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RESEARCH ARTICLE

An Investigation into the Prevention of Dark Cutting in Cattle Due to the Effects of Altitude and Silage [1] [2] [3]

Mustafa UĞURLU [1] Ceyhan ÖZBEYAZ [2]

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[1] Department of Animal Science and Husbandry, Faculty of Veterinary Medicine, TR-55200 Samsun - TURKEY
[2] Department of Animal Science and Husbandry, Faculty of Veterinary Medicine, TR-06110 Diskapi, Ankara - TURKEY

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Summary

The objective of the study was to investigate methods for the prevention of dark cutting in meat from cattle due to high altitude origin and silage use in fattening. Brown Swiss male vealers (n=83) were sourced from the highlands of the Eastern Anatolian Region of Turkey, where the altitude is approximately 1.800 m, and transported to Antalya province. Holstein male vealers (n=43) were sourced from Antalya province. Both Brown Swiss and Holstein male veal were divided into four groups. Group-I: Basic ration plus sunflower meal (SFM); Group-II: Basic ration(BR) plus sunflower meal(SFM) and 2.000 IU vitamin E/head/day; Group III: Basic ration(BR) plus cottonseed meal(CSM) and 2.000 IU vitamin E/head/day and Group IV: Basic ration(BR) plus cottonseed meal. Vitamin E supplements were provided for 120 day before slaughter. Mean musculus longissimus dorsi dark carcass rates measured in Brown Swiss and Holstein male vealers were 55.40% and 67.40% at pH≤6.01, respectively, at 24 h after slaughter. Vit-E supplementation lessened the dark carcass problem so meat color traits of bulls transported from high altitude to low altitude and raised with high levels of silage can be improved with cottonseed meal plus Vit-E supplementation.

Keywords: *Cattle, Altitude, Silage, Vitamin E, Gossypol*

Sığır Karkaslarında Yüksek Bölge ve Silaj Etkisiyle Oluşan Koyuluğun Önlenmesi İmkanlarının Araştırılması

Özet

Bu araştırma, sığır karkaslarında yüksek bölge ve silaj etkisiyle oluşan koyuluğun önlenmesi imkânlarının araştırılması amacıyla yapılmıştır. Esmer ırk erkek danalar (n=83) Doğu Anadolu bölgesinden, yaklaşık 1.800 m yükseklikten, temin edilip Antalya ilindeki bir besi işletmesine nakledilmişlerdir. Holştayn ırkı erkek danalar (n=43) ise Antalya ilinden temin edilmiştir. Esmer ve Holştayn ırkı erkek danalar dört gruba ayrılmıştır. Her iki genotip için Grup I: Temel rasyon+ayçiçeği tohumu küspesi; Grup II: Temel rasyon + ayçiçeği tohumu küspesi + 2.000 IU E vitamini/gün/baş; Grup III: Temel rasyon + pamuk tohumu küspesi + 2.000 IU E vitamini /gün/baş; Grup IV: Temel rasyon+pamuk tohumu küspesi vitamini grupları oluşturulmuştur. Rasyona kesimden 120 gün önce vitamin E katkısı yapılmaya başlanmıştır. Kesim sonrasındaki 24. saatte pH≤6.01 olduğunda Esmer ve Holştayn ırkı erkek danalarda normal karkas oranları sırasıyla %55.40 ve %67.40 olarak tespit edilmiştir. Vitamin E katkısı koyu karkas problemini azaltmıştır. Yüksek rakımdan düşük rakıma nakledilen ve yüksek seviyede silajla beslenen sığırlarda et rengi özelliklerinin pamuk tohumu küspesi ve E vitamini ile birlikte iyileştirilebileceği söylenebilir.

Anahtar sözcükler: *Sığır, Yükseklik, Silaj, Vitamin E, Gossipol*

INTRODUCTION

Fattening of beef cattle occurs worldwide, and more recently, the production of high quality meat has become increasingly important. Meat color, which is a criterion for determining meat quality, is one of the most important traits for both the market and customers. Furthermore, the correct meat colour convinces customers of the freshness

İletişim (Correspondence)
+90 362 3121919/3782
mustafaugurlu55@hotmail.com

of meat and is pre-eminent in the decision to purchase it. Owing to its colour, dark cutting meat negatively affects purchasing decisions by customers and is therefore reluctantly purchased from slaughter houses by both wholesalers and butchers [1,2].

Dark cutting carcass is attributable to various factors, including genotype [3,4] decreases in muscle glycogen levels and stress factors such as abnormal ambient temperature, humidity changes, animal density, social group changes, lariage time at pre-slaughter, season and feeding regime [2,4-8].

The use of high quality silage has been widely adopted to reduce the costs of feeding. However, dark cutting has become a problem for fattening companies worldwide. O'Sullivan et al.[9] reported that the feeding of beef cattle mainly on forage negatively affects meat colour and quality traits.

Holstein and Brown Swiss genotype bulls are commonly used for the production of meat in Turkey. Fattening companies have sourced Brown Swiss crossbred bulls from the East Anatolian Region, much of which is at an altitude of more than 1.800 m. However, the fattening companies have regularly voiced complaints about problems in the marketing of dark cutting carcasses from Brown Swiss bulls. The number of red blood cells per unit of volume in both humans and animals living at high altitudes is higher than in those living at low altitudes. When red blood cells are broken down, the residual iron is released and transferred from the blood to the body tissues by transferrin [10].

Gossypol, like cotton seed meal(CSM), has been widely used as a protein supplement in cattle fattening rations. *In vitro,* gossypol complexes with iron cations at 1:1 or 1:4 rates [11]. Plasma gossypol levels *in vivo* decline linearly with increasing supplementary dietary Fe [12,13]. Such results indicate that gossypol may be a useful dietary supplement for reducing blood iron levels and consequently reducing the problem of dark cutting.

Therefore, the current study compared the effects of cotton seed meal(CSM) and sun flower meal(SFM), with and without supplementary Vit-E, on the colour and pH of musculus longissimus dorsi meat, and also their effects on dark cutting.

MATERIAL and METHODS

Animals, Diets and Housing Type

A total of 126 Brown Swiss (n=83) and Holstein (n=43) male vealers, aged from 6 to 8 months, were used in the study. The Brown Swiss meal vealers were transported to Antalya province from the highlands of the Eastern Anatolian Region of Turkey at an altitude of approximately 1.800 m. The Holstein meal vealers were obtained from Antalya province. The treatment groups were kept in sheltered housing with an eternit roof and fencing. The allocated area for each animal was 7 m^2. Bulls from both genotypes were randomly allocated to two separate subgroups to form 4 groups in total. The treatment groups were as follows: Group I, Basic ration(BR) + sunflower meal (SFM) (G-I); Group II, Basic ration(BR) + sunflower meal (SFM) and 2.000 IU Vit-E/day/per bull (G-II); Group III, Basic ration (BR) + cotton seed meal (CSM) and 2.000 IU Vit-E/ day/per bull (G-III), and Group IV, Basic ration(BR) + cotton seed meal(CSM) (G-IV). The Vit-E supplement used in the animal feed was supplied by BASF Ireland, Ltd. (Ekol Food and Agricultural Co, Istanbul). Animals were fed concentrate and maize silage *ad libitum*. The rations included 50.00% maize silage, 41.10% barley, 3.30% wheat bran and 2.70% SFM or CSM. The same management regime was applied for the duration of the study. Bulls were fattened over the course of 10 months and Vit-E was supplied for 120 d prior to slaughter. The animals were slaughtered at about 16-18 months of age, without stunning or electroshock. They were slaughtered by shackling the right leg and exsanguination while hanging.

pH and Meat Colour

pH and colour of the fresh longissimus dorsi muscle samples were determined. A digital pH meter (Mettler-Toledo SG2 with Inlab 427) was used for that purpose as soon as possible after dressing, and at 45 min, 24 h, 72 h, 120 h and 168 h after slaughter. The colour parameters, L* (lightness), a* (redness) and b* (yellowness), were measured with a Minolta CR 400 colorimeter at 0 min, 45 min, 24 h, 72 h, 120 h and 168 h after slaughter.

*Determination of Muscle α-Tocopher*ol

Meat samples collected at 24 h postmortem were frozen at -18°C prior to the determination of the alfa-tocopherol content. The level was determined with a method modified slightly from Salvatori et al.[14]. The mobile phase was 4% 1-4 dioxane and 0.04% acetic acid in hexane and had a flow rate of 1 ml/min at 25°C. Alfa-tocopherol content was determined with high-performance liquid chromatography (HPLC); (Agilent 1100 model LC MSD (Liquid Chromatography Mass Spectrofotometry)). The detection wavelengths were 292 nm for UV and 292-330 nm for fluorescence.

Determination of CSM Gossypol Amount

CSM in the feed was sampled at the beginning, middle and end of the fattening period. The gossypol content was determined with a method adapted from Hron et al.[15]. The mobile phase contained 80% acetonitrile and 20% 10 mM KH_2PO_4 and had a flow rate of 1 ml/min. The flask was filled to volume with the mobile phase and the gossypol amount was determined by HPLC (Agilent 1100 LC MSD). A 20 µl sample was injected into an Inertsil ODS3 (25 cm × 4.6 cm) column and the gossypol content was calculated from the peak area response of a standard curve

established by chromatography and referenced against known amounts of pure gossypol.

Measurement of Non-transferrin Bound Iron (NTBI)

Blood samples were collected in vacutainer collection tubes by venipuncture from the same animals at the beginning, midpoint and endpoint of the fattening period. They were centrifuged for 5 min at 3.000 rpm. Serum samples were collected and stored frozen at -20°C until analysis. NTBI content in the blood serum was determined using a method modified from Gostriwatana et al.[16]. The non-transferrin bound iron (NTBI) level was measured by using a graphite furnace and atomic absorption spectrophotometry (Perkin Elmer, Analyst 800).

Statistical Analyses

Using a factorial design, the color parameters (L*, a*, b*) and pH were analyzed with two-way analysis of variance (ANOVA) to reveal genotype, treatment and genotype × treatment interactions [17].

RESULTS

pH and Meat Colour

The means of the pH values for the Brown Swiss and Holstein groups are summarized in *Table 1*. The ultimate pH (24 h) in the musculus longissimus dorsi ranged from 5.87 to 5.97 for Brown Swiss and from 5.92 to 5.98 for the Holstein. Among treatments, no differences were determined at 0 min, 45 min, 24 h, 72 h, 120 h and 168 h for the Brown Swiss. However, significant differences were determined 0 min (P<0.05), 45 min (P<0.01), 72 h (P<0.05), 120 h (P<0.01) and 168 h (P<0.01) for the Holstein *(Table 1)*.

The pH values of Brown Swiss and Holstein bulls are presented for normal and dark carcass rate and meat quality traits (L*, a*, b*) for pH≤6.00 in *Table 2* and *3*. The normal carcass rate (pH≤6.00) at 24 h was 55.40% for Brown Swiss and 67.40% for Holstein bulls (*Table 2* and *3*). In the present study, G-III had the highest normal carcass rate of pH≤6.00 among groups, with Brown Swiss at 66.70% and Holstein at 90.00% (*Table 2* and *3*). Overall, the interactions of pH, genotype and treatment were not significant (P>0.05) *(Table 4)*. The L* values ranged from 33.11 to 35.79 for Brown Swiss and from 29.52 to 37.94 for Holstein bulls for pH≤6.00 (*Table 2* and *3*), and both the Holstein and Brown Swiss CSM groups had higher numbers of animals with a pH≤6.00 than the SFM groups (*Table 2* and *3*). The a* value ranged from 20.92 to 23.79 for Brown Swiss and from 18.54 to 24.18 for Holstein bulls when the pH was≤6.00 (*Table 2* and *3*). In the present study, the effects of genotype, ration and genotype x ration interaction were significant for a* values *(Table 4)*. The b* value ranged from 10.90 to 13.45 for Brown Swiss and 8.65 to 14.69 for Holstein bulls when the pH was ≤6.00 (*Table 2* and *3*).

Muscle α-tocopherol (Vitamin E) Concentration and Gossypol Amount in CSM

The Vit-E concentration was determined in musculus longissimus dorsi samples with HPLC. Vit-E amounts for G-I, G-II, G-III and G-IV Brown Swiss vealers were 0.65, 1.02, 1.09 and 0.46 µg/g, respectively, and 0.65, 1.18, 1.75 and 0.47 µg/g for the Holstein vealers, respectively *(Table 5)*. The Vitamin E amount was not significantly different between genotypes in the treatment groups (P>0.05). Muscle α-tocopherol concentration was not significanly different for treatment groups of the Brown Swiss genotype. However, it was significant for treatment groups of the Holstein genotype (P<0.001) *(Table 5)*.

Table 1. *Least square means for pH for Brown Swiss and Holstein feeding groups*
Tablo 1. *Esmer ırk ve Holştayn ırkında deneme gruplarında pH ortalamaları ve standart hataları*

Breed	Characters	Treatment				P
		Mean SE	Mean SE	Mean SE	Mean SE	
		I	II	III	IV	
Brown Swiss	pH 0 min	6.81±0.06	6.80±0.04	6.86±0.06	6.56±0.04	-
	pH 45 min	6.69±0.05	6.63±0.04	6.56±0.04	6.56±0.04	-
	pH 24 h	5.95±0.11	5.89±0.11	5.87±0.08	5.97±0.09	-
	pH 72 h	6.19±0.12	6.16±0.12	5.86±0.09	6.06±0.10	-
	pH 120 h	6.20±0.12	6.15±0.12	5.87±0.09	6.13±0.11	-
	pH 168 h	6.31±0.12	6.24±0.13	5.89±0.10	6.10±0.12	-
Holstein	pH 0 min	7.08±0.12^{b}	6.73±0.04^{a}	6.82±0.09^{ab}	7.05±0.11^{b}	*
	pH 45 min	6.97±0.11^{b}	6.58±0.05^{a}	6.66±0.14^{a}	6.98±0.05^{b}	**
	pH 24 h	5.98±0.09	5.92±0.16	5.97±0.14	5.97±0.12	-
	pH 72 h	6.06±0.08^{a}	6.24±0.17^{ab}	6.56±0.17^{b}	5.96±0.12^{a}	*
	pH 120 h	6.04±0.07^{a}	6.12±0.18^{a}	6.63±0.15^{b}	5.96±0.13^{a}	**
	pH 168 h	6.10±0.10$^{a.}$	6.18±0.17^{a}	6.63±0.17^{b}	6.00±0.13^{a}	**

a,b: *Means within a row with different superscripts significantly differ (P<0.05), - non-significant (P>0.05); * P<0.05; ** P< 0.01;* ***I:*** *BR+SFM,* ***II:*** *BR+SFM+vit-E,* ***III:*** *BR+CSM+vit-E,* ***IV:*** *BR+CSM*

Table 2. *pH values, 24th h color traits for Brown Swiss*
Tablo 2. *Esmer ırkta 24. saatte renk ve pH özellikleri*

Characters	Brown Swiss						
	Group	n	Carcass Rate (%)	pH	L*	a*	b*
pH≥ 6.01	I	11	52.40	6.22±0.76	29.27±0.59	17.20±1.19	7.74±0.93
	II	8	40.00	6.16±0.06	30.32±1.11	20.35±1.45	9.54±1.05
	III	7	33.30	6.32±0.12	32.91±1.22	21.12±1.18	11.36±1.17
	IV	11	52.40	6.14±0.07	32.42±1.38	17.09±1.61	7.92±1.38
	Total	37	44.60	6.20±0.04	31.12±0.59	18.58±0.74	8.87±0.61
pH≤ 6.00	I	10	47.60	5.65±0.04	35.79±1.57	23.79±1.57	13.45±1.11
	II	12	60.00	5.71±0.06	33.11±1.00	21.57±0.84	10.90±0.85
	III	14	66.70	5.65±0.03	35.33±0.80	22.70±0.84	12.17±0.73
	IV	10	47.60	5.80±0.04	34.80±1.24	20.92±0.99	11.62±0.80
	Total	46	55.40	5.70±0.02	34.74±0.48	22.26±0.53	11.99±0.44

L: *Lightness,* ***a:*** *Redness,* ***b:*** *Yellowness,* ***I:*** *BR+SFM,* ***II:*** *BR + SFM + vit-E,* ***III:*** *BR + CSM + Vit-E,* ***IV:*** *BR + CSM*

Table 3. *pH values, 24 h color traits for Holstein*
Tablo 3. *Holştayn ırkında 24. saatte renk ve pH özellikleri*

Characters	Holstein						
	Group	n	Carcass Rate (%)	pH	L*	a*	b*
pH≥ 6.01	I	5	50.00	6.19±0.11	36.00±1.22	23.39±1.21	13.99±1.07
	II	4	36.40	6.17±0.05	30.72±0.05	21.10±1.08	10.62±0.71
	III	1	10.00	6.02±0.00	33.14±0.00	18.76±0.00	8.48±0.00
	IV	4	33.30	6.49±0.14	32.99±1.99	20.05±1.79	11.10±1.50
	Total	14	32.60	6.26±0.68	33.43±0.94	21.45±0.82	11.81±0.74
pH≤ 6.00	I	5	50.00	5.77±0.05	37.94±1.19	24.18±1.14	14.69±0.90
	II	7	63.60	5.77±0.38	33.53±1.00	22.19±1.08	12.17±1.20
	III	9	90.00	5.97±0.01	29.52±0.57	18.54±1.75	8.65±1.19
	IV	8	66.70	5.72±0.04	36.23±0.77	23.84±1.20	14.12±0.57
	Total	29	67.40	5.81±0.02	33.79±0.72	21.86±0.81	12.05±0.67

L: *Lightness,* ***a:*** *Redness,* ***b:*** *Yellowness,* ***I:*** *BR+SFM,* ***II:*** *BR + SFM + vit-E,* ***III:*** *BR + CSM + Vit-E,* ***IV:*** *BR + CSM*

Table 4. *Effects of genotype (Brown Swiss and Holstein) and treatment on quality traits of MLD samples*
Tablo 4. *MLD kaite özellikleri üzerine genotip (Esmer ırk ve Holştayn) ve denemenin etkisi*

Variaton Source	pH			L*			a*			b*		
	df	ms	F	df	ms	F	df	ms	F	df	ms	F
Genotype	1	1.92	3.09	1	74.65	2.47	1	325.69	12.19***	1	112.21	7.64**
Treatment	3	0.17	0.28	3	19.03	0.63	3	160.40	6.01***	3	56.58	3.85*
Interaction	3	1.51	2.43	3	286.58	9.49***	3	331.56	12.41***	3	183.30	12.48***
Error	118	0.62	-	118	30.20	-	118	26.71	-	118	14.69	-

*Values are degrees of freedom (df), mean squares (ms) and significant (F) from two way variation analysis, * P<0.05, ** P<0.01, *** P<0.001,* ***L:*** *Lightness,* ***a:*** *Redness,* ***b:*** *Yellowness*

The gossypol amount of 4 847.63 mg/kg in cotton seed meal was determined with HPLC *(Table 6)*. Cotton seed meal supplement was used as 400 g/day/per velaer into ration. Gossypol consumption was 1 939.05 mg/d for the cotton seed groups.

NTBI Amount

NTBI was high in all groups at the beginning of the fattening period, with the exception of those receiving Vit-E supplementation, which had lower values. In pre-slaughter blood values, differences in NTBI amount between the genotypes were determined to be significant. NTBI values moderately increased in groups with Vit-E supplementation. However, for those Holstein groups without Vit-E supplementation, there was a dramatic increase *(Fig. 1)*.

DISCUSSION

pH and Meat Colour

The ideal range of pH values at 24 h postmortem has

Table 5. *Vitamin E value in MLD samples from Brown Swiss and Holstein vealers*
Tablo 5. *Esmer ve Holstayn MLD kasında E vitamini değerleri*

Genotype	Groups				P
	Group - I n (6) X±Sx	Group - II n (6) X±Sx	Group - III n (7) X±Sx	Group - IV n (7) X±Sx	
Brown Swiss	0.65±0.21	1.02±0.21	1.09±0.27	0.46±0.63	-
Holstein	0.65±0.14^{a}	1.18±0.29^{ab}	1.75±0.42^{b}	0.47±0.63^{a}	***
P	-	-	-	-	

*Group I: Basic ration + sunflower meal; Group II: Basic ration + sunflower meal + Vitamin E; Group III: Basic ration + cotton seed meal + Vitamin E; Group IV: Basic ration + cotton seed meal; ^{a,b} Means within a row with different superscripts differ (P<0.05), non-significant (P>0.05); ***P<0.001, MLD: Musculus longissimus dorsi*

Table 6. *Gossypol amount into the cotton seed meal*
Tablo 6. *Pamuk tohumu küspesindeki gossypol miktarı*

Sample	Gossypol (mg/kg)
1st sample	4789.90
2nd sample	4898.50
3th sample	4854.50
Total	4847.63

colour traits (L*, a*, b*) for pH≤6.00 in *Table 2* and *3*. In the present study, when the silage and concentrate balance of the diet was 1:1, L* values ranged from 29.27 to 35.79 for Brown Swiss and 29.52 to 37.94 for Holstein bulls. L* values ranged from 38.30 to 40.00 in Brown Swiss bulls fed with concentrated rations available *ad libitum* [20]; they were higher than the range demonstrated in the present study. The L* values (30.51-32.98) reported by Baublits et al.[21] were close to the results of the present study for the roughage groups. Sunflower meal and cotton seed meal supplements were used in this study. The redness value of the sunflower meal groups was higher than for the cotton seed meal groups in groups without vitamin E supplementation *(Table 2, Table 3)*. In the present study, the 24 h redness values were similar to those of Baublits et al.[21] who reported 19.34 to 20.47 and the 20.20 to 22.40 of Bruce et al.[22]. However, the values from the present study were lower than those of Belgian Blue cattle (23.00 - 23.10) that were fed rations supplemented with Vit-E [23]. In the present study, the effects of genotype, ration and genotype x ration interaction were significant for b* values. The b* value of the sunflower meal groups was higher than for the cottonseed meal groups in those groups not

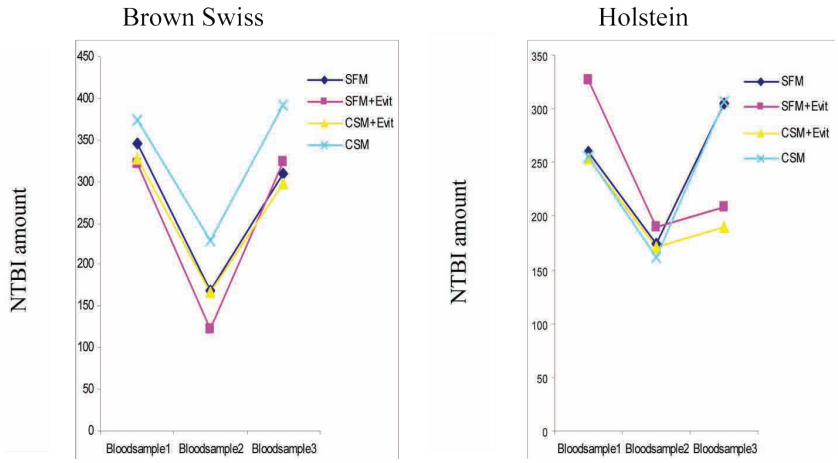

Fig 1. NTBI values for Brown Swiss and Holstein groups in blood sera samples

Şekil 1. Kan serumu örneklerinde Esmer ve Holştayn ırkında TBDM değerleri

been reported as 5.6 to 5.8 [1,18]. However, no meat quality problems have been reported up to pH 6.00 [19]. In the present study, pH values≤6.00 at 24 h ranged from 5.87 to 5.98 and were considered acceptable. The dark carcass rate for the Brown Swiss genotype was higher than for the Holstein genotype, so genotype clearly has a role in meat color (*Table 2* and *3*). Hence, the Brown Swiss genotype was considered predisposed to dark-colored meat [4]. In the present study, G III had the highest normal carcass rate of pH≤6.00 among groups, with Brown Swiss at 66.70% and Holstein at 90.00%. Accordingly, it appears that there was a synergistic effect between vitamin E and CSM in reducing dark cutting. Hence, it may be feasible to use vitamin E and cottonseed meal in combination to reduce the dark cutting problem.

The pH values of Brown Swiss and Holstein bulls are presented for normal and dark carcass rate and meat supplemented with Vit-E. The b* values in the present study approximated those of Baublits et al.[20] who reported values of 7.71 to 9.65 for different rations and, Abril et al.[24] who reported 10.68 for pH≤6.10 and 6.73 for pH>6.10 at 2 d. These results show that supplementation with different protein sources and Vit-E in rations can affect b* values.

Muscle α-tocopherol (Vitamin E) Concentration and Gossypol Amount in CSM

Vit-E content in meat samples in the current study was lower than in several other studies [25-27] but was similar to others [23,28]. The Vit-E amount in Brown Swiss meat (0.46-1.09 µg/g) was lower than in Holstein meat (0.47-1.75 µg/g) in the current study. Dufrasne et al.[23], Lanari et al.[25] and Yang et al.[29] reported that increasing the amount of maize silage in the diet may decrease the vitamin E level in Brown Swiss meat.

The average gossypol consumption was 1 939.05 mg/d for the cotton seed groups. A safe amount of gossypol for cattle per day was reported to be 24 g [30]. Hence gossypol consumption by both genotypes in the present study was well under the reported safe maximum amount and no toxic or harmful effects were observed in the test cattle.

NTBI Amount

NTBI was high in all groups at the beginning of the fattening period, with the exception of those receiving Vit-E supplementation, which had lower values. For pre-slaughter blood values, differences in NTBI amount were determined to be significant between the genotypes. NTBI values moderately increased in groups with Vit-E supplementation. Marwah et al.[31] noted a negative correlation between vitamin E and NTBI. Compared with the control group, Vit-E supplementation dramatically decreased the level of NTBI for Holstein bulls *(Fig. 1)*. Similarly, Marwah et al.[31] found a negative correlation between Vit-E and NTBI. However, in the present study, NTBI values dramatically increased in Brown Swiss groups at the third blood sampling, with or without vitamin E supplementation. The binding of Fe to transferrin protein may be related to environmental conditions or genotype characteristics in Brown Swiss bulls. Transferrin is responsible for the transportation of free iron from blood to tissues. Ferric ion is bonded to N and C regions within transferrin. The N region is endothermic and the C region is exothermic. Ferric ion is bound to the C region in higher amounst than the N region [32].

The current study determined that cottonseed plus Vit-E supplementation can be used to reduce the formation of particularly dark carcass in Holstein and Brown Swiss genotypes. More specifically, the meat color traits of bulls transported from high altitude to low altitude and raised with high levels of silage can be improved with cottonseed plus Vit-E supplementation. To meet the consumer demand for bright red meat, meat producers should pay careful attention to counteracting the effects of silage on blood iron levels by administering appropriate levels of Vit-E to Brown Swiss. It can also be concluded that, according to the results for CSM groups, cotton seed may be used as an alternative feed material to help reduce dark cutting in bulls predominantly fed silage or forage.

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