Effects of Vitamin A on Carcass Composition Concerning Younger Steer Fattening of Wagyu Cattle

T. Nade*, S. Hirabara, T. Okumura and K. Fujita
National Livestock Breeding Center, Nishigo-mura, Fukushima 961-8511, Japan

ABSTRACT : Regarding the fattening of younger cattle that the Ministry of Agriculture Forestry and Fisheries (MAFF) recommends in Japan, this study looked at vitamin A control in feed and blood and its effect on performance of production and carcass composition of Wagyu steers. Five sets from 10 Wagyu artificial identical twins were divided to into 2 groups, a restricted group (Test) and a supplied group (Control). The body weight at the finishing time of the Test was significantly lower than that of the Control ($p<0.05$). The daily gain from 13 to 21 months old, as the animals in the Test were fed the concentrated feed without Vitamin A, was significantly different ($p<0.05$) between the Test and the Control. The total daily gains for the Test and the Control for the fattening period were 0.82 kg/day and 0.93 kg/day, respectively, which showed a significant difference ($p<0.01$). Regarding the rib thickness, the Test was thinner than the Control. The Beef Marbling Scores of the Test and Control were 3.60 and 2.80, respectively. The muscle weight of the Test was significantly smaller than that of the Control ($p<0.01$). However, regarding the ratio to the carcass, the Test was significantly higher than the Control ($p<0.05$). For the fat weight, the Test was smaller by about 15 kg than the Control ($p<0.01$). Furthermore, for the fat ratio to the carcass, the Test was significantly lower than the Control ($p<0.05$). The bone weights of the two groups were approximately the same. Regarding the ratio of bone to carcass, the Test was higher than the Control ($p<0.01$). For the younger fattening method, the low level vitamin A in the serum had the effect that the muscle ratio to the carcass weight was greater and the fat was less, but the carcass and muscle weight were less. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 3 : 353-358)***

Key Words : Wagyu, Younger Fattening, VA, Carcass Composition

INTRODUCTION

In the Japanese market, beef carcass value depends greatly on the marbling scores, and the meat with a high degree of marbling is preferable. As a result, the fattening period for beef cattle (Wagyu) has become longer in Japan than in other countries; having now reached approximately 30 months old in Japan. Since the profits are becoming lower using a method of fattening like this, the Ministry of Agriculture and Forestry Fisheries (MAFF) in Japan recommends a shorter fattening period and a younger finishing time. However, it is difficult to produce meat with much marbling using this fattening method. In Japan, the short fattening method has hardly spread yet.

It has been said for some time that fattening using a lower level of vitamin A (VA) in the serum produced a lot of marbling in the meat (Oka, 1998). On the other hand, it is important to note that VA influences the growth, visual function and generative function of the animal negatively. Also, a VA decrease exceeding the limit in beef cattle shows a falling off of the appetite, blindness, edema of the joints and various other signs of degeneration. Thus, it was difficult to control the VA concentration of beef cattle.

Recently Kinoshita et al. (1999) reported that a lower level of VA in the middle period of fattening produced a lot of marbling in meat and produced effectively higher profits. Thus, the method of fattening using a controlled level of VA concentration in the blood has spread throughout the whole of Japan. This fattening method is now normal in Japan.

We thought that the younger fattening method added to VA control would be more profitable than the present method for business. Recently, not only a beef carcass which has a high degree of marbling but also that which has bigger weight and/or higher yield is preferred in the Japanese market. However, until now, the VA influence on carcass composition and production performance of younger fattening steers in Japan has not been studied at all to any depth. Regarding the fattening of younger cattle that the ministry recommends, this study will look at VA control in feed and blood and its effect on carcass composition and performance of production of Wagyu steers, which are identical twins produced artificially and have identical genes.

MATERIALS AND METHODS

Animal and diet

Five sets from 10 Wagyu artificial identical twins were divided between 2 groups, a restricted group (Test) and a supplied group (Control). Each set of them was produced from a cow into which were transferred 2 embryos artificially split from one using super ovulation.

The animals were fattened between 7 and 24 months old. They were fed the concentrated feed containing TDN

* Reprint request to: T. Nade. Tel: +81-248-25-6165, Fax: +81-248-25-3990, E-mail: t0nade@nlbc.go.jp
Received June 10, 2002; Accepted November 7, 2002

72.5% and CP 14.3% from 7 to 12 months old, and then TDN 73% and CP 12.3% from 13 to 24 months old (Table 1). They were also fed hay containing timothy from 7 to 12 months old, and then rice straw from 13 to 24 months old. The VA content of the feed was not measured.

The animals in the Test were fed the concentrated feed containing the 50% VA level compared with the Japanese Feeding Standard for Beef Cattle (1995) from 7 to 12 months old, and from 22 to 24 months old. The animals in the Control were fed the concentrated feed containing the 50% VA level compared with the Japanese Feeding Standard for Beef Cattle (1995) from 7 to 24 months old. VA wrapped in rice bran (VA material, BASF CO., Tokyo) was used for this study, and it contained 500,000 IU per kg.

Growth performance

The body weights were measured every month from start to finish of the fattening period. Daily gains were calculated at each stage of VA supply for the Test.

VA concentrations in serum were also measured by HPLC with a UV detector every month along with the weights.

Carcass characteristics

The animals were slaughtered at 24 months old and the carcasses were graded by the Japan Meat Grading Association (JMGA, 1988) in the slaughter house; the left side of the carcasses were then transported to our center. At that point, the carcasses were dissected into muscle, fat and bone. The total weights of these and their ratio to the carcass were measured. Next, the 6 principal muscles (*M. semitendinosus*, *M. semimembranosus*, *M. iliopsoas*, *M. latissimus*, *M. longissimus* and *M. supraspinatus*) were measured for weight and the ratio to total muscle. Furthermore, the 3 parts of the fat, as the subcutaneous fat, intermuscular fat and abdominal wall and perirenal fat, were measured for weight and the ratio to the total fat.

Statistical analysis

Five sets of artificial identical twins were divided in this study. We were able to regard two steers of a set as the same animal because they have the same abilities and genes. Since the study used artificial identical twins and so was able to remove the genetic influence, it was more highly precise than a study using many animals (H. Hirooka, 1991). The differences in data between the Test and Control were calculated using the Paired T-test.

Table 1. Ingredient composition of concentrated feed (%)

	Feeding periods	
	7-12 mon. old	Old-finishing
Corn	20	30
Barley	50	45
Wheat bran	20	20
Soybean meal	9	4
Calcium carbonate	1	1
TDN	72.5	73.0
CP	14.3	12.3

RESULT AND DISCUSSION

Growth performance

The body weights at the starting time of the Test and the Control were 200.4 kg and 189.6 kg, respectively. The body weight of the Test showed a tendency to be higher than that of the Control ($p=0.098$, Figure 1). The body weights of the Test and the Control were the almost same at 15 months old, 8 months after the starting time. The degree of increase in the body weight of the Test then became reduced, and the difference between the body weight of the Test and the Control increased month by month. The body weights at the finishing time of the Test and the Control were 634.2 kg and 678.8 kg, respectively; hence, the body weight of the Test was significantly lower than that of the Control ($p<0.05$). As Table 2 shows, the daily gain from 7 to 12 months old of the Test and the Control were 1.01 kg/day and 0.99 kg/day; thus they were approximately the same. However, the daily gain from 13 to 21 months old, during which the animals of the Test were fed the concentrated feed without VA, was significantly different ($p<0.05$), i.e., the Test was lower than the Control. Their daily gains were 0.75 kg/day and 0.93 kg/day, respectively. In the period from 22 months old to the finishing time during which the animals of the Test were fed the concentrated feed with VA

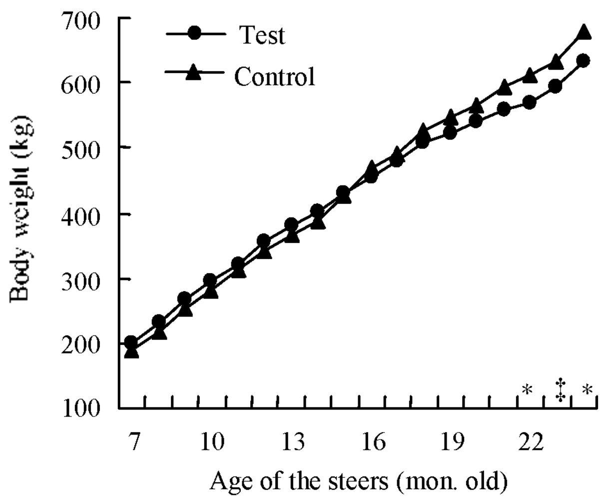

Figure 1. The body weight of the steers fed diets of restricted (Test) and supplied (Control) vitamin A during the fattening period
* p-value at the age<0.05
‡ p-value at the age<0.01

Table 2. The daily gains in the steers at each stage of vitamin A supply for the Test (kg/day)

	Test	Control	Significance
Start-12 mon. old	1.01±0.03	0.99±0.05	ns
13-21 mon. old	0.75±0.02	0.93±0.03	*
22 mon. old-finish	0.71±0.07	0.80±0.05	*
Start-finish	0.82±0.02	0.93±0.03	**

[1)] Means±Standard error.
ns: p>0.05, * p<0.05, ** p<0.01.

again, the daily gain of the Test did not further decrease, but rather the Control decreased. However, there was still a significant difference between the groups (p<0.05). Concerning the total daily gain for the fattening period, the Test and the Control were 0.82 kg/day and 0.93 kg/day, respectively, which shows a significant difference (p<0.01). As Figure 2 shows, the level of VA in the Test decreased dramatically from 2 months after being fed concentrated feed without VA. We guessed that the animal began to consume the VA in the blood, because the accumulated VA in the liver was exhausted. At 15 months old, the Test value was 22.9IU/dl, which was the level of VA deficiency disease (Kohlmeier and Burroughs, 1970). Since some animals in the Test showed a falling off of appetite and blindness with a low level of VA, the animals were then fed the concentrated feed with the 50% added VA value for 2 weeks. When the all animals in the Test were fed the concentrated feed with VA again, the level of VA in the Test increased dramatically. The level of VA in the Test became approximately the same as that in the Control.

The decrease in the body weight and daily gain of the Test coincided with the lower level of VA concentration.

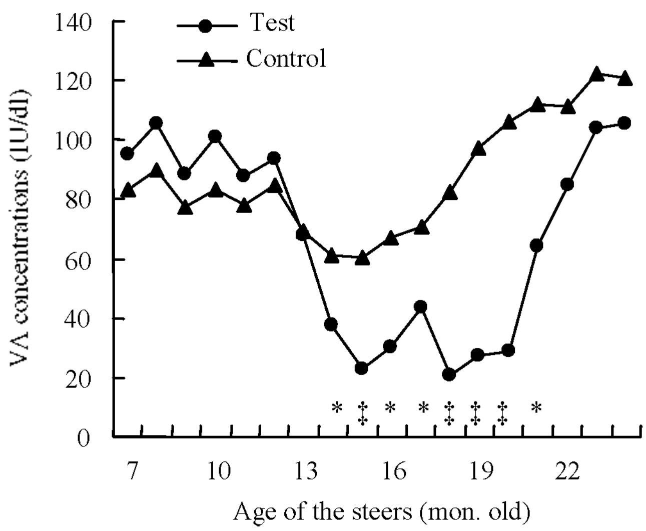

Figure 2. Vitamin A concentration in serum of the steers fed diets of restricted (Test) and supplied (Control) vitamin A during the fattening period.
* p-value at the age<0.05
‡ p-value at the age<0.01

The lower level of VA concentration in the blood caused a decrease in the growth of the animal (Kohlmeier and Burroughs, 1970; Oka et al., 1998; Oka et al., 1998). In this study, the 50% VA level compared with the Japanese Feeding Standard for Beef Cattle had to be small to maintain satisfactory growth of the animal. When the VA concentration in the blood of the beef cattle is less than 30 IU/dl, the animal shows VA deficiency disease (R. H. Kohlmeier and W. Burroughs, 1970; Salakij et al., 1994; Japanese Feeding Standard for Beef Cattle, 1995). These results agreed with this fact. Furthermore, the growth of the Test with low level VA recovered and increased again on feeding the concentrated feed with VA; these results were the same as those of Kohlmeier and Burroughs (1970) and Oka et al. (1998).

Carcass characteristics

As Table 3 shows, the carcass weight reflected the final body weight, and the Test was significantly small compared with the Control. Oka et al. (1998) reported that there was no difference between the high and low level of VA concentration in the blood on the final body weight. On the carcass ratio to final body weight, the Test was also small, and the difference between the groups was about 1.34% (p<0.01).

The rib-eye area of the Test was as big as that of the Control, though the carcass weight and muscle weight of the Test were smaller than the those of the Control (p<0.01). Regarding the rib thickness, the Test was also thin compared with the Control. The BMS (Beef Marbling Score in Japan) of the Test and Control were 3.60 and 2.80; respectively, the Test was significantly higher than the Control. Torii et al. (1994, 1996) reported that the retinoin or VA restrained the adipocyte differentiation of preadipose cells in the muscle of beef cattle. This restraint was released by the low level VA nutrition status, so that the marbling increased. Furthermore Torii et al. (1994, 1996) reported that the adipogenic activity in the serum has a negative

Table 3. Carcass characteristics in the steers fed diets of restricted (Test) and supplied (Control) vitamin A treatment

	Test	Control	Significance
Carcass weight (kg)	388.40±14.42[1)]	424.90±17.44	**
Carcass ratio to final body weight (%)	61.25±0.40	62.58±0.65	**
Grading by JMGA[2)]			
Rib-eye area (cm^2)	49.40±1.86	49.00±1.58	ns
Rib thickness (cm)	7.32±0.16	7.92±0.31	*
Backfat thickness (cm)	2.16±0.28	2.28±0.36	ns
BMS (No.)	3.60±0.24	2.80±0.20	*

[1)] Means±Standard error.
[2)] Japan Meat Grading Association.
ns: p>0.05, * p<0.05, ** p<0.01.

Table 4. Carcass composition and its characteristics in the steers fed diets of restricted (Test) and supplied (Control) vitamin A treatment

	Test	Control	Significance
Muscle			
Total weight (kg)	104.18±4.47[1)]	107.82±4.88	**
Ratio to carcass weight (%)	52.94±0.54	50.07±0.95	*
The 6 principal muscles weight (kg)			
M. Semitendinousus	2.24±0.15	2.31±0.17	ns
M. Semimembranosus	4.30±0.35	4.57±0.33	**
M. iliopsoas	2.54±0.13	2.58±0.15	ns
M. latissimus	2.11±0.10	2.34±0.13	*
M. lomgissimus	8.39±0.39	8.50±0.18	ns
M. supraspinatus	1.51±0.06	1.55±0.05	ns
Ratio to total muscle weight (%)			
M. Semitendinousus	2.15±0.10	2.13±0.09	ns
M. Semimembranosus	4.11±0.21	4.22±0.18	ns
M. iliopsoas	2.43±0.04	2.39±0.06	ns
M. latissimus	2.03±0.02	2.17±0.03	**
M. lomgissimus	8.08±0.38	7.93±0.31	ns
M. supraspinatus	1.45±0.03	1.44±0.04	ns
Fat			
Total weight (kg)	65.76±1.66	80.55±4.22	**
Ratio to carcass weight (%)	33.52±0.73	37.39±1.22	*
The 3 parts of fat weight (kg)			
Subcutaneus fat	28.14±1.55	35.10±3.99	ns
Intermuscular fat	24.10±0.43	29.68±1.40	**
Abdominal and periren	13.52±0.95	15.77±1.20	*
Ratio to total fat weight (%)			
Subcutaneus fat	42.74±1.83	43.23±2.95	ns
Intermuscular fat	36.70±0.66	37.07±1.79	ns
Abdominal and periren	20.59±1.33	19.71±1.46	ns
Bone			
Total weight (kg)	26.75±1.24	20.68±1.33	ns
Ratio to carcass weight (%)	10.47±0.30	9.57±0.28	**

[1)] Means±Standard error.
ns: p>0.05, * p<0.05, ** p<0.01.

correlation with the retinol concentration in the serum. Fattening using a low level of VA concentration in the blood increased the marbling in the beef, according to the previous report (Kohlmeier and Burroughs, 1970; Torii, 1996; Oka et al., 1998; Oka et al., 1998). On the other items of grading, there were no significant differences between the groups.

Table 4 shows the carcass composition of the animals. For the carcass composition, muscle weight reflected the carcass weight, and the Test was significantly smaller than the Control (p<0.01). However, for the ratio to the carcass, the Test was significantly higher than the Control (p<0.05). Regarding the weight of the 6 principal muscles, there were significant decreases in the weight of the *M. semimembranosus* and *M. latissimus* of the Test (p<0.05). There were no significant differences between the groups in the other muscles. The weights of the 6 principal muscles reflected the decrease in muscle weight in the Test. Furthermore, for the ratio to total muscle weight, *M. latissimus* of the Test was significantly smaller than that of the Control (p<0.05). This might reflect the thinner rib thickness of the Test. There was no significance between the groups in the other muscles.

Some muscles in the carcass influenced the weight and the ratio to the carcass due to a low level of VA. The other muscles in the carcass had little or no influence. However, there was no specific influence of the muscles. The growth of each muscle was influenced little by little and led to the difference of the weight of the muscle and the ratio of the muscle as a total.

The animals with low level VA in the serum had less fat weight than those with a high level of VA. The Test was smaller by about 15 kg than the Control (p<0.01). Furthermore, for the fat ratio to total fat, the Test was significantly lower than the Control (p<0.05).

The weights of the intermuscular fat, abdominal and perirenal fat of the Test were significantly smaller than those of Control. The p-value for the subcutaneous fat between groups was 0.061. All 3 parts of the fat were decreased with a low level VA concentration in the serum. The ratios of the increase in each of the parts were 1.25, 1.23 and 1.17 times, respectively, and they were approximately the same ratio. Furthermore, the ratio of the 3 parts to the total fat was not significant. Therefore, the growth of fat with the low level VA concentration showed no differing characteristics among the 3 parts. This might show that there was no significant difference in the back fat thickness between the groups, though the weight and ratio to total fat of the Test was significantly smaller. The bone weights of the two groups were approximately the same. Regarding the ratio of bone to carcass, the Test was higher than the Control ($p<0.01$). The reason for this was that the carcass weight of the Test was smaller than the Control with the approximate same weight of bone. This spoke of the fact that VA concentration after 13 months old did not influence the growth of bone in this study. The animals of the two groups were fattened using the same methods until 13 months old, at which time the bones had nearly finished growing.

The level of VA in the serum might have influenced the body and carcass weight, and the difference in carcass weight between the groups was relatively caused by the fat weight.

Hammond (1932) studied the fact that tissue growth occurred in a nerves, bones, muscles and fat, in that order. Fukuhara et al. (1968) also reported that in the carcass, bone, muscle and fat grew in that order using Wagyu steers with young fattening; the muscle and fat grew steadily from 8 to 24 months old, especially increasing between 12 to 16 months old. The bone grew steadily up to 14 month old; after that there was little more bone growth.

Looking at this study and these previous papers, the peak of the muscle growth might be before that of fat. Therefore, almost all of the muscle might have grown in the first half of the fattening, at which time the fat was in the early stages of growth. Torii et al. (1998) reported that the adipogenic activity showed a tendency to differ among the ages of Wagyu cattle.

Intramuscular adipose tissue is acknowledged to be a late developing tissue and later developing than body storage fat. The preadipose cells from subcutaneous adipose tissue differentiated into adipocytes at an earlier stage than intramuscular adipose tissue (R. L. Hood, 1982). Miller et al. (1989) reported that the number of adipocytes per gram of tissue was greater in intramuscular adipose tissue than in subcutaneous and that cell diameters and cell volumes were less in intramuscular adipose tissue than in subcutaneous. This suggests that the intramuscular adipose tissue was an immature storage site and in the early stages of fattening might still differentiate or proliferate.

In this study, the difference in the VA concentration in the animals after 13 months old had to affect the deposit of body storage fat and the intramuscular fat.

It was said that the greater intake produced much subcutaneous fat (Zembayashi, 1994; Brosh et al., 1995; Aharoni, 1995; Walter, 1996). There is a paper concerning how an increase in propionic acid in the rumen can cause higher back fat thickness (Iguchi et al., 1992). The total feed intake of the Test was smaller than the Control, and there was a significant difference. Therefore, propionic acid might have been increased in the rumen of the Control animals.

Torii et al. (1996) reported that no significant relationship was observed between adipogenic activity in the serum and subcutaneous fat depth. The differentiation or proliferation between the body storage fat tissue and intramuscular fat tissue might be due to different systems. For example, the deposition of body fat might be influenced by the feed intake, and the deposition of marbling might be influenced by the adipogenic activity.

It may be necessary to study the depositing difference between the body storage fat and intramuscular fat in the animals with the high and low level VA concentration in the blood using an ultrasonic technique. The preadipocytes from the body storage fat and those from intramuscular culture in vitro may be necessary to study the difference in the differentiation and proliferation.

The effects of VA on carcass composition and meat quality were shown more clearly, because of this study using artificial identical twins. It was most suitable to use artificial identical twins in a feeding experiment such as this study, because artificial identical twins do not have genetic variety.

In the younger fattening method that the MAFF in Japan praises, the low level of VA in the serum had the effect in which the muscle ratio to the carcass weight was greater and the fat was less, but the carcass and muscle weight were less. All in all, fattening with VA control in the blood affects body composition and growth. The energy which the animal with added VA consumed in had to be used for fat production instead of muscle production. This is not an efficient fattening method. In the Japanese market, a good quality carcass is produced by controlling the VA in the blood, and profitability will increase if the carcass weight is small, because a carcass with sufficient meat quality is highly regarded. It is important in beef production to control the VA in the blood of beef cattle.

The meat industry must ask for a bigger carcass, in order to use this fattening method, but there are some problems with carcass weight, etc. We are going to examine these points from now on.

ACKNOWLEDGEMENTS

In case we publish this report, we are thankful to Dr. M. Irie from Osaka Prefectural Agricultural and Forestry Research Center who taught us.

REFERENCES

Aharoni, Y., E. Nachtoni, P. Holstein, A. Brosh, Z. Holzer and Z. Nitsan. 1995. Dietary effects on fat deposition and fatty acid profiles in muscle and fat depots of Friesian bull calves. J. Anim. Sci. 73:2712-2720.

Brosh, A., Y. Aharoni, D. Levy and Z. Holzer. 1995. Effect of energy concentration and of age of Holstein-Friesian bull calves on growth rate, urea space and fat deposition, and ruminal volume. J. Anim. Sci. 73:1666-1673.

Fukuhara, T., H. Tsuchiya, M. Nishino and T. Yamazaki. 1968. Studies on changes in body composition and carcass characters of beef cattle during fattening. Bulletin of the Chugoku Agricultural Experiment Station. 16:123-162.

Hammond, J. 1932. Growth and development of mutton qualities in the sheep. Oliver & Boyd, London.

Hirooka, H. 1991. Evaluation of the experimental design with clonse of cattle. Anim. Sci. Technol. (Jpn.), 62:1104-1106.

Hood, R, L. 1982. Relationships among growth, adipose cell size, and lipid metabolism in ruminant adipose tissue. Fed. Proc, 41(9):2555-2561.

Iguchi, A., T. Ito, M. Kobayashi and H. Morinaga. 1992. Effect of calcium soaps of fatty acids supplementation on fattening and meat quality of Japanese Black×Holstein steers. Bulletin of the Chiba Prefectural Livestock. Experiment Station, 16:1-10.

Japanese Feeding Standard for Beef Cattle, 1995. Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries, 27-28, Tokyo, Japan.

JMGA, 1988. New beef carcass grading standards. Japan Meat Grading Association, Tokyo, Japan.

Kinoshita, M., K. Otake, T. Fujita, K. Shiga, K. Kimoto, M. Uchida and Y. Sasae. 1999. Manual of high quality beef production: Effect of Vitamin A on beef quality. Bulletin of the Oita Prefectural Animal Industry Experimental Station, 28:7-14.

Kohlmeier, R. H. and W. Burroughs. 1970. Estimation of critical plasma and liver vitamin A levels in feedlot cattle with observations upon influences of body stores and dairy dietary requirements. J. Anim. Sci. 30:1012- 1018.

Miller, M. F., H. R. Cross, J. J. Wilson and S. B. Smith. 1989. Acute and longterm lipogenic response to insulin and clenbuterol in bovine intramuscular and subcutaneouse adipose tissue. J. Anim. Sci. 67:928-933.

Oka, A., Y. Maruo, T. Miki, T. Yamasaki and T. Saito. Influence of vitamin A on the quality of beef from the Tajima strain of Japanese Black Cattle. Meat Sci. 48:159-167.

Oka, A., T. Dohgo, M. Juen and T. Saito. 1998. Effects of Vitamin A on beef quality, weight gain, and serum concentrations of thyroid hormones, insulin-like growth factor-1, and insulin in Japanese Black steers. Anim. Sci. Technol. (Jpn), 69:90-99.

Salakij, J., H. Yano, F. Yano, M. Kitagawa, T. Matsui, S. Torii and R. Kawashima. 1994. Vitamin A status of beef Cattle in Japan. Bulletin of Beef Cattle Science 57: 23-27.

Torii, S., T. Matsui, N. Kimura, T. Kawada and H. Yano. 1994. Assay of adipogenic activity in sera of fattening cattle. Bulletin of Beef Cattle Science, 58:28-33.

Torii, S., T. Matsui and H. Yano. 1996. Development of Intramuscular fat in Wagyu beef cattle depends on adipogenic or antiadipogenic substances present in serum. Anim. Sci. 63:73-78.

Torii, S., T. Kawada, K. Matsuda, T. Matsui, T. Ishihara and H. Yano. 1998. Thiazolidinedione induces the adipose differentiation of fibroblast - like cells resident within bovine skeletal muscle. Cell Biology International, 22:421-427

Walter, J. J., G. Gerrits, Henk Tolman, Johan, W. Schrama, Seerp Tamminga, Marlou, W. Bosch, Martin and W. A. Verstegen. 1996. Effect of protein and protein-free energy Intake on protein and fat deposition rates in preruminant calves of 80 to 240 kg live weight, J. Anim. Sci. 74:2129-2139.

Zembayashi, M. 1994. Effects of nutritional planes and breeds on intramuscular-Lipid deposition in *M. longissimus dorsi* of steers. Meat Sci. 38:367-374.