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Carcass Characteristics and Profitability Analysis Based on Slaughter Age of Hanwoo Steers

Sang-Cheol Lee, Hyun-ho Choi, Jeong-Seop Shin, Kyoung-Hoon Kim, Young-Kyoon Oh and Dong-won Cheon*
National Institute of Animal Science, RDA, Suwon 441-350, Korea

ABSTRACT

This study analyzed optimal slaughter ages and carcass traits to investigate factors that affect farm incomes. Carcass characteristics and economical analysis of 81 Hanwoo steers previously tested (Expt. 1) and 5,826 steers from Gangwon-Do, area A (Expt. 2) were used. In Expt. 1, the strongest relationship was between the slaughter age and the carcass weight based on the R^2 value, and the weakest relationship was between the slaughter age and the marbling score based on the R^2. The slaughter age, marbling score, and rib-eye area of steers slaughtered from 26 to 31 months of age had a positive effect on income, but back fat thickness had a negative effect. In the economical analysis of Expt. 1, the optimal time for slaughter was 31 months of age. In Expt. 2, composed of steers slaughtered from 26 to 35 months of age in farms site of area A, the income was highest from steers slaughtered at 28 months of age, after which the income decreased. From the results of Expt. 1 and 2, it is evident that the optimal slaughter age of Hanwoo steers is affected by the genetic differences of calves, the feeding program and management, fattening skills, or carcass price. In order to improve the income of individual farms, the slaughter age must be precisely decided by understanding the exact relationship between the feeding cost of Hanwoo steers and slaughter results, such as carcass weight, yield grade and quality grade.
(**Key words :** Hanwoo steer, Slaughter ages, Carcass characteristics, Income)

INTRODUCTION

Since 2000, the Hanwoo industry has steadily delivered high quality products through improvements in the expansion of bull castration, breeding, and fattening technology. As a result, the number of the heads to feed has consistently increased because the consumer preference for Hanwoo meat has increased. However, the supply of Hanwoo beef now exceeds consumption, due to oversupply. In addition, the income of Hanwoo farms has decreased because the feed costs have continuously increased in recent years.

A majority of farms have extended the fattening period of Hanwoo steers to satisfy the taste of consumers and to get the best profit for each head. According to the survey results of The Statistics Korea (2012), the feeding period was increased a total of 225 days (from 502 days in 2001 to 727 days in 2011). As a result, the appearance-rate of above 1 Quality Grade increased by 31.7% between 2001 and 2011 (Korea Institute for Animal Products Quality Evaluation, 2012). The gross receipt per head increased because the fattening period was extended however, the feed cost and other costs increased approximately twice as much during the same period. Therefore, in 2010, the Ministry of Agriculture, Food and Rural Affairs (MAFRA) recommended a policy to reduce feed costs by shortening the fattening period, as the feed cost amounted to 49.5% of Hanwoo management costs, and the cost of feed grain was continuously unstable.

In previous studies of Hanwoo slaughter ages, Kim et al. (2005) reported no differences in weight gain based on the total digestible nutrient (TDN) level of the concentrate, the feed intake, or the carcass grade of Hanwoo steers under the same feeding management conditions. From analyzing the profitability of slaughter age (26-31 months of age) through product costs and calculating results of the meat quality/ quantity grade and the carcass weight, the income index was high, even when the slaughter age increased to 31 months of age. However, the optimal slaughter age of 29 months was advised considering the increased inedible fat and the inefficient feed intake per weight gain during late fattening.

Kim et al. (2002) also concluded that the appropriate age was 28 months according to an analysis of the marginal profits and costs during testing of slaughter ages at 24, 26,

* Corresponding author : Dong-won Cheon, National Institute of Animal Science, RDA, Suwon 441-350, Korea. Tel: 031-290-1772, Fax: 031-290-1225, E-mail: cdw1@korea.kr

and 28 months. The Korean feeding standard for Hanwoo (2012) showed that the appropriate time to maximize farm profits changed based on factors such as genetic traits, feed quality, management method for each feeding stage, and the auction price. Lee et al. (2010) reported that establishing a goal for slaughter ages is a dangerous policy because the appropriate age for the slaughter of Hanwoo steers is different between farms and individuals. However, they also reported the importance of conditions for reducing slaughter age, as if they are too long, feed costs increase such that farm profits decrease due to a low capital flow rate.

Still, many Hanwoo farms have a difficult time deciding the appropriate time to slaughter because they do not understand the correlation between the investment cost and the slaughter grades of individual Hanwoo steers for income improvement. Therefore, this study performed an analysis of slaughter ages and carcass traits to establish factors that affect farm incomes, and assessed the optimal slaughter age to improve farm incomes.

MATERIALS AND METHODS

1. Animals and experimental design

Experiment 1 (Expt. 1) was from our previous study (Kim et al., 2005) in which 81 Hanwoo steers purchased at about 6 months of age (average 167 kg for body weight) by the Livestock Improvement Main Center were slaughtered from 26 and 31 months of age. Operation cost and income are individually analyzed in present terms based on data of feeding and carcass grade.

For Experiment 2 (Expt. 2), the data on the feeding and carcass grade of 5,826 Hanwoo steers slaughtered in area A of Kangwon-Do with the same feeding program during 2010 to 2012 were used to determine the optimal slaughter period between 26 to 35 months of age.

2. Experimental diets, feeding, and management

In Expt. 1, the steers were fed certain amounts of concentrate and roughage at stages of growth and fattening (early, mid and late fattening stages) under the same feeding conditions. Steers fed orchard grass hay during the growth stage, fed rice straw (reducing grass hay) at a constant rate during the early fattening stage, and only fed rice straw after the mid-fattening stage. The concentrate was restricted to approximately 1.5% of body weight per day during the growth stage, gradually increased from 1.6% to 1.8% of body weight during the early fattening stage, and restricted to 1.8% of body weight during the mid-fattening stage. Steers were fed the concentrate ad libitum during the late fattening stage, and could access roughage freely during the entire experimental period.

In Expt. 2, the farms participating in this study used their own feeding program for high quality beef production. Steers were fed approximately 4~5 kg of the fermented feed during late fattening, which was gradually increased from 2 kg at the beginning of the period.

3. Measured items and analyses

In Expt. 1, feed intake was calculated based on the feeding management program of area A, and body weight was measured at 9 am once a month. The estimated carcass characteristics included carcass weight, back fat thickness, rib-eye area, and marbling score.

The gross income in economic analysis was calculated using carcass weight and auction costs by carcass grade according to Korea Institute for Animal Products Quality Evaluation in 2012. Management expenses included the cost of the animal purchased, feed costs, and other expenses (e.g., water utilities, animal disease treatment, material, selling fee etc.). Data on carcass weight, carcass grade, feed intake, and meat quality grade obtained from the two experiments (Expt. 1 and Expt. 2) were analyzed through multiple regression and significance tests using the SPSS statistics program. Management expense items from livestock production costs of the National Statistical Office (2012) were used.

RESULTS

1. Carcass characteristics

As shown in Table 1 for Expt. 1, the monthly average carcass weight increased consistently by 23.2 kg per month from 373 kg at 26 months of age to 489 kg at 31 months of age. In addition, the rib-eye area increased by 87.3 cm^2 at 26 months of age to 107.8 cm^2 at 31 months of age. The yield index, however, was significantly lower ($p<0.05$) at 28 months of age compared to 26 months of age because the back fat thickness consistently increased from 7.8 mm at 26 months of age to 14.8 mm at 31 months of age.

Table 1. Carcass characteristics of Hanwoo steers at different slaughter ages (Expt. 1)

Items	Slaughter ages (months)						
	26	27	28	29	30	31	SEM
No. of Head	10	16	7	14	18	16	
Starting age (days)	222	216	184	196	201	210	1.342
Slaughter age (days)	573	603	682	693	718	746	6.361
Fattening days	794	819	865	889	919	956	6.927
Cold carcass wt. (kg)	373^{d}	406^{c}	456^{b}	466^{ab}	475^{ab}	489^{a}	5.574
Yield grade[1)]							
A	8	9	2	5	5	4	
B	2	7	4	5	8	9	
C			1	4	5	3	
Back fat thickness (mm)	7.8^{d}	9.2^{cd}	10.9^{bcd}	11.2^{bc}	12.9^{ab}	14.8^{a}	0.476
Rib-eye area (cm^2)[2)]*	87.3^{d}	89.0^{cd}	94.4^{bcd}	95.7^{bc}	99.2^{b}	107.8^{a}	1.267
Yield index (%)[3)]*	68.9^{a}	67.5^{ab}	66.0^{bc}	65.7^{bc}	64.9^{c}	64.5^{c}	0.351
Quality grade							
1^{++}	3	5	4	2	3	1	
1^{+}	6	9	2	9	9	8	
1	1	2	1	3	6	7	
Marbling score[4)]	6.00^{ab}	6.06^{ab}	5.71^{b}	6.36^{ab}	6.72^{ab}	7.06^{a}	0.157

[1)] A : over 67.0 in yield index; B : 63.3~67.2 in yield index ; C : below 63.3 in yield index
[2)] Area was measured from the longissimus muscle taken at the 13th rib
[3)] Yield index = 68.184 − (0.625 × back fat thickness (mm) + (0.13 × rib-eye area(cm^2)) − (0.024 × carcass wt. (kg)) + 3.23
[4)] Grading ranges are 1 to 9 for marbling score with higher numbers for better quality (1 = devoid, 9 = abundant)
[abcd] Means with different superscripts in the same row and significantly different (P<0.05)

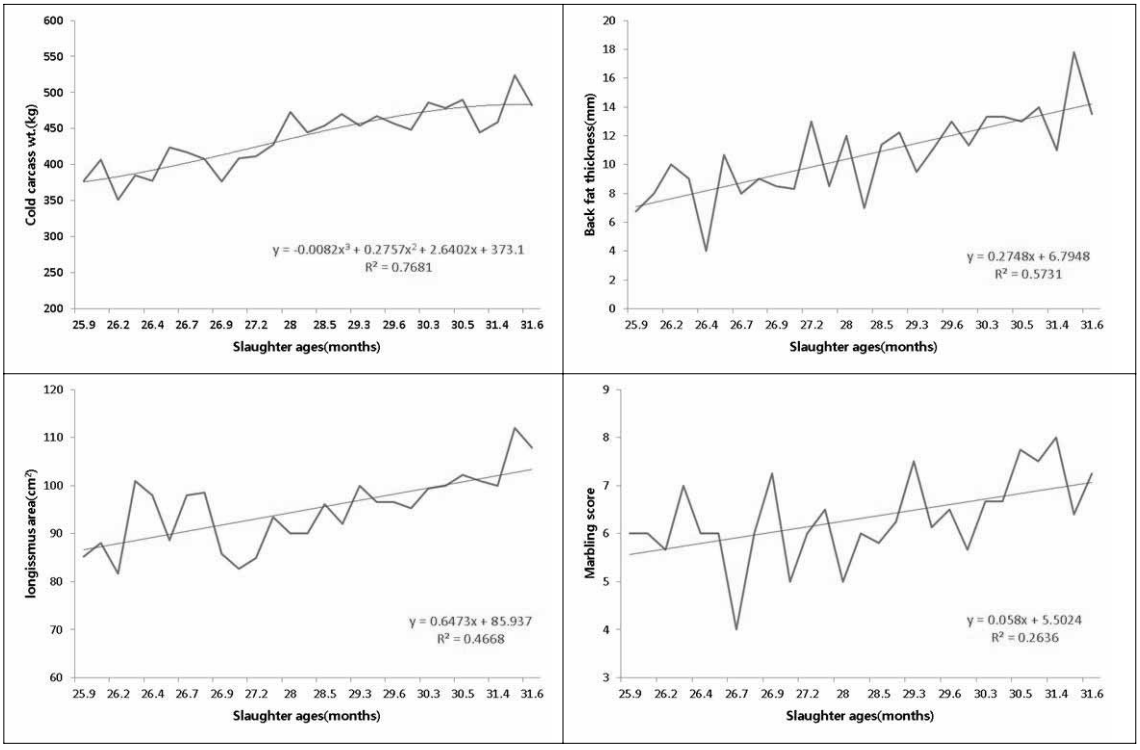

Fig. 1. Changes in the carcass characteristics of Hanwoo steers with slaughter ages in Expt. 1.

The marbling score did not change between 26 and 28 months of age, and increased between 29 and 31 months of age, but this was not statistically significant. This test showed 17.2% at a 1^{++} Quality Grade appearance rate, 55.2% at a 1^{+} Quality Grade appearance rate, and 20.7% at a 1 Quality Grade appearance rate. An appearance rate of more than 1 Quality Grade was 93.1%, 11.5% higher than the national average in 2012 (Korea Institute for Animal Products Quality Evaluation) for feeding heads from 26 to 31 months of age. The results for yield grade showed 40.2% at the A Grade, 42.5% at the B Grade, and 17.4% at the C Grade. The C Grade started to appear at about 28 months of

Table 2. Carcass characteristics of Hanwoo steers at different slaughter ages (Expt. 2)

Items	Slaughter ages (months)					
	26	27	28	29	30	31
No. of Head	122	164	369	738	1,092	1,192
Cold carcass wt. (kg)	394^{f}	399^{f}	421^{e}	429^{d}	435^{cd}	442^{bc}
Yield grade[1)]						
A	50	60	115	193	276	304
B	53	77	190	391	567	550
C	19	27	64	154	249	338
Back fat thickness (mm)	11.8^{d}	12.1^{d}	13.0^{c}	13.7^{bc}	14.0^{b}	14.6^{ab}
Rib-eye area (cm^2)[2)]	87.2^{d}	90.3^{c}	92.4^{b}	93.5^{ab}	93.9^{ab}	94.6^{a}
Yield index (%)[3)]	65.92^{a}	66.01^{a}	65.19^{b}	64.69^{bc}	64.40^{cd}	63.98^{de}
Quality grade						
1^{++}	13	25	66	146	230	261
1^{+}	39	51	123	259	416	428
1	36	49	120	227	313	353
2	29	35	55	101	126	146
3	5	4	5	5	7	4
Marbling score[4)]	4.9^{d}	5.2^{c}	5.4^{bc}	5.7^{ab}	5.8^{a}	5.8^{a}

Items	Slaughter ages (months)				
	32	33	34	35	SEM
No. of Head	892	644	404	209	
Cold carcass wt.(kg)	446^{b}	447^{b}	456^{a}	457^{a}	0.659
Yield grade[1)]					
A	208	140	87	47	
B	434	301	201	104	
C	250	203	116	58	
Back fat thickness (mm)	14.6^{ab}	15.1^{a}	15.1^{a}	15.2^{a}	0.073
Rib-eye area (cm^2)[2)]	94.6^{a}	94.4^{a}	95.1^{a}	94.4^{a}	0.144
Yield index (%)[3)]	63.87^{def}	63.53^{ef}	63.38^{ef}	63.24^{f}	0.05307
Quality grade					
1^{++}	220	149	90	43	
1^{+}	294	223	145	67	
1	268	198	123	73	
2	105	71	46	24	
3	5	3		2	
Marbling score[4)]	5.8^{a}	5.8^{a}	5.8^{a}	5.7^{ab}	0.026

[1)] A : over 67.0 in yield index; B : 63.3~67.2 in yield index ; C : below 63.3 in yield index
[2)] Area was measured from the longissimus muscle taken at the 13th rib
[3)] Yield index = 68.184 − (0.625 × back fat thickness (mm) + (0.13 × longissimus area(cm^2)) − (0.024 × carcass wt. (kg)) + 3.23
[4)] Grading ranges are 1 to 9 for marbling score with higher numbers for better quality (1 = devoid, 9 = abundant)
[abcdef] Means with different superscripts in the same row and significantly different ($P<0.05$)

age. The entire result of the yield grade was 6.9% higher than the 75.8% national average in 2012 (Korea Institute for Animal Products Quality Evaluation).

The relationship between carcass evaluation items (carcass weight, back fat thickness, rib-eye area, and marbling score) according to the slaughter ages is presented in Fig. 1. The carcass weight, back fat thickness, rib-eye area, and marbling score increased because of the increased slaughter age. The strongest relationship was between slaughter age and carcass weight based on the R^2 value, and the weakest relationship was between slaughter age and marbling score based on the R^2.

From Expt. 2, the slaughter percentage at each slaughter age (from 5,826 total heads) was the highest at 30 and 31 months of age, which combined to account for 39.2%. The percentage of those slaughtered was approximately 15.3% at 32 months of age, 12.7% at 29 months of age, and 11.1% at 33 months of age. Also, the slaughter percentage above 31 months of age was 57.3% of the total number (Table 2).

The carcass weight at each month of age tended to increase with slaughter age, but the increase was very low. The carcass weight above 31 months of age remained at 440~450 kg. Results showed that the increase for each month of age was lower than the test categories of Expt. 1. Back fat thickness tended to increase from 12.1 mm at 27 months of age ($p<0.05$), but leveled off at a thickness of approximately 15 mm at 33 months of age. Rib-eye area increased ($P<0.05$) from 87.2 cm^2 at 26 months of age to 92.4 cm^2 at 28 months of age, but there were no statistically significant gains from 29 months until 35 months of age. As a result, the yield index was low ($P<0.05$) above 28 months of age compared to 27 months of age.

The marbling score was about 5.4 at 28 months of age, and reached a level of 5.7~5.8 between 29 to 35 months of age. An appearance rate of more than 1^+ Quality Grade increased from 42.6% at 26 months of age to 59.2% at 30 months of age, but decreased to 52.6% at 35 months of age. The 1^{++} Quality Grade appearance rate was highest at 32 months of age (24.7%). The average appearance rate for above 1 Quality Grade was 5.0% higher than the national average in 2012 (Korea Institute for Animal Products Quality Evaluation) with 21.3% at the 1^{++} Quality Grade, 35.1% at the 1+ Quality Grade, and 30.2% at the 1 Quality Grade. The appearance rate of C Quantity Grade rapidly increased to 28.4% at 31 months of age and tended to increase with additional months of age.

Looking at the relationship between carcass evaluation items (carcass weight, back fat thickness, rib-eye area, and

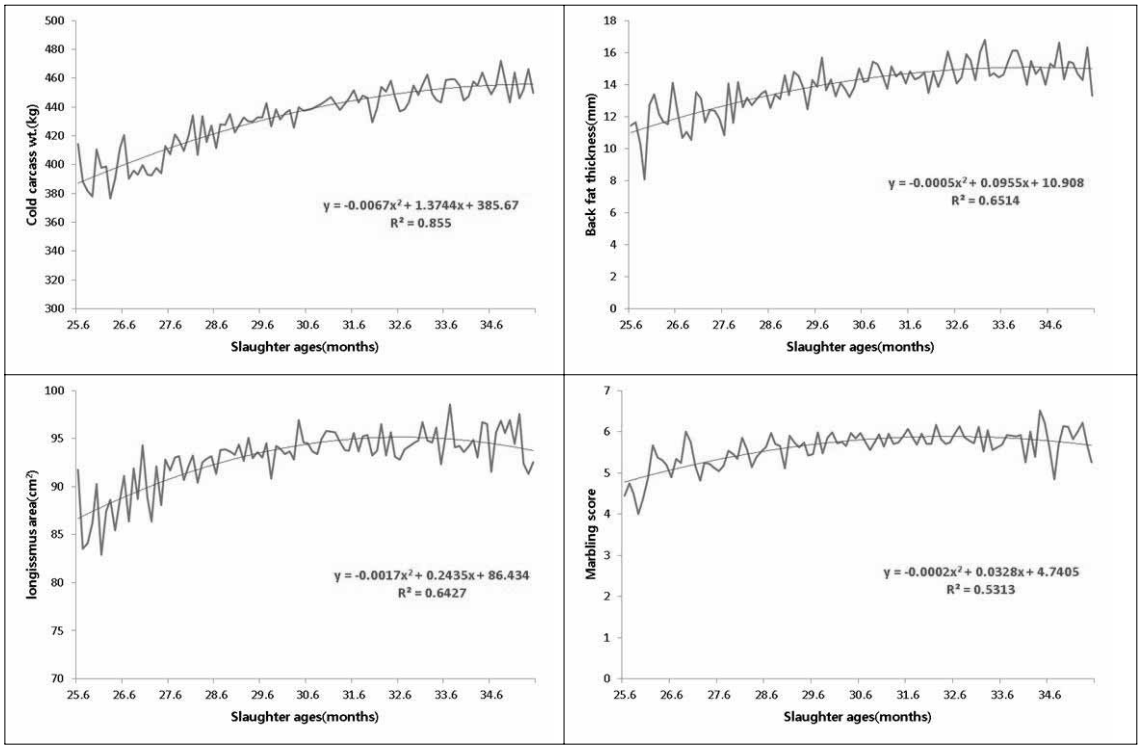

Fig. 2. Changes in the carcass characteristics of Hanwoo steers with slaughter ages in Expt. 2.

marbling score) according to slaughter ages (Fig. 2), carcass weight increased but back fat thickness, rib-eye area, and marbling score showed limited increases each month, followed by a limited growth period each month between 26 to 35 months of age.

2. Relationships between income, slaughter age, and carcass characteristics

For Expt. 1 and 2, multiple regression analysis was used to explore the relationship between income as the dependent variable and carcass characteristics (back fat thickness, marbling score, and rib-eye area) and slaughter age as the independent variables (Table 3).

The results of the analyses in Expt. 1 showed that slaughter age, marbling score, rib-eye area, and back fat thickness affect income ($R^2 = 0.763$, $P<0.05$ for the slaughter ages, marbling score, and the rib-eye area, and $p < 0.059$ for the back fat thickness). As shown in Table 3, the slaughter age, marbling score, rib-eye area had a positive effect from 26 to 31 months of age, such that income increased when these variables (factors) increased. Back fat thickness had a negative effect, such that income decreased when it increased. marbling score impacted income the most the marbling score was highest at 0.488 according to the parameter of these variables (standardized estimates) and the rib-eye area was the next highest at 0.424.

The relationship between income and slaughter age was analyzed from Expt. 2 (Fig. 3). According to the trend between income and slaughter age, the net balance was negative after 34 months of age because income decreased around 28 months of age (Table 5). The results of the analysis, based on the same variables assessed from 26 to 36 months of age in Expt. 1, showed that slaughter age, back fat thickness, marbling score, and rib-eye area affect income ($P<0.05$). The slaughter age negatively affected income, while back fat thickness, marbling score, and rib-eye area positively affected income. This indicated that income decreased according to the extended fattening period (35 months). Analysis showed that income increased when the back fat thickness, marbling score, and rib-eye area increased (standardized estimate is 0.629 based on marbling score and 0.321 based on rib-eye area). Back fat thickness had a lower positive effect (a negative effect on the auction unit price) on income with a standardized estimate of 0.075. An estimate of variables that affected income in Expt. 1 and 2 is shown below, and results on the relationship between slaughter during long period fattening (after the optimal slaughter age) and income can be found in Table 5.

<Expt. 1>

$Y = -4530.477 + 72.770X_1 + 260.827X_2 + 28.041X_3 - 22.341X_4$

R^2 : 0.763, Constant t : −6.536, X_1 t : 2.242, X_2 t : 7.677, X_3 t : 5.533, X_4 t : −1.917

<Expt. 2>

$Y = -564.186 - 138.396X_1 + 356.150X_2 + 32.335X_3 + 14.826X_4$

R^2 : 0.693, Constant t : −4.094, X_1 t : 33.893, X_2 t : 80.150, X_3 t : 40.711, X_4 t : 10.091

* Where; Y(income), X_1(slaughter age), X_2(marbling score), X_3(rib-eye area), X_4(back fat thickness)

Table 3. Multiple regression analysis of income, slaughter, and carcass charaecteristics

Model		Unstandardized estimates		Standardized estimates	t	P-value	Collinearity	
		B	Standard error	Beta			Common difference	VIF
Expt. 1	Constant	−4,530.477	693.174		−6.536	.000		
	Slaughter age	72.770	32.462	.182	2.242	.028	.450	2.222
	Back fat thickness	−22.341	11.654	−.127	−1.917	.059	.676	1.479
	Marbling score	260.827	33.976	.488	7.677	.000	.731	1.368
	Rib-eye area	28.041	5.068	.424	5.533	.000	.505	1.982
Expt. 2	Constant	−564.186	137.791		−4.094	.000		
	Slaughter age	−138.396	4.083	−.249	−33.893	.000	.977	1.024
	Back fat thickness	14.826	1.469	.075	10.091	.000	.959	1.042
	Marbling score	356.150	4.444	.629	80.150	.000	.856	1.169
	Rib-eye area	32.335	.794	.321	40.711	.000	.847	1.181

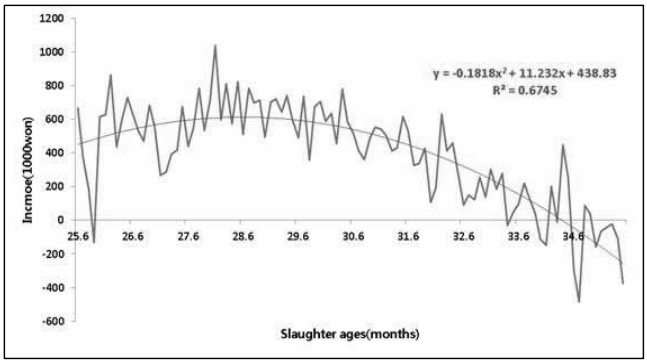

Fig. 3. Changes of income from Hanwoo steers with slaughter ages in Expt. 2.

3. Economical analyses of Hanwoo steers at different slaughter ages

The impact of slaughter age on the profitability of Hanwoo steers in Expt. 1 is shown in Table 4. The operating costs increased from 4,850 thousand won at 26 months of age to 5,794 thousand won at 31 months of age. However, income was highest at 2,153 thousand won at 31 months of age and continuously increased until 31 months of age because of an improvement in carcass grade and increased carcass weight. Therefore, the study of Expt. 1 clearly showed that feeding Hanwoo steers until 31 months of age, the final stage in the long period feeding management program, is the most profitable.

The impact of slaughter age on the profitability of Hanwoo steers in Expt. 2 is shown in Table 5. The income was highest at 714 thousand won at 28 months. Relative to 26 months of age, the income index was 142% at 28 months, 133% at 29 months, and 120% at 30 months, and decreased after 31 months. This was because the marbling score and rib-eye area, which affect carcass price, were limited after the optimal slaughter age (Table 2, Table 3, and Fig. 2). The carcass price decreased from its peak at 28 months of age and income was negative at 35 months of age when management costs, including feed costs, were continuously invested during the longest period of fattening. The average grade result in Expt. 2 was slightly better than the national average grade in 2012 (Korea Institute for Animal Products Quality Evaluation).

DISCUSSION

This study analyzed the correlation of main carcass characteristics of Hanwoo steers (carcass weight, back fat thickness, rib-eye area, and marbling score) to determine the optimal slaughter age. It also analyzed the relationships between slaughter age and carcass characteristics on income,

Table 4. Economical analyses for Hanwoo steers at different slaughter ages (Expt. 1)

Items	Slaughter ages (months)							
	26	27	28	29	30	31	Mean	SEM
Gross receipts (1000 won)	5,909	6,387	6,906	7,346	7,563	7,948	6,949	−
Carcass wt. (kg)	373^{d}	406^{c}	456^{b}	466^{ab}	475^{ab}	489^{a}	448	5.574
Unit price of carcass (Won/kg)[1)]	15,834	15,717	15,159	15,754	15,920	16,245	15,511	−
Operating cost (1000 won)	4,850	5,062	5,402	5,534	5,587	5,794	5,236	−
Hay[2)]	392	409	377	397	382	380	392	−
Rice straw[3)]	88	93	99	101	101	103	98	−
Concentrate[4)]	1,727	1,890	2,189	2,289	2,336	2,518	2,016	−
Livestock	2,152	2,152	2,152	2,152	2,152	2,152	2,152	−
Others[5)]	492	518	585	595	616	641	584	−
Income (1000 Won) (d)	1,059^{d}	1,325^{cd}	1,504^{bcd}	1,812^{abc}	1,976^{ab}	2,153^{a}	1,713	83.834
Index (%)	100	125	142	171	187	203	162	−

[1)] Auction price(won/kg) : A1^{++} 17,958, A1^{+} 17,302, C1^{++} 16,263, A1^{++} 16,087, B1^{+} 15,742, C1^{+} 14,682, A1 14,684, B1 14,434, C1 13,332, A2 12,387, B2 12,083, C2 10,964.
[2)] Orchard grass (won/kg) : 508. [3)] Rice straw(won/kg) : 130.
[4)] Concentrate (won/kg) : growing 423, early fattening 443, middle fattening 439, late fattening 444.
[5)] includes water, power&fuel, veterinary & medicine, repairing, small implements, interest on borrowed capital, rent, hired labor, depreciation, manure disposal, miscellaneous expenses.

Table 5. Economical analyses for Hanwoo steers at different slaughter ages (Expt. 2)

Items	Slaughter ages (months)					
	26	27	28	29	30	31
Gross receipts (1000 won)	5,671	5,838	6,279	6,434	6,568	6,639
Carcass wt. (kg)	394^{f}	399^{f}	421^{e}	429^{d}	435^{cd}	442^{bc}
Unit price of carcass (Won/kg)[2)]	14,384	14,623	14,927	15,000	15,098	15,028
Operating cost (1000 won)	5,168	5,367	5,565	5,764	5,962	6,159
Feed[1)]	2,524	2,697	2,870	3,043	3,216	3,389
Livestock	2,152	2,152	2,152	2,152	2,152	2,152
Others[3)]	492	518	543	569	594	618
Income (1000 Won)	503^{bcd}	471^{cd}	714^{a}	670^{ab}	606^{abc}	480^{cd}
Index (%)	100	94	142	133	120	95

Items	Slaughter ages (months)					
	32	33	34	35	Mean	SEM
Gross receipts (1000 won)	6,730	6,717	6,855	6,809	6,578	−
Carcass wt. (kg)	446^{b}	447^{b}	456^{a}	457^{a}	438	0.659
Unit price of carcass (Won/kg)[1)]	15,074	15,010	15,039	14,906	15,010	−
Operating cost (1000 won)	6,358	6,556	6,754	6,953	6,135	−
Feed[2)]	3,562	3,735	3,908	4,081	3,368	−
Livestock	2,152	2,152	2,152	2,152	2,152	−
Others[3)]	644	669	694	720	615	−
Income (1000 Won)	372^{d}	161^{e}	101^{e}	− 145^{f}	442	14.510
Index (%)	74	32	20	− 29	−	−

[1)] Auction cost (won/kg) : A1^{++} 17,958, A1^{+} 17,302, C1^{++} 16,263, A1^{+} 16,087, B1^{+} 15,742, C1^{+} 14,682, A1 14,684, B1 14,434, C1 13,332, A2 12,387, B2 12,083, C2 10,964

[2)] includes rice straw 130 (won/kg), concentrate (growing 423 (won/kg), early fattening 443, middle fattening 439, late fattening 444), Fermented feed (326 won/kg)

[3)] includes water, power & fuel, veterinary & medicine, repairing, small implements, interest on borrowed capital, rent, hired labor, depreciation, manure disposal, miscellaneous expenses.

the final goal of farms.

Expt. 1 analyzed feeding test results, adjusted to present price and carcass grade, from pedigree-registered castrated bull calves until 31 months of age. These calves were purchased by the Livestock Improvement Main Center of the National Agricultural Cooperative Federation. By restricted feeding until middle fattening and *ad libitum* feeding during late fattening, using those genetically superior calves, there is strong evidence that the optimal age for slaughter is 31 months of age for high feed efficiency across all stages of feeding. This age also leads to a high carcass weight and grade, and decreased management costs due to reduced feed costs. There were no tests, however, on whether giving the same amount of feed (as that given at 31 months of age) to steers during the shorter period fattening stage at 28~30 months or to steers during the longer period fattening stage at 31~35 months of age. Such tests are urgently needed.

Expt. 2 yielded results that analyzed the field data area A farms until 35 months of age. The fattening periods of each farm in the area are different from those of farms analyzed in Expt. 1. Based on the economic analysis results, the highest income was at 28 months of age (Kim et al., 2002) because the relationships between both marbling score and rib-eye area to the slaughter age showed similar trends. After 28 months, the net balance was negative because income decreased. Concluding that 28 months of age represents the optimal slaughter age is premature because the slaughter rate at 28 months is low (6.3%). In these results, however, the carcass grade did not improve, but rather decreased, by increasing the slaughter age. This evidence suggests that too many Hanwoo steers, slaughtered at 31 months of age on average, might not have an optimal carcass weight and grade at the time of slaughter. This may indicate that individual Hanwoo steers either have genetic differences or were raised

under different feeding conditions. Also, income may have appeared high because of the problem of cost increases due to high feed costs in area A would provide an advantage to the shorter slaughter ages. In other words, the advantage of a shorter slaughtering age appears when cost increases, due to high feed costs, are greater than the benefit of improving the carcass by increasing the fattening period. This also happens when the carcass price range between different grades decreases.

In the two experiments, marbling scores were not clearly different according to feeding time. There are several reports on changes in marbling score during the fattening period (Chung, 1997; Okumura et al., 2007, 2012; Yamazaki, 1981; Zembayashi et al., 1999). Zembayashi et al. (1999) reported that intramuscular fat increased up to 36.7 months of age in Japanese Black cattle. This report is supported by Okumura et al. (2012), in which an additional fattening period of 6 months, from 24 to 30 months of age, in Japanese Black steers resulted in an increase in intramuscular fat. On the other hand, Yamazaki (1981) reported that marbling increased linearly from 12 to 24 months of age; however, a remarkable increase from 24 to 30 months of age was not seen. In Korea, Chung (1997) reported that marbling in Hanwoo steers increased up to 26 months of age, but stopped increasing at 28 months.

Given the results of Expt. 1 and 2, it is evident that the optimal slaughter age of Hanwoo steers is affected by the genetic differences of calves, the feeding program and management, fattening skill, and carcass price. This agrees with the report by Lee et al. (2010) that an appropriate age to maximize profits could be different between farms and individuals (Korean feeding standard for Hanwoo, 2012).

In conclusion, to improve the income of individual farms, the slaughter age must be precisely decided by understanding the exact relationship between the feeding cost of Hanwoo steers and slaughter results such as carcass weight, yield grade, quality grade, and marbling score in the rib-eye of a live animal.

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