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Effect of vitamin E, potassium, and alcohol-fermented feed supplementation before transport on body weight, carcass characteristics, and meat color of Hanwoo steers

Efecto de la suplementación con vitamina E, potasio y alimento fermentado con alcohol antes del transporte en el peso corporal, características de la canal y color de la carne de novillos Hanwoo

Efeito da suplementação com vitamina E, potássio e ração fermentada com álcool antes do transporte sobre o peso corporal, as características da carcaça e a cor da carne de bovinos Hanwoo

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Abstract

Background: During cattle transport, not only does weight loss occur due to transport stress, but meat quality also deteriorates because of changes in meat color. Hence, stress induced by transportation causes economic losses for livestock farms. **Objective:** To investigate the effect of vitamin E, potassium, and alcohol-fermented feed supplementation before transport on body weight, carcass characteristics, and meat color of Hanwoo steers. **Methods:** Forty steers were divided into four treatment groups, with 10 animals per group, housed in two pens per treatment. The experimental treatments were as follows: (1) Vitamin E supplemented at 500 IU/head/day. (2) Alcohol-fermented feed provided at 1.58 kg/head/day for six months prior to transport. (3) Potassium supplemented at 1.45% of the daily feed intake one day before transport. (4) A control group (not supplemented). Transportation loss, carcass characteristics, and meat surface color were measured. Data were analyzed using GLM (Generalized Linear Model) and Duncan's Multiple Range Test in SAS (v. 8.01; 2000). **Results:** Weight loss due to transport stress was lower in the treatment groups than in the control, particularly in the potassium-treated group. Meat color, redness, clarity, and hue angle were significantly improved in the treatment groups compared to the control. However, fat color, marbling score, back fat thickness, carcass percentage, and meat production index showed no significant differences among treatments. **Conclusion:** Supplementation with alcohol-fermented feed, potassium, or vitamin E before transport enhances productivity by reducing body weight loss and preventing deterioration in meat color caused by transportation stress.

Keywords: *alcohol-fermented feed; carcass grade; Hanwoo steers; meat characteristics; meat quality; potassium; productivity; transportation stress; vitamin E; weight loss.*

Resumen

Antecedentes: Durante el transporte de ganado, no solo se produce pérdida de peso debido al estrés del transporte, sino que la calidad de la carne también se deteriora a causa de cambios en su color. Por lo tanto, el estrés inducido por el transporte ocasiona pérdidas económicas para las explotaciones ganaderas. **Objetivo:** Investigar el efecto de la suplementación con vitamina E, potasio y alimento fermentado con alcohol antes del transporte en el peso corporal, las características de la canal y el color de la carne de novillos Hanwoo. **Métodos:** Cuarenta novillos fueron divididos en cuatro grupos de tratamiento, con 10 animales por grupo, alojados en dos corrales por tratamiento. Los tratamientos fueron: (1) Vitamina E, administrada a dosis de 500 UI/cabeza/día. (2) Alimento fermentado con alcohol a razón de 1,58 kg/cabeza/día durante seis meses antes del transporte. (3) Potasio, administrado oralmente al 1,45% de la ingesta diaria de alimento un día antes del transporte. (4) Grupo control (sin suplementación). Se midieron las pérdidas de peso durante el transporte, las características de la canal y el color superficial de la carne, y los datos se analizaron mediante un Modelo Lineal Generalizado (GLM) y la prueba de Rango Múltiple de Duncan, utilizando el paquete estadístico SAS (v.8.01; 2000). **Resultados:** La pérdida de peso por estrés del transporte fue menor en los grupos de tratamiento que en el grupo control, especialmente en el tratamiento con potasio. El color de la carne, la intensidad de rojez, la claridad y el ángulo de tonalidad mejoraron significativamente en los tratamientos en comparación con el grupo control. Sin embargo, el color de la grasa, la puntuación de marmoleo, el grosor de la grasa dorsal, el porcentaje de canal y el índice de producción de carne no mostraron diferencias significativas entre los tratamientos. **Conclusión:** La suplementación con alimento fermentado con alcohol, potasio o vitamina E antes del transporte mejora la productividad al reducir la pérdida de peso corporal y prevenir el deterioro del color de la carne causado por el estrés del transporte.

Palabras clave: *alimento fermentado con alcohol; calidad de la carne; características de la carne; estrés por transporte; grado de la canal; novillos Hanwoo; pérdida de peso; potasio; productividad; vitamina E.*

Resumo

Antecedentes: Durante o transporte de gado, não ocorre apenas perda de peso devido ao estresse do transporte, mas a qualidade da carne também se deteriora devido a mudanças na sua coloração. Por isso, o estresse gerado durante o transporte causa perdas econômicas para as fazendas pecuárias. **Objetivo:** Investigar o efeito da suplementação com vitamina E, potássio e ração fermentada com álcool antes do transporte sobre o peso corporal, as características da carcaça e a cor da carne de bovinos Hanwoo. **Métodos:** Quarenta bovinos foram divididos em quatro grupos de tratamento, com 10 bovinos por tratamento em dois currais. Tratamentos: (1) Vitamina E foi fornecida a 500 UI/cabeça/dia. (2) Ração fermentada a álcool foi fornecida a 1,58 kg/cabeça/dia durante seis meses antes do embarque. (3) Potássio a 1,45% da quantidade diária de ração foi fornecido por via oral um dia antes do embarque. (4) Grupo controle (não suplementado). A perda de peso durante o transporte, as características da carcaça e a cor da superfície da carne foram medidas, e os dados foram analisados pelo modelo linear generalizado (GLM) e pelo teste de intervalo múltiplo de Duncan, usando o pacote estatístico SAS (V.8.01; 2000). **Resultados:** A perda de peso devido ao estresse do transporte foi menor nos grupos de tratamento do que no grupo controle, especialmente com o tratamento com potássio. A cor da carne, a intensidade do vermelho, a claridade e o ângulo de matiz melhoraram significativamente nos tratamentos em comparação com o grupo controle (adicionar valor de p), enquanto a cor da gordura, o índice de marmorização, a espessura da gordura dorsal, a porcentagem de carcaça e o índice de produção de carne não apresentaram diferenças entre os tratamentos. **Conclusão:** A suplementação com ração fermentada com álcool, potássio ou vitamina E antes do transporte melhora a produtividade ao prevenir a perda de peso corporal e a deterioração da cor da carne decorrentes do estresse do transporte.

Palavras-chave: *bovinos Hanwoo; características da carne; estresse do transporte; grau da carcaça; perda de peso; potássio; produtividade; qualidade da carne; ração fermentada com álcool; vitamina E.*

Introduction

During cattle transport, weight loss occurs not only due to transport stress (Deng et al., 2017), but also meat quality deteriorates as a result of changes in meat color (Lister et al., 1989; Sun et al., 2017). Hence, stress induced by transportation causes economic losses for livestock farms (He et al., 2010). A recent study on transport losses showed that the average loss is about 3–10% of body weight, and young cattle experience greater transport loss compared to older cattle or those with higher body fat accumulation (González et al., 2012).

Various factors affect transport loss, including breed, season, climatic conditions (González et al., 2012; Schaefer et al., 1997), age, weight, transport density, transport duration (Jacobsen et al., 1993), transport speed (Warriss and Brown, 1990; Phillips et al., 1982), and pre-transport feeding (Schaefer et al., 1997). Additionally, transport stress has been reported to influence meat pH, color, texture, and water content, leading to darker meat and reduced meat quality (Lister et al., 1989; Price and Tennessen, 1981). Minimizing stress in pre-slaughter operations, including transport and handling, has been reported as an effective strategy to reduce transport loss (Haurez and Chupin, 1986).

The autonomic nervous system of livestock is activated when animals face stress from transportation, causing an increase in cations such as sodium and potassium and a decrease in anions such as chloride. This imbalance in ion concentrations and the resulting excitement of the nervous system are known to cause stress in the body (Schaefer et al., 1990). To mitigate this, a previous study reported that administering alcohol to Holstein steers reduced transport loss by approximately 9 kg (Choi et al., 2002). Additionally, numerous studies have demonstrated the effect of cation administration, such as potassium, in reducing transport-related weight loss (Schaefer et al., 1990; Haurez and Chupin, 1986; Tarrant et al., 1992; Warner, 1988). On the other hand, vitamin E, known for its antioxidant properties, has been found to prevent changes in meat color. Schaefer et al. (1997) reported that feeding vitamin E prior to the final fattening phase helped prevent economic losses due to meat color deterioration. In a study on Holstein beef cattle, 91% of consumers preferred the meat color and fat distribution of cattle supplemented with vitamin E (Sanders et al., 1997).

Since transport stress not only contributes to weight loss but also leads to meat color and quality deterioration, appropriate pre-transport measures are necessary to maintain meat quality. To date, studies have explored strategies to reduce transport stress by supplementing various compounds such as electrolytes (Schaefer et al., 1990; Schaefer et al., 1997; Haurez and Chupin, 1986; Tarrant et al., 1992; Warner, 1988) and vitamin E (Sanders et al., 1997) before transport.

Therefore, the aim of this study was to investigate the effect of vitamin E, potassium, and alcohol-fermented feed supplementation before transport on body weight, carcass characteristics, and meat color in Hanwoo steers.

Materials and methods

Ethical considerations

All procedures involving animals were carried out in compliance with South Korean regulations (Animal and Plant Quarantine Agency – Ministry of Food and Drug Safety Joint Animal Testing and Laboratory Animal-Related Committee Standard Operating Guidelines).

Location of the experiment

This experiment was conducted at Hanwoo Farm, Hongcheon-gun, Gangwon-do, Korea (37°40'45"N, 127°55'56"E, 159 m a.s.l.).

Animals, management, and treatments

The study was conducted using forty Hanwoo steers (average body weight: 572.2 kg), which, six months before transport, were randomly assigned to one of four dietary treatments:

- No treatment (Control).
- Alcohol-fermented feed treatment (T1).

- Potassium treatment (T2).
- Vitamin E treatment (T3).

The alcohol-fermented feed was provided at 1.58 kg/head/day, vitamin E at 500 IU/head/day for six months prior to transport, and potassium was dissolved in water at 1.45% of the daily feed intake and administered orally one day before transport.

The alcohol-fermented feed used in this study was prepared by mixing corn grit and brewers' grain in a 50:50 ratio. Molasses and yeast were added before fermentation for 48 hours at approximately 30 °C under anaerobic conditions (Table 1).

Table 1. Chemical composition of the experimental diets.

Ingredients	Commercial feed	Fermented diet	Rice straw
Dry matter (%)	96.33±0.09	66.09±0.59	89.56±0.30
Crude protein (% of dry matter)	12.39±0.37	11.69±0.44	5.66±0.16
Ether extract (% of dry matter)	4.05±0.33	6.81±0.11	4.51±0.21
Crude ash (% of dry matter)	6.89±0.01	3.80±0.11	8.44±0.03
NDF (% of dry matter)	30.71±0.24	17.79±0.08	53.36±0.37
ADF (% of dry matter)	10.77±0.74	3.98±0.20	29.78±1.90

NDF: Neutral detergent fiber. **ADF:** Acid detergent fiber.

Transportation loss

The experimental animals were transported by a truck with a capacity of 8,000 kg, with an average transport density of five cattle per vehicle. The transportation duration was approximately two hours, and transportation loss was calculated by comparing the weight before transport (pre-transport weight) and the weight upon arrival at the slaughterhouse (post-transport weight).

Carcass characteristics

Feed was withdrawn from animals at the farm 24 hours prior to slaughter, while cattle continued to have access to water. For the evaluation of carcass refrigeration 24 hours post-slaughter, the following parameters were assessed according to national carcass grading standards (MAFRA, 2018): carcass ratio, meat quantity index, back fat thickness, rib-eye area, marbling score, meat color, fat color, and meat quality grade.

Surface meat color

Color measurement was performed using a colorimeter (CR-310, Minolta Co., Japan), which measured CIE L* (lightness), a* (redness), b* (yellowness), and chroma values. The chromaticity values of the standard white plate were Y = 93.7, x = 0.3129, and y = 0.3194. As the spectrophotometer was equipped with a reflectance attachment (UV-2410PC, Shimadzu, Japan), reflectance at 630 nm and 580 nm was measured to calculate the R_{630}-R_{580} value (Strange et al., 1974).

Statistical analysis

Generalized linear models (GLM) were used for statistical inferences. After fitting the linear model, Duncan's Multiple Range Test was applied to determine the statistical significance of differences between variables.

The SPSS v.8.01 software package (2000) was used for statistical analysis.

For weight, carcass characteristics, and meat color, the following statistical model was adopted:

$$Y_{ijk} = \mu + T_i + C_{ij} + e_{ijk}$$

in which Y_{ijk} is the dependent variable, μ is the general average, T_i is the effect of diets, C_{ij} is the effect of the covariate, and e_{ijk} is the experimental error.

Results

Transportation loss

The pre-transport body weight of the control, alcohol-fermented feed, potassium, and vitamin E treatments was 652.0, 688.9, 677.5, and 745.7 kg, respectively (Table 2). Pre-transport body weight was higher in the treatment groups than in the control group. The post-transport body weight was also higher in the treatments than in the control (control, alcohol-fermented feed, potassium, and vitamin E: 626.0, 670.0, 660.0, and 725.0 kg, respectively).

The transport loss of the control, alcohol-fermented feed, potassium, and vitamin E treatments was 26.0, 18.9, 17.5, and 20.7 kg, respectively, indicating that the transport loss was lower in the treatments than in the control ($p< 0.05$). In addition, the transport loss of the test groups was shown in the following order: control group > vitamin E group > alcohol-fermented feed group > potassium group. Compared to the control and vitamin E, alcohol-fermented feed and potassium were found to be significantly effective in controlling transport loss. Transport loss occurred in both the control and treatment groups in this experiment, but transport loss was significantly reduced in the treatment groups compared to the control group.

Table 2. Effect of alcohol-fermented feed, potassium, and vitamin E on transportation shrinkage in Hanwoo steers.

Items	Control	T1[1]	T2[2]	T3[3]
SW[4] (kg)	652.0 ± 66.76^{b}	688.9 ± 31.89^{a}	677.5 ± 18.87^{a}	745.7 ± 28.33^{a}
LW[5] (kg)	626.0 ± 67.08^{b}	670.0 ± 28.28^{a}	660.0 ± 18.71^{a}	725.0 ± 35.00^{a}
Shrinkage (kg)	26.0 ± 4.06^{a}	18.9 ± 4.15^{b}	17.5 ± 1.12^{b}	20.7 ± 8.67^{b}

[1]T1: group fed alcohol-fermented feed; [2]T2: fed potassium before transportation; [3]T3: fed vitamin E before transportation; [4]SW: farm shipping weight; [5]LW: slaughterhouse live weight.
[a, b]Means in same row with different superscripts differ ($p< 0.05$).

Carcass characteristics

The meat color scores for the control, alcohol-fermented feed, potassium, and vitamin E treatments were 5.50, 5.00, 5.25, and 4.25, respectively (Table 3), and these values were lower in the treatment groups, except for the potassium treatment ($p < 0.05$). Among the treatments, meat color in the vitamin E group was significantly lower ($p < 0.05$) than in the alcohol-fermented feed and potassium groups.

Regarding fat color, no significant differences were observed ($p > 0.05$) between treatments. For the marbling score, the alcohol-fermented feed, potassium, and vitamin E groups showed a higher tendency compared to the control group, but the differences were not statistically significant ($p > 0.05$).

Among the factors determining meat yield, no differences ($p > 0.05$) were found between treatments for back fat thickness, carcass percentage, and meat production index. However, rib-eye area was significantly larger in the treatment groups compared to the control ($p < 0.05$). On the other hand, meat color improved in each treatment group (alcohol-fermented feed, potassium, and vitamin E) compared to the control, and the vitamin E treatment resulted in a greater improvement in meat color compared to the alcohol-fermented feed and potassium treatments.

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Therefore, feeding Hanwoo steers alcohol-fermented feed, potassium, and vitamin E for a specific period before transportation, or at a key time point, may help suppress stress induced by transportation, thereby improving meat color and marbling score. In particular, supplying vitamin E for a certain period before transport could effectively prevent meat color deterioration caused by transportation stress.

Table 3. Effects of alcohol-fermented feed, potassium, and vitamin E on carcass characteristics of Hanwoo steers.

Items	Treatment			
	Control	T1	T2	T3
Quality traits				
Meat color	5.50±0.58^{a}	5.00±0.00^{b}	5.25±0.50^{ab}	4.25±0.50^{c}
Fat color	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00
Marbling score	3.25±1.26	4.50±1.29	4.50±1.29	3.55±1.89
Quality grade	2.00±0.82	2.00±0.82	1.50±0.58	2.50±1.00
Quantity traits				
Back fat thickness (mm)	10.00±4.08	6.50±1.73	7.75±0.50	8.75±3.50
Rib-eye area (cm^2)	81.25±5.19^{b}	88.75±2.36^{ab}	96.75±7.41^{a}	92.25±4.35^{a}
Carcass percent (%)	59.43±5.49	55.89±0.92	59.71±0.50	58.72±2.03
Meat yield index score	68.12±1.72	70.10±0.59	70.16±0.72	69.11±1.13

[1]T1: group fed alcohol-fermented feed; [2]T2: fed potassium before transportation; [3]T3: fed vitamin E before transportation.
[a, b, c]Means in same row with different superscripts differ ($p < 0.05$).

Meat surface color

Meat color is highly sensitive to nutrient composition and transportation stress (Table 4). The lightness (L) values* of meat for the control, alcohol-fermented feed, potassium, and vitamin E treatments were 34.93, 35.13, 38.15, and 37.64, respectively, and were significantly higher in the potassium and vitamin E treatments than in the control ($p < 0.05$). Although statistical significance was not observed, the alcohol-fermented feed treatment tended to produce lighter-colored meat compared to the control.

Redness is known to be the most important factor in determining meat color. The redness values were 20.48, 22.97, 23.63, and 25.66 in the control, alcohol-fermented feed, potassium, and vitamin E treatments, respectively, and redness in the treatment groups (especially vitamin E) was significantly higher than in the control ($p < 0.05$).

Regarding chroma value, an indicator of red intensity, the values for the control, alcohol-fermented feed, potassium, and vitamin E treatments were 21.94, 24.69, 25.61, and 27.81, respectively, with significantly higher values in the treatment groups compared to the control ($p < 0.05$).

For hue angle, an indicator of meat brownness, the control, alcohol-fermented feed, potassium, and vitamin E treatments had values of 22.63, 21.41, 22.67, and 20.98, respectively. The hue angle in the vitamin E treatment was significantly lower than in the control ($p < 0.05$). Although statistical significance was not observed, the alcohol-fermented feed treatment also tended to have lower hue values than the control. Thus, alcohol-fermented feed and vitamin E may help maintain meat color stability by preventing the browning effect.

For yellowness, which influences fat color and is a factor that reduces meat quality, the values for the control, alcohol-fermented feed, potassium, and vitamin E treatments were 10.73, 9.05, 9.89, and 7.86, respectively. The yellowness values in all treatment groups were significantly lower than in the control ($p < 0.05$). Within the treatment groups, the yellowness values in the alcohol-fermented feed and vitamin E treatments were significantly lower than in the potassium treatment ($p < 0.05$), indicating that alcohol-fermented feed and vitamin E were effective in reducing the yellowness of Hanwoo steer meat.

Overall, brightness, redness, clarity, and yellowness values were superior in the treatment groups compared to the control.

Table 4. Effect of alcohol-fermented feed, potassium, and vitamin E on meat color of Hanwoo steers.

Items	Control	T1	T2	T3
Lightness	34.93 ± 0.98^{b}	35.13 ± 1.90^{b}	38.15 ± 1.65^{a}	37.64 ± 1.43^{a}
Redness	20.48 ± 1.98^{c}	22.97 ± 0.54^{bc}	23.63 ± 2.20^{ab}	25.66 ± 1.15^{a}
Chroma value	21.94 ± 1.98^{c}	24.69 ± 0.66^{b}	25.61 ± 2.28^{ab}	27.81 ± 1.36^{a}
Hue angle	22.63 ± 0.91^{a}	21.41 ± 1.47^{ab}	22.67 ± 0.96^{a}	20.98 ± 0.89^{b}
Yellowness	10.73 ± 0.83^{a}	9.05 ± 0.74^{b}	9.89 ± 0.73^{ab}	7.86 ± 0.39^{c}

[1]T1: group fed alcohol-fermented feed; [2]T2: fed potassium before transportation; [3]T3: fed vitamin E before transportation;

[a, b, c]Means in same row with different superscripts differ ($p< 0.05$).

Discussion

Transportation loss

In this experiment, some manifestations of stress on meat quality appeared to be ameliorated by alcohol-fermented feed, potassium, and vitamin E treatments and balancing the electrolytes in the body. Alcohol-fermented feed and potassium supplementation for Hanwoo steers suppressed weight loss caused by transport stress. Although vitamin E treatment was less effective than alcohol-fermented feed and potassium, it was still beneficial in controlling weight loss during transport compared to the control group.

In this study, pre-transport body weight was not consistent across treatment groups. However, Jacobsen et al. (1993) reported that transport loss increased in proportion to pre-transport weight. In contrast, the present study found that transport loss decreased in the treatment groups with higher pre-transport weights compared to the control group, which had the lowest pre-transport weight.

Potassium supplementation was the most effective in reducing transportation-related effects, while alcohol-fermented feed also demonstrated a positive impact. It is believed that potassium supplementation improves the buffering capacity of livestock, maintains electrolyte balance, and prevents acidification of body tissues. Schaefer et al. (1997) reported that weight loss in beef cattle during long-haul transportation was reduced by approximately 7% with electrolyte supplementation, supporting the results of the present study.

According to Lee et al. (2013), long-term administration of alcohol has a sedative effect that reduces stress, with effects lasting for several hours. In particular, the sedative effect increases with the level of alcohol administration. In an experiment using Holstein steers, weight loss during transport was reduced by approximately 9 kg in the alcohol-supplemented group (Choi et al., 2002).

Therefore, supplementing Hanwoo steers with potassium and alcohol-fermented feed can help reduce transport-related weight loss, minimizing economic losses for farmers.

Carcass characteristics

Although meat color does not directly reflect nutrient content, flavor, or functional properties, it is a crucial quality factor influencing consumer preference (Lee et al., 2001). Meat color was significantly lower in the treatment groups of the present experiment compared to the control group, with the most notable improvement in the vitamin E-supplemented group. Liu et al. (1996) reported that vitamin E supplementation improved meat color and reduced meat quality deterioration. Similarly, in a vitamin E feeding trial with Hanwoo steers, various meat quality improvements were observed, including better surface color preservation and reduced lipid oxidation (Chu et al., 2004).

Alcohol supplementation has also been shown to prevent meat color deterioration. Han et al. (2014) found that alcohol supplementation effectively maintained meat redness during storage.

Baker (1988) reported that feeding electrolytes to beef cattle before transportation improves the body's buffering capacity, thereby reducing stress-related side effects. Although no statistically significant difference was observed, the present study showed a tendency toward improved meat color in the potassium-treated group compared to the control. Potassium may indirectly enhance meat color by reducing transport stress in beef cattle.

Overall, alcohol-fermented feed, potassium, and vitamin E supplementation contributed to numerical improvements in meat color in Hanwoo steers.

Meat surface color

Liu et al. (1996) reported that vitamin E supplementation improved meat brightness, while Schaefer et al. (1997) found that administering electrolytes to beef cattle altered meat color due to stress. In the present study, it was assumed that meat brightness in the treatment groups improved compared to the control due to stress suppression (via antioxidants and electrolytes) from supplementation with alcohol-fermented feed, potassium, and vitamin E.

Previous research has shown that as marbling score and fat content increase, meat brightness also increases (Mitsumoto et al., 1993; Demos and Mandigo, 1996). This suggests that the higher intramuscular fat content in the treatment groups may have contributed to the observed increase in brightness.

This study also demonstrated that the chroma value of the treatment groups was significantly higher than that of the control group. Sherbeck et al. (1995) reported that feeding vitamin E to beef cattle increased consumer preference, as meat clarity was maintained for a longer period compared to non-supplemented cattle. Matter et al. (1986) reported that feeding electrolytes to beef cattle stabilized meat coloration by reducing stress.

It has also been reported that supplementation with vitamin E, antioxidants, or electrolytes, including potassium, improves meat coloration and inhibits fatty acid oxidation (Monahan et al., 1989; Sherbeck et al., 1995; Marusich et al., 1975). Liu et al. (1996) found that adding vitamin E to beef cattle feed not only maintained the stability of redness and meat coloration but also reduced yellowness. Gatellier et al. (2001) similarly reported that dietary vitamin E supplementation improved color stability and reduced lipid oxidation in beef, supporting the findings of this study.

Conclusion

Alcohol-fermented feed, potassium, and vitamin E supplementation positively affect transport loss and meat color. However, further studies with a larger number of experimental animals are needed to better understand the effects of these supplements on stress reduction in livestock.

Declarations

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Conflicts of interest

The authors declare they have no conflicts of interest regarding the work presented in this report.

Author contributions

This study was designed and directed by Jongsuh Shin and Byungki Park. Overall paper was written and edited by Gihwal Son. All co-authors were closely involved in data collection, analysis, and interpretation, as well as in the writing and decision to submit the work for publication.

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

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