.43	449	732
AGE1 (kg)	117	713.00	52.75	594	856
AGE2 (day)	108	556.45	46.45	474	722
CAGE (day)	108	156.01	52.79	29	288
ADG (kg)	116	0.76	0.07	0.55	0.95
CW (kg)	117	328.88	36.23	251	434

WT: live weight, AGE1: days to market, AGE2: feeding period, CAGE: days of castration, ADG: average daily gain, CW: carcass weight, n: number of observations, SD: standard deviation. (Lee, 1996)

superior meat quality compared with non-castrated cattle. However, inferior grades were on eye muscle area and meat quantity. These results were consistent with other research (e.g., Yun et al., 1994).

Characteristics of carcass traits for Korean cattle

Table 16 demonstrates least square means obtained from 550 Korean cattle (female 60, male 465, steer 25) after meat yields by part were measured. They were slaughtered and graded at the National Livestock Cooperative Federation's joint market in Seoul. The average carcass weight was 324.18±37.49, and the average carcass rate was 57.5%.

Steers' least square means of lean meat percentage, fat percentage, and bone percentage were 65.31, 21.88, and 12.80% respectively. When comparing these estimates with those of bulls, the lean meat percentage was 1.96% lower, yet the fat percentage was 2.39% higher. No significant difference was found in the born percentage between the two.

Cow's lean meat percentage and the bone percentage were lower than bull's, but the fat percentage was higher than bull's. A significant difference was found in the bone percentage between cows and steers.

Estimates of genetic parameters and breeding values for economic traits

Recently, records and research data have increased as Korean cattle's performance testing data have been accumulated and records on cows at improvement bases have increased. Table 17 shows genetic estimates of economic traits in Korean cattle. Traits that evaluate reproductive ability are days of age at first service, age of first calving, number of services per conception, gestation length, and calving interval. For cows to produce as many calves as possible, it is essential to induce an earlier first delivery, to improve conception rate, and to reduce calving interval.

Genetic estimates related to reproduction ranged 0.01-0.18, which is generally low. It suggests that not much selection effect has been found to improve reproduction traits. But effort to improve reproduction ability should be continued via improving breeding environment and selecting inferior cattle out of breeding groups. According to Kim (1999), the calving interval can be improved through efficient breeding management and weeding out infertile cows.

Table 18 shows recent data on the trends of breeding value estimates for Korean cattle. Estimates in this table were obtained from simple regression

Table 15. Least square means of carcass traits by sex

	BF (cm)	EMA (cm^2)	MINEX (score)	MS (grade)	DP (%)
Cow	1.180^a	75.346^b	75.269^b	11.296^a	56.610^c
Bull	0.659^c	80.874^a	76.521^a	4.277^b	57.661^b
Steer	1.095^b	75.846^b	75.196^b	11.375^a	58.124^a

* BF: backfat thickness; EMA: eye muscle area; MINEX: meat index=74.80-2.001×BF+.075×EMA-.014×carcass weight; MS: marbling score (1 to 15); DP: dressing percentage. (Lee, 1996)

Table 16. Least square means of carcass yield traits for sex, quality grade and quantity grade

Effect	Traits					
	LMP	FP	BP	Meat/Bone	Meat/Fat	Fat/Bone
Sex						
Cow	65.87 ± 0.49^b	21.67 ± 0.54^a	12.30 ± 0.14^b	5.35 ± 0.05^a	3.26 ± 0.13^b	1.79 ± 0.05^a
Bull	67.27 ± 0.26^b	19.49 ± 0.29^b	13.09 ± 0.07^a	5.16 ± 0.03^b	3.61 ± 0.07^a	1.51 ± 0.03^b
Steer	65.31 ± 0.63^b	21.88 ± 0.69^a	12.80 ± 0.18^a	5.12 ± 0.07^b	3.14 ± 0.17^b	1.74 ± 0.07^a

LMP : lean meat percentage. FP : fat percentage. BP : bone percentage. (Lee, 1996)

Table 17. Estimates of genetic parameters of economic traits in Korean cattle

Reproduction traits			Growth traits			Carcass traits		
Trait	Heritability	Reference	Trait	Heritability	Reference	Trait	Heritability	Reference
Age at first service	0.08 0.05 0.08	Kim (1999) Lee (1998) Kim and Graser (1997)	Birth Weight	0.13 0.17, 0.09 0.18, 0.11 0.15 0.12	Kim (1999) Won (1999) NLRI et al. (1998) Park et al. (1998) Lee et al. (1998)	Backfat Thickness	0.46 0.50, 0.17 0.52	Won (1999) Park (1999) NLRI et al. (1998)
Age at first calving	0.06 0.08 0.06	Kim (1999) Lee (1998) Kim and Graser (1997)	Weight at 3 months	0.46 0.26, 0.22 0.28, 0.27 0.26	Won (1999) Park (1999) NLRI et al. (1998) Park et al. (1998)	Eye muscle Area	0.23, 0.32 0.34 0.42	Park (1999) Won (1999) NLRI et al. (1998)
No. of services per conception	0.05, 0.01 0.01 0.05, 0.07	Kim (1999) Lee (1998) Kim and Graser (1997)	Weight at mature (over 22 months)	0.49 0.31 0.36 0.18	Kim (1999) Park (1999) NLRI et al. (1998) Kim et al. (1997)	Dressing percentage Marbling Score	0.13, 0.47 0.66 0.31 0.32 0.55	Park (1999) NLRI et al. (1998) Park (1999) Won (1999) NLRI et al. (1998)
Getation length calving Interval	0.05, 0.07 0.02, 0.11 0.18 0.01 0.03	Kim (1999) Lee (1998) Kim (1999) Lee (1998) Kim and Graser (1997)	Average daily gain	0.20, 0.21, 0.23	Park (1999)	Carcass weight	0.08, 0.31 0.36 0.55	Park (1999) Won (1999) NLRI et al. (1998)
			Total digestible nutrient efficiency	0.23	Park (1999)	Carcass length	0.21, 0.31	Park (1999)

analyses where the birth year is the independent variable and the breeding value estimates are the dependent variables. Kim (2000) showed, based on the data collected by National Livestock Research Institute, that regression coefficients are increasing as time goes by. Also Park (1999) obtained regression coefficients for yearling weight, and Won (1999) obtained statistically significant regression coefficients for weights at birth, at 6 months, at 18 months, and at sending to market. These collective results indicate that the weight of Korean cattle is genetically increasing as years go by.

In the case of marbling, Won (1999) obtained a significant regression coefficient of 0.006, but the estimate was too small. Park (1999) obtained an estimate of negative value close to 0. Such data show there are insufficient data to claim that marbling degree had been improved.

One piece of research on genetic improvement trends of reproduction ability is available to date. Kim (1999) reported that as time passed, the age of first service, and the age of first calving have been younger. Also the calving interval, and days to 1st service postpartum have been shorter.

CLOSING REMARKS

This paper took a historical look at the Korean cattle industry and surveyed effects of various projects to improve genetic abilities of the Korean cattle. Much effort has been devoted to improve Korean cattle performance and genetic advancement since the Korean cattle industry is important to the national economy as well as to farming households in Korea. Still we have many issues to deal with: (1) effective usage of improvement bases for the Korean cattle; (2) maintenance of a cost-effective performance testing system; (3) effective ways to improve marbling degree; (4) countermeasures for the increasing number of natural services; (5) plans for maintaining stable size of the Korean cattle groups. To solve these issues, more collective research is required.

Table 18. Trends of breeding value estimates of Korean cattle

Growth traits						
BW_0 (kg)	BW_3 (kg)	BW_6 (kg)	BW_{12} (kg)	BW_{18} (kg)	BWF (kg)	Reference
-0.030	0.040**	0.025	0.456**	0.579**	0.477**	Kim (2000)
-	-	-	0.375**	0.327	0.467	Park (1999)
0.010**	-	0.003**	0.500	0.762**	0.621**	Won (1999)
0.006**	0.081**	-	-	-	0.141**	Kim (1999)
Carcass traits						
CW (kg)	DP (%)	BF (cm)	EMA (cm^2)	MS (grade)		Reference
0.306**	0.001	0.000	0.048**	-		Kim (2000)
0.188	-0.006	-0.001	0.039	-0.000		Park (1999)
0.359	-	0.000	0.039**	0.006**		Won (1990)
Reproduction traits						
Age at 1st service (days)	Age at 1st calving (days)	Calving interval (days)	Days to 1st service postpartum (days)			Reference
-0.0473**	0.0313**	-1.3969**	-1.1274**			Kim (1999)

$BW_{0\ (3,\ 6,\ 12,\ 18,\ and\ F)}$: body weight at birth (3, 6, 12, 18 months, and slaughter (usually 22-24 months)); CW: carcass weight; DP: dressing percentage; BF: backfat thickness; EMA: eye muscle area; MS: marbling score.

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