

Impact of feeding cover crop forage containing brassicas to steers during backgrounding on live animal performance, carcass characteristics, and meat color¹

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ABSTRACT: Brassica cover crops are an option for producers to incorporate into their cropping system to improve soil health and also provide a feed resource for cattle. While brassica cover crops have been widely used for grazing cows, their use as a backgrounding feedstuff is relatively unknown. The objective of this study was to determine the impact of feeding a brassica cover crop mixture during backgrounding on live animal performance and carcass characteristics. A total of 30 Angus-based steers were assigned to one of two dietary treatments during backgrounding 1) ad libitum access to a diet containing freshly cut brassica cover crop forage (CC) containing radish, turnip, rapeseed, rye grass, and a liquid supplement or 2) common Midwestern dry lot growing diet containing silage, soybean meal, grass hay, and a liquid supplement (CON). Steers were assigned to electronic feed bunks (Insentec RIC, Hokofarm Group; Marknesse, the Netherlands) for collection of individual feed intake. Diets were formulated to be nutritionally similar on a dry matter basis. Steers were paired by weight across treatments and pair fed. Dry matter intake (DMI)

was calculated daily for steers in the CC treatment and the following day, CON steers were allowed access to an equal amount of dry matter using the Insentec RIC system. Steers were weighed weekly and backgrounded for 44 days before transitioning to a common finishing diet and weighed every 28 days. Steers were harvested at an estimated average backfat thickness of 1 cm. Standard carcass data were measured and strip loins and shoulder clods were collected. Instrumental and subjective color were measured on ground beef for 8 days and instrumental color was measured on strip steaks for 11 days. Treatment did not influence carcass characteristics, average daily gain, and DMI ($P > 0.17$). However, CON steers exhibited increased gain to feed ratio ($P = 0.02$). Additionally, a treatment by day interaction was observed for ground beef discoloration as the CC treatment displayed increased discoloration on days 4, 6, and 7 of case life ($P < 0.01$). These data indicate that brassicas may be utilized in a backgrounding diet without negatively impacting carcass characteristics but may decrease case life of ground beef.

Key words: backgrounding, beef, brassica, color, cover crop, live animal performance

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INTRODUCTION

Backgrounding cattle on cover crops has been a growing practice within the agriculture industry over the past decade. The number of acres seeded into cover crops was an estimated 15.4 million acres in 2017, an increase of almost 50% from 2012 (USDA, 2019). Cover crops are usually planted after the harvest of cash crops such as oats, corn, or wheat and have become an integral part of sustainable agriculture. Two of the main purposes of planting cover crops include soil conservation and feed for grazing livestock (SARE, 2020). Economically, cover crops can benefit farmers and ranchers by providing a low-cost forage to extend the grazing season for ruminants in addition to improving crop yields by improving soil health and reducing soil compaction (Ball et al., 2008; Drewnoski et al., 2018). Brassicas are a cold hardy cover crop category that can be ready for grazing as little as 60 days after planting and include kale, forage rape, turnips, and radish (McCartney et al., 2009). Forage rape, turnip, and forage radish are highly digestible and have been shown to provide over 4,300 kg of dry matter per hectare and the crude protein levels generally hold steady above 18.6% crude protein from October to December, when seeded by mid-June (McCartney et al., 2009; Villalobos and Brummer, 2015). Grazing weaned calves on cover crops such as brassicas, clover, and grasses can be cost-effective alternatives to purchasing hay or other feedstuffs in the late fall and early winter (Cox-O'Neill et al., 2017). The most common use of brassicas in beef cattle diets is the grazing of mature cows during the late fall and early winter. Very limited research has been conducted to evaluate the impact of brassica cover crops on live animal performance or meat quality. This is important as post-weaning management practices can both positively and negatively impact palatability traits (Swanek et al., 1999; Montgomery et al., 2000; Roeber et al., 2005; Harsh et al., 2018). Few studies exist that evaluate the impact of backgrounding weaned calves on brassica cover crops on live animal performance, carcass characteristics, and product case life. Thus, the objective of this study was to determine the effects of feeding brassica-based cover crops and a traditional Midwestern diet to cattle during backgrounding on live animal performance, carcass characteristics, and case life of ground beef and strip steaks. We hypothesize a brassica mixture cover crop diet during backgrounding does not impact live performance, carcass characteristics, or case life attributes compared with a traditional Midwestern diet.

MATERIALS AND METHODS

Animals and Experimental Diets

Animal procedures were reviewed and approved by the South Dakota State University (SDSU) Institutional Animal Care and Use Committee (approval number 18-010A). Angus-based steers ($n = 30$; initial BW 315 ± 25 kg) of similar genetics were obtained from a single local producer. Three days after arrival at the SDSU Cow Calf Education Research Unit (CCERF), steers were vaccinated for prevention of Bovine Rhinotracheitis, Parainfluenza 3, Bovine Respiratory Syncytial Virus, *Mannheimia haemolytica*, and Bovine Viral Diarrhea Types 1 and 2 (Inforce3 and ONE SHOT BVD, Zoetis Inc, Kalamazoo, MI) administered an anthelmintic (Safe-Guard, Merck Animal Health, Madison, NJ) and an insecticide (Clean-Up II; Bayer Healthcare LLC, Shawnee Mission, KS), weighed, and provided an electronic identification tag. Steers were stratified into treatments by initial shrunk body weight. The control treatment (CON) received a traditional Midwestern backgrounding diet consisting of corn silage, grass hay, soybean meal, and a liquid supplement-containing monensin (Table 1). Feed ingredients for both treatments were sampled weekly, analyzed for DM, and composited into one sample per ingredient. Backgrounding diet nutrient analysis was conducted by Servi-Tech Laboratories (Hasting, NE). The cover crop treatment (CC) received a backgrounding diet of freshly cut brassica cover crop foliage including annual ryegrass (*Lolium multiflorum*; 64.50%), radish (*Raphanus sativus L.*; 15.08%), trophy rape seed (*Brassica napus*; 9.42%), purple top turnip (*Brassica rapa* subsp. *rapa*; 9.40%), and the same liquid supplement as the CON treatment (Table 1). After treatment allocation, steers were assigned to 1 of 10 automated feed bunks within a single pen that monitored and controlled individual intake (Insentec RIC, Hokofarm Group; Marknesse, the Netherlands). Bunk assignments were made based on treatment and initial BW. Steers were blocked by BW into light, middle, or heavy groups for each treatment. Within each treatment, one steer from each bodyweight block was assigned to each of the five bunks in a single pen for each treatment. Steers were allotted 4 weeks to become acclimated to the feeding system. Acclimation was done by introducing each steer to their assigned bunk and offering them the acclimation diet. All steers received a common diet of grass hay and corn silage for the duration of the acclimation process. Once steers

Table 1. Backgrounding diet composition for steers backgrounded on a cover crop mixture including brassicas (CC)^a or a common Midwestern backgrounding diet (CON) prior to transitioning to a common finishing diet^b

Ingredient	CC ^c	CON ^c	CC	CON
Diet composition	d 0–14		d 15–44	
Cover crop mixture, %	95.06	–	96.39	–
Corn silage, %	–	54.43	–	58.11
Ground hay, %	–	18.83	–	20.25
Soybean meal, %	–	14.99	–	16.85
Liquid supplement ^d , %	4.94	11.75	3.61	4.16
Nutrient composition ^e				
ADF ^f , %	36.03	22.54	36.53	24.47
NDF ^g , %	43.73	35.45	44.34	38.46
Ether extract, %	0.87	1.66	0.87	1.77
Crude protein, %	13.31	17.02	13.06	16.10
Ash, %	10.74	5.21	10.89	5.56
NE _M ^h , Mcal/kg	1.37	1.58	1.33	1.60
NE _G ⁱ , Mcal/kg	0.76	0.99	0.76	1.00

^aCover crop mixture included annual ryegrass (*Lolium multiflorum*; 64.50%), radish (*Raphanus sativus L.*; 15.08%), trophy rape seed (*Brassica napus*; 9.42%), and purple top turnip (*Brassica rapa* subsp. *rapa*; 9.40%).

^bCalculated on a dry matter basis.

^c*n* = 15.

^dContains 512 g/ton (DM) of monensin; Dakotaland Feeds, Huron, SD.

^eAnalyzed by Servi-Tech Laboratories, Hastings, NE.

^fAcid detergent fiber.

^gNeutral detergent fiber.

^hNet energy, maintenance; calculated from ADF by the following equation $NE_M = (1.37 * ME) - (0.3042 * ME^2) + (0.051 * ME^3) - 0.508$.

ⁱNet energy, gain; calculated from ADF by the following equation $NE_G = (1.42 * ME) - (0.3836 * ME^2) + (0.0593 * ME^3) - 0.7484$.

were familiar with their assigned bunk, the system was turned on and gates were incrementally lifted as the steers learned how to activate the gate with their electronic identification tag. Acclimation was considered complete when all steers were able to access their feed without help for 3 consecutive days.

After acclimation was complete, steers were fed their experimental diets for 44 days beginning on 15 October 2018. On day 15 of backgrounding, the diets were altered slightly to accommodate a change in liquid supplement inclusion (Table 1). The tops of the cover crops were cut daily at height of 10.2–15.2 cm above the ground using a sickle bar mower (New Idea, Model 522) and collected using a forage harvester. Collected forage consisted predominately of brassica tops according to visual inspection. Cover crops were transported to the CCERF within 1 h of being harvested.

In order to achieve similar growth during the backgrounding phase, diets were formulated to be similar based upon nutrient composition on a dry matter (DM) basis based on feed samples taken prior to study initiation. Daily feed intakes were recorded by the feeding system. Steers were pair fed to achieve a similar nutritional profile between treatments. To accomplish a pair feeding system,

the steer in the CC treatment was allowed ad libitum access to feed, and the following day, the CON steer was allowed the same amount of DM that his pair consumed the previous day. Cover crop DM was evaluated weekly and the diet was adjusted accordingly. Body weights were collected every 7 days for the duration of the backgrounding phase. The backgrounding phase was ended on day 44 due to inclement weather that prevented proper harvesting of the cover crop forage.

Finishing Phase, Harvest, and Product Collection

Upon completion of the backgrounding phase, all steers were transitioned to a common finishing diet which was offered on an ad libitum basis for an additional 187 days as described in Table 2. The diet was stepped up over a 61 day period. Feed ingredients were sampled weekly, analyzed for DM, and composited into monthly samples for nutrient analysis. Finishing diet nutrient analysis was conducted by Servi-Tech Laboratories (Hasting, NE). During the finishing phase steers were weighed every 28 days. Once steers were adapted to the finishing diet, they received an anabolic implant containing 200 mg

Table 2. Common finishing diet composition for steers backgrounded on a cover crop mixture including brassicas or a common Midwestern backgrounding diet^a

Ingredient	Step 1	Step 2	Step 3	Step 4	Step 5
Diet composition	d 45–72	d 73–91	d 92–98	d 99–105	d 106–231
Corn silage, %	58.11	–	–	–	–
Ground hay, %	20.25	34.97	28.81	18.94	10.66
Soybean meal, %	16.85	–	–	–	–
Liquid supplement ^b , %	4.16	5.82	6.35	6.48	6.47
Earlage, %	–	44.34	30.44	20.89	11.62
Dry rolled corn, %	–	1.11	18.31	36.44	52.34
Dried distillers grains with solubles, %	–	13.77	16.09	17.24	18.90
Nutrient composition ^c					
ADF ^d , %	24.47	20.24	17.15	12.94	9.76
NDF ^e , %	38.46	35.18	30.70	24.45	19.49
Ether extract, %	1.77	2.72	3.01	3.34	3.49
Crude protein, %	16.10	12.63	12.71	13.07	13.73
Ash, %	5.56	3.32	4.81	3.95	3.17
NE _M ^f , Mcal/kg	1.60	1.68	1.75	1.84	1.90
NE _G ^g , Mcal/kg	1.00	1.07	1.13	1.22	1.28

^aCalculated on a dry matter basis.

^bContains 512 g/ton (DM) of monensin; Dakotaland Feeds, Huron, SD.

^cAnalyzed by Servi-Tech Laboratories, Hastings, NE.

^dAcid detergent fiber.

^eNeutral detergent fiber.

^fNet energy, maintenance; calculated from ADF by the following equation $NE_M = (1.37 * ME) - (0.3042 * ME^2) + (0.051 * ME^3) - 0.508$.

^gNet energy, gain; calculated from ADF by the following equation $NE_G = (1.42 * ME) - (0.3836 * ME^2) + (0.0593 * ME^3) - 0.7484$.

trenbolone acetate and 28 mg estradiol benzoate (Synovex-Plus; Zoetis, Parsippany, NJ) on day 80 of the experiment. Steers were ultrasounded on day 164 for prediction of slaughter date to target an entire study group average of 1 cm of backfat.

All steers were transported approximately 240 km to a commercial abattoir for harvest on day 231 of the experiment. Steers were harvested after overnight lairage at the abattoir. Standard carcass data and instrumental longissimus color were recorded (Chroma Meter CR-410; Konica Minolta, INC. Osaka, Japan) by trained personnel at 28 h postmortem. Untrimmed shoulder clods (IMPS 114) and strip loins (IMPS 180) were collected and transported under refrigeration to the SDSU Meat Laboratory for fabrication.

Strip Loin Fabrication

Three days postmortem, strip loins were trimmed of external fat and the anterior end was faced to obtain an even cut surface prior to slicing 2.54-cm steaks. The portion removed when facing the strip loins was frozen and utilized for proximate analysis. The first through fifth steaks were utilized for data analysis, not included in this manuscript. The sixth steak was used for case life, evaluated by objective color analysis.

Proximate Analysis

Proximate analysis samples were trimmed of external fat and connective tissue and prepared by freezing in liquid nitrogen, and then powdered using a Waring commercial blender (Model 51BL32, Waring Products Division, New Hartford, CT) to produce a homogenous sample. Proximate analysis was conducted to determine moisture, fat, crude protein, and ash content of the samples. To determine moisture content, approximately 5.5 g of sample were weighed, placed in pre-weighed foil pans, covered in pre-weighed filter paper, and placed in an oven (Thelco Laboratory Oven, Precision Scientific, Winchester, VA) for 24 h at 101°C (method 950.46(a); AOAC, 2000). Moisture content was calculated as the difference between wet and dried weight and expressed as a percentage of wet weight.

After drying and reweighing, dried samples were extracted with petroleum ether in a side arm Soxhlet (method 960.39; AOAC, 2000) for 60 h. Excess ether was allowed to evaporate from samples under the fume hood prior to drying at 101°C for 4 h and subsequent reweighing. Fat content was calculated as the difference between pre- and post-extracted weight and expressed as a percentage of pre-extracted weight.

Crude protein was determined by weighing approximately 250 mg of powdered sample into a crucible. Samples were analyzed using the Dumas method (method 992.15; AOAC, 1996) with a protein analyzer (rapid MAX N exceed, Elementar, Langensfeld, Germany).

To determine ash content, 3 g of sample was placed in a pre-weighed crucible, dried for 24 h at 101°C, and ashed for 16 h at 500°C in a muffle furnace (Isotemp Programmable Muffle Furnace, Fischer Scientific, Waltham, MA) and reweighed following cooling in a desiccator. Ash content calculated by dividing the ashed weight by the wet weight and is reported as a percentage.

Strip Steak Instrumental Color

Strip steaks chosen for shelf life color evaluation were wet aged until 6 d postmortem before they were overwrapped in black 21.6 cm × 16.5 cm × 2.54 cm polystyrene trays (Dyne-A-Pak, Quebec, Canada) with oxygen permeable polyvinyl chloride film (15,500–16,275 cm³/m²/24 h oxygen transmission rate). Samples were placed into a cooler at 4°C with fluorescent lighting (F32 T8, 2,975 lumens, 2.54 cm diameter fluorescent bulbs; General Electric, Boston, MA). Lux was measured in 12 locations of the cooler daily and averaged to calculate light intensity (Digital Lux Meter; Model LX1330B, Dr. Meter, London, England). Average light intensity was 1,651 lux throughout the 10-day case life evaluation. Samples were rotated daily to eliminate a cooler location effect on sample color.

Instrumental color was evaluated at 1600 h daily for the duration of the trained color panel. Instrumental L*, a*, and b* values were measured with a colorimeter (Chroma Meter CR-410; Konica Minolta, INC. Osaka, Japan) at three locations on each sample and averaged to obtain daily color values.

Chuck Clod Processing and Ground Beef Color Evaluation

Chuck clods were trimmed of subcutaneous fat and ground twice through a 0.476 cm plate (4822 Hobart Mfg. Co., Troy, OH). One 0.454 kg portion was placed on white 14 cm × 14 cm × 1.27 cm polystyrene trays (Dyne-A-Pak, Quebec, Canada), overwrapped with oxygen permeable polyvinyl chloride film (15,500–16,275 cm³/m²/24 h oxygen transmission rate), and assigned a three-digit identification code. Trays were placed in a cooler under conditions as previously described for strip steaks.

Light intensity through the duration of the color panel was measured at eight locations daily and average intensity was 1,445 lux. Samples were rotated daily to eliminate a cooler location effect on sample color.

Subjective color evaluation was conducted by eight trained panelists between 1400 and 1600 h daily for 8 days. On day 0, panelists evaluated ground beef color on a scale of 1–8 with 1 indicating “Bleached Red” and 8 indicating “Very Dark Red.” Color evaluations on day 1 through 7 were evaluated on a scale of 1–8 with 1 indicating “Very Bright Red” and 8 indicating “Tan to Brown.” Discoloration for all days was evaluated on a scale of 1–6 with 1 indicating 0% discoloration and 6 indicating 81% to 100% discoloration. Panelists were allowed to evaluate lean color in 0.5-point increments and discoloration in 1-point increments. Beginning on day 3, panelists were asked to indicate if they considered the samples were acceptable for display in a retail setting. The panel was terminated on day 7 when all panelists considered at least 90% of samples unacceptable for retail. Instrumental color was evaluated as described for strip steaks.

Statistical Analysis

All data were analyzed using the MIXED procedure of SAS 9.4 (SAS Institute Inc., Cary, NC) with the fixed effect of treatment. Animal was considered to be the experimental unit. Live animal performance data were analyzed by diet phase (backgrounding or finishing) as well as overall. Case life color measurements were analyzed as repeated measures with the fixed effect for treatment and day of case life utilizing the Toeplitz covariance structure. Means were separated for the repeated measures utilizing the PDIFF option in SAS 9.4. Treatment by day interactions were evaluated where appropriate and are reported when significant. Significance was declared at $P < 0.05$ and trends were considered at $P > 0.05$ and $P < 0.10$.

RESULTS AND DISCUSSION

Live Animal Performance

The cover crop forage varied greater than the extent predicted which resulted in a lower dietary protein content and energy content of the cover crop backgrounding diet as reported in Table 1. Even with the difference in nutrient composition of the backgrounding diets no differences were observed in body weight, average daily gain (ADG), or dry matter intake

Table 3. Live animal performance of steers backgrounded on a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON) prior to transitioning to a common finishing diet^a

Variable	CC ^b	CON ^b	SEM	P-value
Backgrounding phase ^c				
Initial weight, kg	314	316	6.608	0.840
ADG ^d , kg/d	0.33	0.41	0.063	0.397
DMI ^e , kg/d	6.47	6.48	0.330	0.982
G:F ^f	0.051	0.062	0.009	0.423
BW ^g , kg	329	334	5.482	0.503
Finishing phase ^c				
ADG ^d , kg/d	1.49	1.52	0.034	0.578
DMI ^e , kg/d	10.81	10.80	0.219	0.971
G:F ^f	0.138	0.141	0.002	0.450
BW ^g , kg	607	618	9.148	0.433
Overall				
ADG ^d , kg/d	1.27	1.30	0.028	0.367
DMI ^e , kg/d	9.51	9.14	0.188	0.175
G:F ^f	0.134	0.143	0.003	0.022

^aLeast square means.

^b $n = 15$.

^cBackgrounding phase was 44 d; finishing phase was 187 d.

^dAverage daily gain.

^eDaily dry matter intake.

^fGain to feed ratio.

^gBody weight at the end of the feeding phase.

(DMI) throughout the study ($P > 0.17$) (Table 3). The lack of differences observed could be due having only 15 steers in each backgrounding treatment.

Gain to feed (G:F) ratio did not differ in the backgrounding or finishing phase ($P > 0.42$). However, overall G:F was increased for the CON treatment compared to CC ($P = 0.02$). This is likely due to the numeric increases observed in G:F for both the backgrounding and finishing phases. Similarly, Nenn (2017) observed no differences in overall ADG or final BW when comparing steers allowed to graze turnips prior to being moved to a dry lot compared with steers that were not allowed to graze prior to entering a dry lot setting. Conversely, Cox-O'Neill et al. (2017) observed an increase in backgrounding phase ADG, finishing phase DMI, and final live weight as well as a decrease in growing phase DMI for a brassica/oat grazing system compared with a dry lot system. A possible explanation for the differing performance data between the current study and Cox-O'Neill et al. (2017) is the overall availability of feed. In the current study, the diets were delivered to the steers in a dry lot feeding system while the brassica/oat treatment calves in Cox-O'Neill et al. (2017) were allowed to graze the forage directly from the field. This means that the calves had access not only to the leafy forages, but also the bulbs and tubers of the brassicas. The ad libitum access to feed for the brassica/oat

treatment in Cox-O'Neill et al. (2017) possibly contributed to the increased ADG observed over the dry lot treatment.

Carcass Characteristics and Proximate Analysis

Carcass characteristics and longissimus color recorded at the time of grading did not differ between treatments ($P > 0.19$; Table 4). The lack of difference in backfat thickness was not unexpected as cattle were harvested at a common backfat thickness predicted with ultrasound on day 232 of the experiment. Similar to the current study, Fehrman (2016) did not observe differences in carcass characteristics in the comparison of a backgrounding diet including turnips to a dry lot diet. Additionally, Cox-O'Neill et al. (2017) reported no difference in backfat thickness or calculated yield grade of cattle grazing a brassica/oat mixture compared to a dry lot backgrounding diet. However, Cox-O'Neill et al. (2017) did observe a decrease in REA and HCW for the dry lot treatment compared with the cover crop treatment. No differences were observed in the proximate analysis of longissimus steaks between treatments ($P > 0.14$; Table 4). These results reflect the carcass data characteristics, as no differences in marbling scores were detected, thus no difference in percent fat was expected.

Table 4. Carcass data, longissimus muscle color, and proximate analysis of steers backgrounded on a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON)^a

Variable	CC ^b	CON ^b	SEM	P-value
Hot carcass weight, kg	385	395	4.906	0.210
Ribeye area ^c , cm ²	88.05	92.83	2.704	0.222
Backfat ^c , cm	0.93	1.01	0.062	0.352
Marbling score ^d	469	503	17.880	0.190
Yield grade	2.67	2.59	0.123	0.650
L* ^e	41.59	41.26	0.438	0.606
a* ^e	24.53	24.40	0.180	0.611
b* ^e	9.82	9.58	0.134	0.214
Moisture, %	72.32	71.85	0.327	0.315
Fat, %	5.48	6.08	0.411	0.313
Protein, %	21.18	20.85	0.154	0.138
Ash, %	1.05	1.04	0.009	0.322

^aLeast square means.

^bn = 15.

^cRibeye area and backfat measured between the 12th and 13th rib.

^dMarbling score: 300 = Slight⁰, 400 = Small⁰, 500 = Modest⁰.

^eMeasured on the longissimus muscle at time of carcass grading.

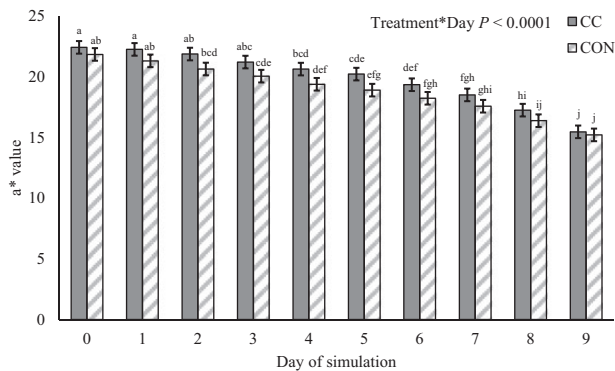


Figure 1. Impact of feeding a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON) during backgrounding on a* (redness) color values during a simulated retail display of strip steaks*. *Least square means. ^{abcde fghij}Means lacking common superscripts differ $P < 0.05$.

Strip Steak Color Analysis

No differences in instrumental L* values were observed for strip steaks between treatments (46.61 vs. 46.88 ± 0.12; $P = 0.11$; CC vs. CON, respectively) or by day of case life ($P = 0.99$; data not shown). A treatment by day interaction was observed for a* values ($P < 0.01$; Figure 1). Additionally, a treatment by day interaction was also observed for b* values ($P < 0.01$; Figure 2). Steaks from the CC treatment displayed increased b* values compared with steaks from the CON treatment on day 2 (8.43 vs. 7.78; $P = 0.04$) and day 5 (7.86 vs. 7.23; $P = 0.05$), while remaining numerically increased on all other day ($P > 0.05$). Fehrman (2016) also evaluated instrumental color during case life on strip steaks over 8 d and observed no treatment effects for L*, a*, or b* values. To the authors knowledge, no other

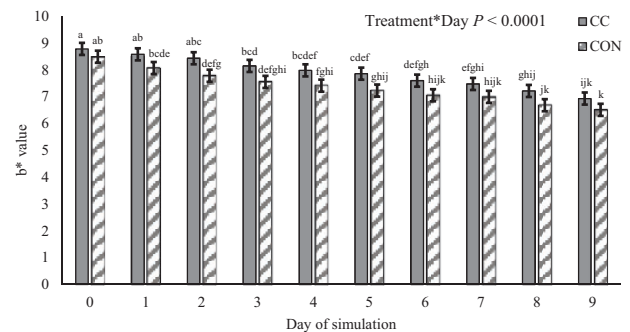


Figure 2. Impact of feeding a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON) during backgrounding on b* (yellowness) color values during a simulated retail display of strip steaks*. *Least square means. ^{abcde fghijk}Means lacking common superscripts differ $P < 0.05$.

studies have reported the impact of backgrounding on cover crops on strip steak case life.

Interestingly, the a* values for ground beef responded in an opposite manner compared with the steaks. The ground beef a* values were numerically increased for the CON treatment, while steak a* values were increased for the CC treatment. The differences in behavior of the two types of sample could be attributed to differences in lipid content, muscle type, or mitochondrial activity, all of which impact meat color (Cassens and Cooper, 1971; Hunt and Hedrick, 1977; Ramanathan et al., 2009).

Ground Beef Color Analysis

During evaluation of initial ground beef color, the trained color panelists tended to rate CC ground beef closer to a cherry red color compared

to CON (4.03 vs. 3.82; $P = 0.07$). No treatment by day interactions were observed for trained color panel scores for day 1 through 7 ($P > 0.05$). However, trained panel color scores were increased for CC ground beef samples compared with CON samples (5.79 vs. 5.48; $P < 0.01$). These values indicate the CC treatment was closer to a reddish tan/brown color while the CON treatment was closer to a slightly more desirable moderately dark red color. Additionally, color scores were increased from day 1 to day 7 ($P < 0.01$; Figure 3). Color scores increased from day 1 to day 5, and from day 6 to day 7. The change in color over time was expected as the myoglobin state of meat changes from oxy-myoglobin to metmyoglobin as it oxidizes when exposed to oxygen and light (Mancini and Hunt, 2005; Suman and Joseph, 2013). A treatment by day interaction was observed for trained panel discoloration scores when evaluated from day 0 to day 7. Treatments discolored similarly from day 0 to day 3 before the rate of discoloration increased for the CC treatment compared with CON ($P < 0.01$; Figure 4). The increased color scores coupled with the increased rate of discoloration for CC compared with CON treatments are likely due to an increase in metmyoglobin formation. Suman and Joseph (2013) noted that discoloration is generally referred to as the amount of surface area covered by metmyoglobin. Therefore, it can be inferred that the CC treatment could have resulted in an increased oxidation rate of ground beef. The evaluation of the impact of backgrounding diets on ground beef case life is largely unstudied. However, Fehrman (2016) reported a treatment by day interaction for beef color scores evaluated by a trained panel and noted a less desirable increase in color scores for the cover crop treatment compared with the control on days

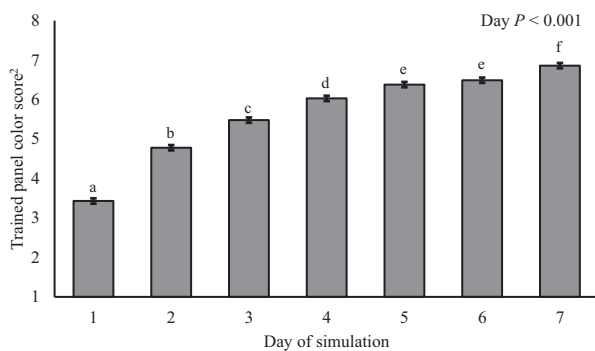


Figure 3. Impact of simulation day on trained panel color scores during a simulated retail display of ground beef. *Least square means. †Trained panel color scores: 1 = very bright red, 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark red, 6 = reddish tan/brown, 7 = dark reddish tan/brown, 8 = tan to brown. ^{abcd}Means lacking common superscripts differ $P < 0.001$.

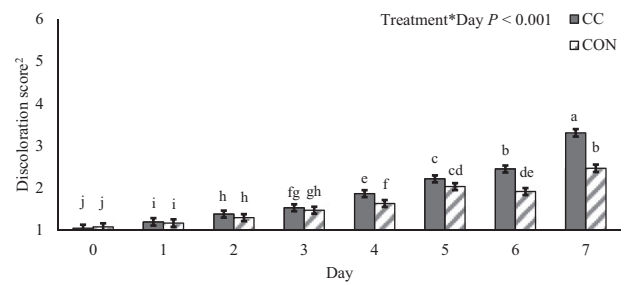


Figure 4. Impact of feeding a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON) during backgrounding on trained panel discoloration scores during a simulated retail display of ground beef. *Least square means. †Discoloration score: 1 = no discoloration, 0%; 2 = slight discoloration, 1% to 20%; 3 = small discoloration, 21% to 40%; 4 = modest discoloration, 41% to 60%; 5 = moderate discoloration, 61% to 80%; 6 = extensive discoloration, 81% to 100%. ^{abcd}Means lacking common superscripts differ $P < 0.05$.

1–4 of case life where decreased scores represented brighter more cherry red color and increased scores represented brown to green color. Additionally, trained panelists found samples from the cover crop treatment to be less desirable than the control on days 1–4 (Fehrman, 2016). Fehrman (2016) did observe a treatment by day interaction for discoloration scores of ground beef. However, unlike the current study, the author reported differences in discoloration on days 2–4 before all treatments became similar for days 5–7 (Fehrman, 2016). The increased discoloration in ground beef has great economic impact. Feuz et al. (2020) found that even minimal discoloration of ground beef products can reduce the average consumer's willingness to pay by as much as 50% as consumers associate discoloration with unwholesomeness. This has the potential to turn consumers from purchasing beef to other protein options.

Instrumental L^* values of ground beef did not differ between treatments (48.08 vs. 48.33 ± 0.12 ; $P = 0.14$; CC vs. CON, respectively) or day of case life ($P = 0.98$; data not shown). A treatment by day interaction was observed ($P < 0.01$; Figure 5) for redness (a^*). While no differences were observed between treatments on any day, values for CON samples were numerically increased throughout the observation period. A treatment by day interaction was also observed for yellowness (b^*) values ($P < 0.01$; Figure 6). Yellowness values were increased for both treatments on day 0 compared with days 1 and 2. Then, values remained similar from day 2 to day 5. Day 6 values were increased ($P < 0.05$) compared with days 2 and 3 and similar to days 4, 5, and 7. The instrumental color results of this study coincide with the trained panel observations. As the panel went on, the panelists

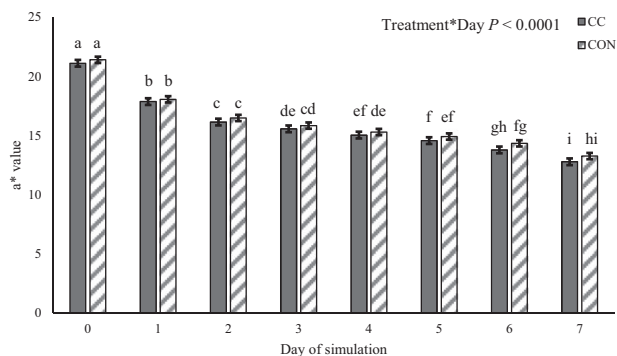


Figure 5. Impact of feeding a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON) during backgrounding on instrumental a* (redness) color values during a simulated retail display of ground beef*. *Least square means. ^{abcde}Means lacking common superscripts differ $P < 0.05$.

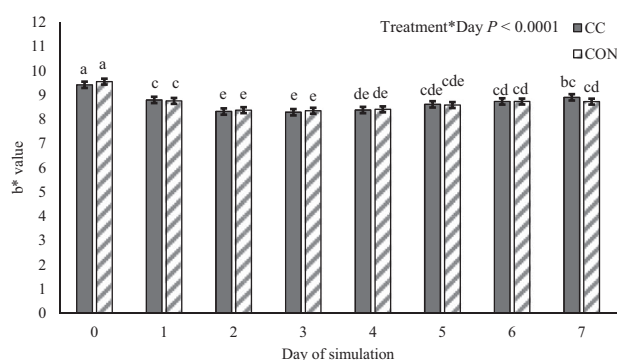


Figure 6. Impact of feeding a cover crop mixture including brassicas (CC) or a common Midwestern backgrounding diet (CON) during backgrounding on instrumental b* (yellowness) color values during a simulated retail display of ground beef*. *Least square means. ^{abcde}Means lacking common superscripts differ $P < 0.05$.

indicated the color of the samples became more brown and less red, which would be associated with decreasing a* values. O'Sullivan et al. (2003) noted that panelists generally associated b* values with brown colors, thus the increasing b* values after day 3 are consistent with their findings. It is possible that the differences in observed color were due to differences in oxidation rate of the samples as lipid oxidation has been shown to impact color (Faustman and Cassens, 1990; Mancini and Hunt, 2005). However, oxidation of the samples was not evaluated in this study and no evidence supporting this hypothesis could be generated.

CONCLUSION

Dietary management during the backgrounding phase has the ability to influence meat color, even after a common finishing diet. The rate of discoloration of ground beef was increased for the CC treatment. As color is an important quality attribute to consumers, additional research is warranted to

continue to evaluate the impacts of dietary brassica cover crop forages during backgrounding on meat quality. However, these data indicate that brassicas may be utilized in a backgrounding diet without negatively impacting carcass characteristics.

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Conflict of interest statement. None declared.

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