JAST (Journal of Animal Science and Technology) TITLE PAGE

Upload this completed form to website with submission

ARTICLE INFORMATION	Fill in information in each box below
Article Type	Research article
Article Title (within 20 words without abbreviations)	Effect of fattening period on growth performance, carcass characteristics, and economic traits of Holstein steers
Running Title (within 10 words)	Relationship of fattening period and productivity of Holstein steers
Author	Sung Il Kim1#, Sungkwon Park2#, Jung Hwan Myung3, Young Min Jo 4, Chang Bon Choi4, Keun Ki Jung5 # These authors contributed equally to this work.
Affiliation	1 Department of Animal Science, Gyeongbuk Provincial College, Yecheon 36830, Korea 2 Department of Food Science and Biotechnology, Sejong University, Seoul 05006, Korea 3 Deahan Livestock & Feed Co., Incheon 22300, Korea 4 Department of Biotechnology, Yeungnam University, Gyeongsan 38541, Korea 5 Moksan Hanwoo Research Institute, Gyeongsan 38507, Korea
ORCID (for more information, please visit https://orcid.org)	Sung Il Kim (https://orcid.org/0000-0003-3756-2800) Sungkwon Park(https://orcid.org/0000-0002-7684-9719) Jung Hwan Myung (https://orcid.org/0000-0002-0176-6740) Young Min Jo (https://orcid.org/0000-0002-7084-3551) Chang Bon Choi (http://orcid.org/0000-0001-8218-1914) Keun Ki Jung (https://orcid.org/0000-0002-5417-0238)
Competing interests	No potential conflict of interest relevant to this article was reported.
Funding sources State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available.	Not applicable.
Acknowledgements	Not applicable.
Availability of data and material	Upon reasonable request, the datasets of this study can be available from the corresponding author.
Authors' contributions Please specify the authors' role using this form.	Formal analysis, validation, and writing: S Kim, S Park Methodology and data curation: J Myung, Y Jo Conceptualization and validation: S Kim, C Choi, K Jung Validation and writing – review & editing: K Jung Writing - review & editing: S Park
Ethics approval and consent to participate	This article does not require IRB/IACUC approval because there are no human and animal participants.

CORRESPONDING AUTHOR CONTACT INFORMATION

For the corresponding author (responsible for correspondence, proofreading, and reprints)	Fill in information in each box below
First name, middle initial, last name	Sung Il Kim
Email address – this is where your proofs will be sent	sungkwonpark@hotmail.com

Secondary Email address	Ksi-30@hanmail.net
Address	Department of Animal Science, Gyeongbuk Provincial College, Yecheon 36830, Korea
Cell phone number	010-2402-6375
Office phone number	054-650-0341
Fax number	054-650-0342

6
7

Abstract

This study was conducted to investigate the effect of different fattening periods on the growth performance, carcass characteristics, and economic traits of Holstein steers. Sixty Holstein steers (8.0 ± 0.28 months old) with an average body weight (BW) of 231.88 ± 2.61 kg, were randomly allocated to five different fattening period treatments: 20, 21, 22, 23, and 24 months (n = 12 in each treatment group). Final BW and average daily gain (ADG) did not differ among the treatment groups during the early fattening period. At the late stage of the fattening period, the final BW of steers in the 24-month treatment group (812.84 kg) was greater ($p < 0.05$) than that of steers in the 20-month treatment group (750.39 kg). During the same period, steers in the 20- and 21-month treatment groups had a significantly higher ($p < 0.05$) ADG than those in the 22-month treatment group. The highest ADG (1.36 kg/day) was found in the 20-month treatment group (1.36), followed by the 21- (1.33 kg/day), 22- (1.22 kg/day), 23- (1.21 kg/day), and 24- (1.14 kg/day) month treatment groups. The feed conversion ratio (FCR) increased as the fattening period increased, and the FCR was 12.88% lower in the 20-month treatment group than in the 24-month treatment group. However, no significant differences were detected in back-fat thickness, loin area, marbling score, and chemical characteristics (water, crude protein, and crude fat content) among the treatment groups. The composition of fatty acids including C18:0, C18:1, saturated fatty acids, unsaturated fatty acids, and poly-unsaturated fatty acids did not differ among the experimental groups. As the fattening period increased, production costs increased, resulting in a decrease in gross income. The gross income for steers in the 24-month treatment group was 35.8% and 23.5% lower than that for steers in the 20- and 21-month treatment groups, respectively. Taken together, the best performance, including the ADG, FCR, and gross income, was obtained when the fattening program of the Holstein steers lasted 20 months.

Keywords (3 to 6): Holstein, steer, carcass characteristics, gross income, performance

Introduction

Hanwoo is the most consumed beef in Korea due to its superior meat quality. Holstein is mainly bred for milk production. Comparing the chemical composition of Hanwoo and Holstein beef, the crude fat content was not significantly different, but Holstein breed had a greater content of crude protein [1, 2]. Although Holstein is less popular with consumers than Hanwoo, the number of Holstein being fattened is increasing because of its greater mature body weight, more consistent and predictable daily gain as well as feed efficiency [1, 3]. Compared to Hanwoo of the same age, Holstein has a greater body weight including skeletal muscle and bone showing 1.3kg ~ 1.5kg more daily gain, but shows lower rate of intramuscular fat accumulation (marbling) in carcasses [4]. There is an increasing demand for male Holstein calves because they are cheaper and have shorter production cycle than Hanwoo steers. In 2020, 62,382 Holstein steers were sent to slaughterhouses, which is approximately 15.3% of the total number of Hanwoo steers slaughtered (405,785) [5]. However, the Holstein fattening system in Korea was recently modified with extended fattening period without considering the type of cattle or feed supplies, resulting in decreased feed efficiency and increased production costs [6]. Feeding and fattening strategies of Holstein steers then better be optimized to achieve improved growth performance and economic returns. Therefore, this study was performed to establish the optimal slaughter age by evaluating the growth performance, carcass characteristics, and profitability of Holstein steers slaughtered at different fattening periods.

Materials and Methods

Experimental animals and design

All experimental protocols were approved by the Institutional Animal Committee of Yeungnam University, Korea (approval #: YUH-12-0340-016). Each treatment group was allotted based on animal's body weight and age and the feeding period was from 387 days to 533 days at cattle farm located in Gyeongbuk province, Korea (Gunwi Chuk-Hyup). A total of 60 Holstein steers (8 months old and an

average weight of 231.88 ± 2.61 kg) were randomly allotted into 5 groups with different slaughter ages of 20, 21, 22, 23, and 24 months (12 steers per group).

Experimental diets

Experimental diets were formulated by an animal feed manufacturing company located in Incheon, Korea and divided into 2 stages including fattening (~10 month) and finishing (11 ~24 month) periods. Rice straw was used as the forage source. The chemical composition of the experimental diets is shown in Table 1, and the formula of the feed ingredients is shown in Table 2. Feeding program including the amount of concentrate and roughage used in the experimental diets was determined by growth stage and nutrient requirements of the steers (Table 3).

Feeding management

Steers in each treatment group were placed in 5.0 m × 10.0 m pens (three steers per pen), and assigned diets were administered twice per day. Steers were fed early fattening diets until they were 11 months old, and then switched to late fattening diets until slaughter. All steers had *ad libitum* access to water. Feed intake was recorded every day, and the steers were weighed every month throughout the experiment. Steers were cared for and managed according to traditional Korean farm regulations.

Carcass evaluation

At the end of the experimental period, steers were fasted for 24 h, and weighed and slaughtered at a commercial abattoir located in Daegu, Korea. Carcass characteristics were obtained after chilling for 24 h at 4 ℃. Carcass yield and quality were graded by meat graders using criteria provided by Livestock Quality Assessment [5].

Evaluation of carcass chemical composition

Sampling

Musculus longissimus dorsi (LD) muscles were obtained from the 12th and 13th rib sections and cooled at 0–5 ℃ for laboratory analysis. Samples were trimmed and then minced using a Hanil Mini Cooking Cutter (HMC-150T, Hanil Electronics, Seoul, Korea), and stored at -80 ℃ for cholesterol, melting point, and fatty acid composition analysis.

Chemical composition

The chemical composition of meat samples, including moisture, ash, crude protein, and fat content, were analyzed according to the AOAC methodology [7]. Moisture content (%) of loin muscle samples (2 g) was measured by homogenizing and drying the samples at 105 ℃ in an oven and measuring the weight loss during drying. Ash content was determined according to AOAC method using muffle furnace. Total lipids were analyzed using the Soxhlet extraction method. Crude protein content was measured using the Kjeldahl method. Briefly, loin samples (0.5 g) were digested at 450 ℃ for 5 h, distilled by addition of 50% sodium hydroxide (NaOH), titrated with hydrochloric acid (HCl), and the amount of protein was calculated by multiplying the % nitrogen (N) by 6.25 [8].

Meat color

Meat color of loin sample slices including Hunter L (lightness), a* (redness), and b* (yellowness), was determined using a Chroma Meter (CR-200, Minolta Corporation, LTD, Japan). The standard color used in this study was set to Y=94.5, x=0.3132, and y=0.3203 according to the manual, and three parts per sample were measured and expressed as an average value.

Cooking loss

Cooking loss was measured by calculating difference between raw sample weight and cooked sample weight. LD muscle samples that were approximately 0.5 mm thick and weighed approximately 25 g were wrapped in film and roasted in a water bath at 70 ℃ (center temperature) for 30 min. Samples were then cooled for 1 h, and cooking loss was determined using the amount of liquid removed.

Fatty acid composition of longissimus dorsi

Fatty acids composition was measured according to previous methods with modifications [9, 10, 11]. Briefly, approximately 3 g of each sample was put in liquid nitrogen, homogenized (Polytron PT-MR-2100, Kinematica AG, Lucerne, Switzerland) with chloroform:methanol (2:1, v/v), and filtered. Extracted FAMEs were then mixed with 2 mL methanol:benzene (4:1, v/v), 200 μL acetyl chloride, 1 mL isooctane, and 8 mL 6% potassium carbonate (K_2CO_3), and centrifuged at 1,200 x g for 10 min. The supernatant was analyzed by gas chromatography (Clarus 500, Perkin Elmer, Shelton, USA) equipped with a fused silica capillary column (Supleco SP-2560, 100m × 0.25 mm). One microliter of sample was injected at the split ratio of 100:1 at 250 ℃, nitrogen was used as a carrier gas, and a flame ionization detector (FID) was used to detect the signal at 270 ℃. The oven temperature was set at 170 ℃ for 5 min, increased to 220 ℃ (2 ℃/min), and held for 40 min.

Economic analysis

The feed costs for both concentrate and roughage used in this study were applied as the actual purchase price of the farm where the experiment was performed. The carcass selling price was computed as the average meat price based on the carcass grade during the slaughter period. Profits from by-products were also considered as economic values. Costs for purchasing the calves, expenses of bedding, medicine, utilities (water and heating), and castration were averaged based on the number of steers used in this experiment.

Statistical analysis

The Data was analyzed using the generalized linear model (GLM) procedure in SAS [12]. The differences between individual means were evaluated using Duncan's multiple-range test. The significance was considered at $P \leq 0.05$.

Results and Discussion

Growth performance

The growth performance of steers at different fattening periods is shown in Table 4. There was no difference in average daily gain (ADG) between groups, and BW during the early fattening period ranged from 370.82 to 381.24 kg. Final BW was highest ($p < 0.05$) in the 24-month fattening period group among other groups (812.84 kg). The ADG of the steers in the 20- and 21-month treatment groups were greater than that of steers in the 22-month treatment group during the late fattening period. The total weight gain increased ($p < 0.05$) as the fattening period increased. The average ADG of steers in the 22-month treatment group was lower than that of steers in the 20- and 21-month treatment groups, and average ADG values of steers in the 20-, 21-, 22-, 23-, and 24-month treatment groups were 1.36, 1.33, 1.22, 1.21, and 1.14 kg/day, respectively. During the fattening period, the feed conversion ratio increased as the fattening period increased (Table 5). Steers in 20-month treatment group had a 12.88% lower FCR than those in the 24-month treatment group. Maintaining the maximum growth rate is important for increasing the feed efficiency of Holstein steers [13] because ADG begins to decrease after 20 months of age [6]. The final BWs of Holstein steers are similar with previous study [6]. Taken together, these results indicate that Holstein steers in the 20- and 21-month treatment groups had better growth performance, including greater ADG and FCR.

Carcass characteristics

Carcass weight and back fat thickness were lowest in steers in the 20-month treatment group, and highest in steers in the 24-month group (Table 6; $p < 0.05$). There was no difference in loin-eye area, marbling score, meat color, fat color, nor texture between the treatment groups. In general, compared to Japanese black cattle (Wagyu), Holstein steers had greater carcass weight, and lower back fat thickness and marbling scores [14,15]. Cho et al. [16] demonstrated that 24 Holstein steers raised from 5 to 22 months had an average carcass weight of 463.6 kg, and an average marbling score of 2.1–3.6. The percent of quality grade over 1 was 16.33%, and the percent of quality grade over 2 was 74.97%–83.33%.

Physicochemical characteristics of carcass

Carcass moisture and crude protein content did not differ among the treatment groups (Table 7). The content of crude protein in LD muscle ranged from 10.78% to 11.76%, and there were no statistically significant differences between treatments. There were no significant differences in the meat color and cooking loss among the experimental groups. Holstein steers generally have a lower carcass fat content than other breeds [16]. Meat quality grade increases with higher fat content and marbling score. In contrast, moister and protein contents decreases with increasing quality grade [17, 18]. Similarly, cooking loss decreases as crude fat content increases [19] because thermal degradation of fat protects moisture from evaporation [20].

Fatty acid composition

Major fatty acid (C14:0, C16:0, and C18:0) content in beef did not differ significantly among the treatment groups (Table 8). There were no significant differences in one of the unsaturated fatty acids, C18:1, but C18:2 content was significantly greater ($p < 0.05$) in beef from steers in the 24-month treatment group than in beef from steers in the 20- and 21-month treatment groups. There were no significant differences in SFA, UFA, and PUFA contents among the treatment groups that agreed with previous studies showing no significant differences in C18:0, SFA, UFA, and MUFA in loin muscle samples of Holstein steers slaughtered at 18, 21, or 24 months of age [20, 21]. However, other studies reported different results, showing an increase in saturated fatty acids, including C16:0 and C18:0, as the fattening period increased [22], and decreases in UFAs such as C18:1 as the quality grade increased [23, 24]. This discrepancy might stem from the small effects of the fattening period on carcass quality grade found in the present study. The marbling score of Holstein steers was not affected by an increase in the fattening period from 20 to 24 months.

Economic analysis

The carcass sale price ranged from 3,844 to 3,996 thousand won (Table 9), and feed costs for concentrate and forage increased as the fattening period increased. Total operating expenses, including calf purchase

expenses, feed costs, slaughter costs, and other expenses increased, but gross income per head decreased as the fattening period increased. The gross income for steers in the 24-month treatment group was 35.8% and 23.5% lower than that of the steers in the 20-and 21-month treatment groups, respectively. This decrease in total revenue for steers in the 24-month treatment group is attributed to decreased ADG compared to steers in the 20- and 21-month treatment groups.

In conclusion, slaughtering Holstein steers at the age of 20–21 months is most profitable in terms of ADG, FCR, and gross income.

References

1. Hur SJ, Park GB, Joo ST. A comparison of the meat qualities from the Hanwoo (Korean native cattle) and Holstein steer. Food Bioprocess Technol. Springer; 2008;1:196–200.
2. Yim D-G, Chung E-G, Chung K-Y. Meat quality of loin and top round muscles from the Hanwoo and Holstein veal calves. Korean J food Sci Anim Resour. The Korean Society for Food Science of Animal Resources; 2015;35:731.
3. Grant RJ, Stock R, Mader TL. G93-1177 Feeding and Managing Holstein Steers. 1993G93-1177-A.
4. Sung.S.K., K.K. Jung., C.B. Choi., D.G.Kim., S.G. Kim., D.Y. Kim and B. J. Choi. Effects of castration and age on the carcass composition and retail yields of Hanwoo and Holstein. Journal of Animal Science and Technology. 1996,38(3):261-267.
5. Korean Institute for Animal Products Quality Evaluation. Sejong, Korea: KAPE: Annual Report for Animal Products Research. 2016.
6. Kang SW, Oh YK, Kim KH, Choi CW, Son YS. Study on Comparison of Growth Performance, Feed Efficiency and Carcass Characteristics for Holstein and F1 (Holstein♀ x Hanwoo♂) Steers and Heifers. J Anim Sci Technol. Korean Society of Animal Sciences and Technology; 2005;47:593–606.
7. AOAC. Official methods of analysis. (17th ed.) Association of Official Analytical Chemists; Gaithersburg, MD: 2000.
8. Giotto FM, Fruet APB, Nörnberg JL, Calkins CR, de Mello AS. Effects of Muscle and Finishing Diets Containing Distillers Grains with Low Moisture Levels on Fatty Acid Deposition in Two Novel Value-added Beef Cuts. Food Sci Anim Resour. The Korean Society for Food Science of Animal Resources; 2020;40:484.

9. Folch J, Lees M, Stanley GHS. A simple method for the isolation and purification of total lipids from animal tissues. J Biol Chem. American Society for Biochemistry and Molecular Biology; 1957;226:497–509.
10. Lepage G, Roy CC. Direct transesterification of all classes of lipids in a one-step reaction. J Lipid Res. Elsevier; 1986;27:114–20.
11. Choi SH, Park SK, Choi CW, Li XZ, Kim KH, Kim WY, et al. The expression of adipogenic genes in adipose tissues of feedlot steers fed supplementary palm oil or soybean oil. Asian-Australasian J Anim Sci. Asian-Australasian Association of Animal Production Societies (AAAP); 2016;29:404.
12. SAS. 2002. SAS User's Guide:Statistics. SAS Institute Inc. Cary. NC.
13. Comerford JW, Harpster HW, Baumer VH. The effects of grazing, liquid supplements, and implants on feedlot performance and carcass traits of Holstein steers. J Anim Sci. Oxford University Press; 2001;79:325–32.
14. Jung KK, Sung SK, Choi CB, Kim DG, Kim SG, Kim DY, et al. Effect of castration on the carcass grade of Hanwoo and Holstein. Korean J Anim Sci (Korea Republic). 1996
15. Matsuzaki M, Takizawa S, Ogawa M. Plasma insulin, metabolite concentrations, and carcass characteristics of Japanese Black, Japanese Brown, and Holstein steers. J Anim Sci. Oxford University Press; 1997;75:3287–93.
16. Cho W-M, Yang S-H, Lee S-M, Jang S-S, Kim H-C, Hong S-K, et al. Effects of different additives on the growth performance and carcass characteristics of Holstein steers. J Life Sci. Korean Society of Life Science; 2012;22:161–6.
17. Luchak GL, Miller RK, Belk KE, Hale DS, Michaelsen SA, Johnson DD, et al. Determination of sensory, chemical and cooking characteristics of retail beef cuts differing in intramuscular and external fat. Meat Sci. Elsevier; 1998;50:55–72.
18. Nelson JL, Dolezal HG, Ray FK, Morgan JB. Characterization of certified Angus beef steaks from the round, loin, and chuck. J Anim Sci. Oxford University Press; 2004;82:1437–44.
19. Armbruster G, Nour AYM, Thonney ML, Stouffer JR. Changes in cooking losses and sensory attributes of Angus and Holstein beef with increasing carcass weight, marbling score or longissimus ether extract. J Food Sci. Wiley Online Library; 1983;48:835–40.
20. Kim S Il, Cho BR, Choi CB. Effects of sesame meal on growth performances and fatty acid composition, free amino acid contents, and panel tests of loin of Hanwoo steers. J Anim Sci Technol. Korean Society of Animal Sciences and Technology; 2013;55:451–60
21. Kim. J. I. Physico- chemical meat properties and oxidative stability of Holstein steers by fattening period. Master's thesis in department of food science and biotechnology of animal products resources graduate school of Kon-Kuk university. 2012; pp.19-21.
22. Waldman, R.C., G.G. Suess and V.H. Brungardt. 1968. Fatty acids of certain bovine tissue and

their association with growth, carcass and palatability traits. J.Anim. Sci. 27:632

23. Smith SB, Yang A, Larsen TW, Tume RK. Positional analysis of triacylglycerols from bovine adipose tissue lipids varying in degree of unsaturation. Lipids. Wiley Online Library; 1998;33:197–207.
24. Issara U, Park S, Park S. Determination of fat accumulation reduction by edible fatty acids and natural waxes in vitro. Food Sci Anim Resour. The Korean Society for Food Science of Animal Resources; 2019;39:430.

Tables

Table 1. Chemical composition of concentrate diets and roughage

Composition	Concentrate		Roughage	SEM[1)]
	Fattening	Finishing	Rice straw	
Moisture	12.64±0.15[1)]	13.10±0.01	9.59±0.16	0.11
Crude protein	15.90±0.17	11.68±0.12	3.65±0.13	0.08
Crude fat	2.45±0.07	3.41±0.06	0.93±0.01	0.03
Crude fiber	9.82±0.04	10.15±0.04	31.80±0.20	0.09
Crude ash	4.38±0.09	3.31±0.07	9.43±0.06	0.07
NFE	54.84±0.43	58.46±0.07	44.59±0.44	0.31
Ca	0.45±0.01	0.39±0.01	0.19±0.02	0.01
P	0.37±0.01	0.30±0.01	0.15±0.02	0.01
TDN[2)]	72.00	76.00	37.60	

[1)] Standard error of the mean.

[2)] TDN: total digestible nutrient; calculated.

283 Table 2. Formula of concentrates

Item	Concentrate	
	Fattening	Finishing
	%, as-fed	
Ingredient		
Corn grain	33.50	31.50
Wheat	3.00	5.00
Wheat bran	15.50	16.50
Corn gluten feed	9.00	11.00
Soybean meal	7.50	4.50
Palm kernel meal	8.00	10.00
Coconut meal	11.00	8.00
Cotton seeds meal	3.50	4.50
Molasses	5.00	5.00
Salt dehydrated	0.50	0.50
Limestone	1.50	1.50
Vitamin premix[1)]	1.00	1.00
Mineral premix[2)]	1.00	1.00
Total	100	100

284

285

286

287

288

289 Table 3. Feeding program for Holstein steers in the experiment

Fattening phase	Age in month	BW (kg)	Feeding level (BW, %)	Concentrate fed (kg/head/day, as-fed basis)		Roughage fed (kg/head/day, as-fed basis)
				Fattening	Finishing	Rice straw
			%, as-fed			
fattening	7	255~300	2.13	6.4		2.0
	8	300~345	2.13	7.2		2.0
	9	345~390	2.18	8.5		2.0
	10	390~435	2.18	9.5		2.0
finishing	11	435~475	2.11		10.0	1.5
	12	475~515	2.14		11.0	1.2
	13	515~550	2.00		11.0	1.2
	14	550~585	1.88		11.0	1.2
	15	585~620	1.77		11.0	1.1
	16	620~650	1.69		11.0	1.1
	17	650~680	1.62		11.0	1.1
	18	680~710	1.55		11.0	1.0
	19	710~735	1.43		10.5	1.0
	20	735~760	1.38		10.5	1.0
	21	760~785	1.27		10.0	1.0
	22	785~810	1.23		10.0	1.0
	23	810~830	1.23		10.0	1.0
	24	830~840	1.20		10.0	1.0

290

291

292

293

294

295 Table 4. Effect of fattening period on performance of Holstein steers

Item	20 mo	21 mo	22 mo	23 mo	24 mo	SEM[1)]	P-value[2)]
No. of heads	12	12	12	12	12		
BW (kg)							
Initial (8 mo)	236.13	232.32	230.52	231.12	229.32	7.40	0.1342
Fattening (11 mo)	381.24	370.56	371.02	375.85	370.82	8.39	0.1219
Finishing (20~24 mo)	750.39^{b}	773.91^{ab}	776.30^{ab}	806.39^{ab}	812.84^{a}	14.29	0.0913
Average daily gain(kg)							
Fattening phase	1.30	1.23	1.25	1.29	1.26	0.04	0.1530
Finishing phase	1.39^{a}	1.36^{a}	1.21^{b}	1.18^{b}	1.10^{b}	0.03	0.0004
Overall period	1.36^{a}	1.33^{a}	1.22^{ab}	1.21^{ab}	1.14^{b}	0.03	0.0536

296 [1)] Standard error of the mean.

297 [2)] Probability of the F test.

298 [a, b] Means in the same row with different superscripts are significantly (P<0.05) different.

299

300

301

302

303

304

305

306 Table 5. Feed intake and feed conversion in Holstein steers

Item	20 mo.	21 mo.	22 mo.	23 mo.	24 mo.
<Fattening phase>					
Feed intake(kg/head/day)					
Concentrate	6.88	6.93	6.44	6.45	6.44
Rice straw	1.83	1.78	1.97	2.06	2.12
Sub-total	8.71	8.71	8.41	8.51	8.56
Feed conversion ratio, kg/kg	6.72	7.06	6.70	6.59	6.78
<Finishing phase>					
Feed intake(kg/head/day)					
Concentrate	12.39	12.19	11.77	11.64	11.46
Rice straw	1.55	1.53	1.46	1.41	1.47
Sub-total	13.94	13.72	13.24	13.05	12.93
Feed conversion ratio, kg/kg	10.03	10.09	10.93	11.06	11.75
Overall period					
Feed intake(kg/head/day)					
Concentrate	10.79	10.78	10.44	10.42	10.34
Rice straw	1.63	1.60	1.59	1.56	1.61
Sub-total	12.42	12.38	12.03	11.98	11.96
Feed conversion ratio, kg/kg	9.13	9.31	9.86	9.90	10.48

307

308

309 Table 6. Effect of fattening period on carcass characteristics in Holstein steers.

Item	20 mo.	21 mo.	22 mo.	23 mo.	24 mo.	SEM[1)]	P-value[2)]
<Body weight>							
Market wt., kg	750.39[b]	773.91[ab]	776.30[ab]	806.39[ab]	812.84[a]	15.01	0.0913
Cold carcass wt., kg	414.79[b]	434.42[ab]	423.50[ab]	442.92[a]	446.45[a]	8.57	0.0565
Carcass percentage, %	55.28	56.13	54.55	54.92	54.92		
<Yield traits>							
Backfat thickness, mm	5.14[b]	7.50[ab]	6.71[ab]	6.54[ab]	7.73[a]	0.80	0.1915
Longissimus area, cm^2	77.21	77.83	75.14	74.38	74.27	2.00	0.6249
Yield index	65.05[a]	63.19[ab]	63.59[ab]	63.13[ab]	62.29[b]	0.69	0.0869
Yield grade, (%)							
A	8.33	8.33	-	-	-		
B	91.67	83.34	91.67	91.67	66.67		
C	-	8.33	8.33	8.33	33.33		
Marbling score[3)]	2.86	2.50	2.79	2.77	2.55	0.41	0.9648
Meat color[4)]	4.64	4.58	4.93	5.08	4.82	0.17	0.2278
Fat color[5)]	2.07[b]	2.08[b]	2.57[a]	2.46[a]	2.09[b]	0.10	0.0020
Texture[6)]	1.79	1.83	1.93	2.00	1.91	0.06	0.4482
Maturity[7)]	2.00	2.00	2.00	2.00	2.00	0.00	-
Quality grade, (%)	1.79	2.08	1.79	1.92	2.00	0.21	0.8472
1^+	8.33	-	8.33	-	-		
1	25.00	33.33	25.00	25.00	16.67		
2	50.00	41.67	41.67	58.33	66.67		
3	16.67	25.00	25.00	16.67	16.67		

310 [1)] Standard error of the mean, [2)] Probability of the F test.

311 [3)] 9=the most abundant, 1=devoid, [4)] 7=dark red, 1=bright red.

312 [5)] 7=yellowish, 1=white, [6)] 3=coarse, 1=fine, [7)] 9=mature, 1=youthful.

313 [a, b] Means in the same row with different superscripts are significantly ($P<0.05$) different.

Table 7. Effect of fattening period on physicochemical characteristics of longissimus dorsi muscle in Holstein steers

Item	20 mo.	21 mo.	22 mo.	23 mo.	24 mo.	SEM[1)]	P-value[2)]
Moisture, %	66.74	66.51	66.64	66.92	67.59	0.86	0.4482
Crude fat, %	11.34	11.76	10.86	11.53	10.78	0.94	0.1865
Crude protein, %	20.06	20.01	20.80	20.24	20.91	0.36	0.2159
CIE value[3)]							
L[3)]	38.02[ab]	41.33[a]	38.66[ab]	40.27[ab]	36.74[b]	1.10	0.0890
a[3)]	19.86	21.01	20.42	21.03	21.88	0.78	0.4947
b[3)]	8.19[b]	9.82[a]	8.96[ab]	9.78[a]	9.18[ab]	0.47	0.1431
chroma	21.49	23.20	22.31	23.21	23.73	0.89	0.4674
hue	22.21[b]	25.03[a]	23.63[ab]	24.79[a]	22.58[b]	0.50	0.0013
Cooking loss	30.81	31.11	31.59	30.39	31.85	0.21	0.2316

[1)] Standard error of the mean.

[2)] Probability of the F test.

[3)] L=lightness, a=redness, b=yellowness.

[a, b] Means in the same row with different superscripts are significantly (P<0.05) different.

322 Table 8. Effect of fattening period on fatty acid of longissimus dorsi muscle in Holstein steers

Fatty acid, %	20 mo.	21mo.	22 mo.	23 mo.	24 mo.	SEM[1)]	P-value[2)]
$C_{14:0}$	3.47	3.38	3.47	3.14	3.03	0.16	0.2565
$C_{14:1}$	1.19	0.98	1.14	0.90	0.89	0.12	0.4083
$C_{15:0}$	0.31	0.30	0.31	0.29	0.29	0.02	0.9401
$C_{15:1}$	0.08	0.06	0.07	0.07	0.07	0.01	0.7391
$C_{16:0}$	28.07	28.12	26.13	28.29	25.98	1.09	0.4300
$C_{16:1}$	4.70	4.32	5.07	4.34	4.47	0.26	0.3257
$C_{17:0}$	0.74	0.72	0.85	0.72	0.82	0.07	0.5274
$C_{17:1}$	0.08	0.08	0.08	0.08	0.08	0.01	0.8293
$C_{18:0}$	11.11	11.89	11.87	11.10	11.44	0.67	0.8547
$C_{18:1}$	47.39	47.25	48.07	48.00	49.29	0.81	0.4365
$C_{18:2}$	2.661^{ab}	2.47^{b}	2.57^{ab}	2.79^{ab}	3.22^{a}	0.22	0.1745
$C_{18:3}$	0.05^{b}	0.05^{b}	0.09^{a}	0.04^{b}	0.06^{ab}	0.01	0.1571
$C_{20:0}$	0.09	0.11	0.12	0.11	0.12	0.02	0.7967
$C_{20:3}$	0.05	0.13	0.13	0.08	0.13	0.03	0.4735
$C_{20:4}$	0.05	0.21	0.25	0.15	0.17	0.06	0.2893
SFA[3)]	43.78	44.49	42.74	43.65	41.67	1.02	0.3842
MUFA[4)]	53.43	52.70	54.43	53.38	54.81	0.92	0.5157
UFA[5)]	56.22	55.51	57.26	56.35	58.33	1.02	0.3842
M/S[6)]	1.23	1.19	1.28	1.23	1.32	0.05	0.4226
U/S[7)]	1.29	1.25	1.35	1.29	1.41	0.06	0.3888

323 [1)] Standard error of the mean.

324 [2)] Probability of the F test, [3)] Saturated fatty acid.

325 [4)] Monounsaturated fatty acid.

326 [5)] Unsaturated fatty acid.

327 [6)] Monounsaturated fatty acid/Saturated fatty acid.

328 [7)] Unsaturated fatty acid/Saturated fatty acid.

329 [a, b] Means in the same row with different superscripts are significantly ($P<0.05$) different.

330 Table 9. **Effect of fattening period on performance** on profits in Holstein steers

Item	20 mo.	21mo.	22 mo.	23 mo.	24 mo.
		—— won / head ——			
Income(A)					
Carcass sales[1)]	3,857,152	3,844,466	3,875,604	3,996,319	3,871,994
Total income	3,857,152	3,844,466	3,875,604	3,996,319	3,871,994
Operating cost(B)					
Calves	1,025,000	1,025,000	1,025,000	1,025,000	1,025,000
Concentrate[2)]	1,003,010	1,082,864	1,118,962	1,189,761	1,244,074
Rice straw[3)]	189,285	200,535	213,123	223,230	242,982
Other cost[4)]	266,500	287,000	307,500	328,000	348,500
Total cost	2,483,795	2,595,399	2,664,585	2,765,460	2,860,556
Profit(A-B)	1,373,357	1,249,067	1,231,015	1,230,859	1,011,438

331 [1)] Carcass price, won/kg

332 (A1+=12,005, B1+=11,300, C1+=10,820, A1=10,930, B1=9,975, C1=9,200,

333 A2=9,350, B2=9,072, C2=8,182, A3=7,930, B3=7,775, C3=7,122)

334 [2)] Concentrated price, won/kg(Fattening : 249.7won/kg, Finishing : 238.0won/kg)

335 [3)] Rice straw price: 300.0won/kg

336 [4)] Hired labor, bedding materials, electricity, transport, water service and veterinary medicine.