

# Impact of a phytogenic feed additive on growth performance, feed intake, and carcass traits of finishing steers

Tassilo Brand,<sup>†,‡</sup> Martin Hünerberg,<sup>†,1</sup> Tim A. McAllister,<sup>‡</sup> Maolong He,<sup>‡,¶</sup> Atef M. Saleem,<sup>‡,§</sup>  
Yizhao Shen,<sup>‡,¶</sup> Bryan Miller,<sup>\*\*</sup> and Wenzhu Yang<sup>‡</sup>

<sup>†</sup>Department of Animal Sciences, University of Goettingen, Goettingen 37077, Germany; <sup>‡</sup>Agriculture and Agri-Food Canada, Lethbridge, Alberta T1J 4B1, Canada; <sup>¶</sup>Lucta Flavours Co. Ltd., Guangzhou 510530, China; <sup>§</sup>Animal and Poultry Production Department, Faculty of Agriculture, South Valley University, Qena 83523, Egypt; <sup>¶</sup>College of Animal Science and Technology, Hebei Agricultural University, Baoding 071001, China; and <sup>\*\*</sup>BIOMIN America Inc., Overland Park, KS 66210

**ABSTRACT:** The purpose of this study was to evaluate the effect of a phytogenic feed additive (Digestaron [DA]; Biomin, Getzersdorf, Austria) on growth performance, feed intake, carcass traits, fatty acid composition, and liver abscesses of finishing steers. One hundred twenty Angus × Charolais crossbred steers (488 ± 26.5 kg) were used in a 110-d feeding experiment. Steers were blocked by weight and randomly assigned to 12 pens with 10 steers per pen. Each pen was allocated to one of three diets. Each diet contained 86.5% barley, 10.0% barley silage, and 3.5% vitamin and mineral supplement on a dry matter (DM) basis. The diets contained 0, 0.05, and 0.1 g DA/kg complete diet (DM basis), to achieve average daily DA intakes of 0 (control), 0.5 (LowDA), and 1.0 g (HighDA) per steer. Diets were prepared once daily and provided ad

libitum. Two pens per treatment were equipped to record individual feed intake behavior. Steers were weighed every 28 d and carcass traits and liver scores were recorded at slaughter. Dry matter intake (average: 9.34 kg/d) did not differ ( $P > 0.05$ ) among diets. Average daily gain tended to increase linearly as DA increased (control: 1.82; LowDA: 1.87; and HighDA: 1.95 kg/d;  $P < 0.09$ ), but gain:feed ratio was not affected. Supplementation of DA affected longissimus muscle area quadratically ( $P = 0.05$ ) with the largest area observed for LowDA. However, dressing percentage decreased linearly in response to increasing level of DA ( $P < 0.01$ ). Total abscessed livers were not affected, whereas proportion of severe liver abscesses was numerically lower with DA (30.8% and 42.5% for LowDA and HighDA) compared to the control (50%).

**Key words:** beef cattle, carcass traits, feed intake, growth performance, phytogenic feed additive

© The Author(s) 2019. Published by Oxford University Press on behalf of the American Society of Animal Science. This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact [journals.permissions@oup.com](mailto:journals.permissions@oup.com)

Transl. Anim. Sci. 2019.3:1162–1172  
doi: 10.1093/tas/txz109

## INTRODUCTION

Phytogenics, also referred to as botanicals or phytobiotics, are plant extracts or mixtures of plant-derived compounds that are marketed as natural growth promotants (Windisch et al., 2008). Phytogenics can be derived from a wide range of plants and plant material including herbs,

<sup>1</sup>Corresponding author: [martin.huenerberg@uni-goettingen.de](mailto:martin.huenerberg@uni-goettingen.de)

Received February 13, 2019.

Accepted July 22, 2019.

spices, roots, peels, and tree bark (Windisch et al., 2008; Yang et al., 2015). Their proclaimed modes of action are diverse and range from antimicrobial, anti-inflammatory, and antioxidant capabilities to a stimulation of feed intake and production of gastric secretions (Smith-Palmer et al., 1998; Dorman and Deans, 2000; Wei and Shibamoto, 2007). Overall, our knowledge regarding the metabolic functions and interactions of phytogenics with other diet components and animal-related factors such as age is limited (Windisch et al., 2008). Therefore, the impact of each phytogenic additive on health and growth performance needs to be examined systematically and results are not transferable among livestock species or even across stages of production.

Although the use of subtherapeutic antibiotics as growth promotants has been banned in the European Union since 2006 (European Union, 2003), other countries still allow the usage of certain feed additives for growth promotion. For example, ionophores (e.g. monensin and lasalocid sodium), which have no relevance in human medicine, are extensively used in the feedlot industry in South and Central America, United States, and Canada. Therefore, it is not only of interest to evaluate the impact of phytogenics alone, but also in combination with ionophores.

High-grain diets, fed during the finishing stage promote marbling and maximize weight gain, but can be associated with increased metabolic stress. Bouts of subacute or acute acidosis can result in the generation of bacterial endotoxins such as lipopolysaccharides or amides (e.g. histamine; Owens et al., 1998) that lead to inflammation and suppress antioxidant activity (Abaker et al., 2017). Therefore, finishing cattle could potentially benefit from feed additives with anti-inflammatory or antioxidant activity. A previous study reported that supplementing milk replacer and calf starter with the phytogenic additive, Digestarom (DA; Biomin, Getzersdorf, Austria), improved average daily gain (ADG) and reduced diarrhea in bull calves (Schieder et al., 2014). More recently, supplementation of DA to pre- and post-weaned Holstein calves tended to increase starter intake, whereas ADG over the complete length of the experiment (67 d) was similar compared to control calves (Akbarian-Tefaghi et al., 2018). Supplementing DA to dairy cows which were abruptly transitioned from a pure forage diet (mixture of grass hay and grass silage) to a diet containing 65% concentrate dry matter (DM), resulted in prolonged rumination time and shorter duration of pH <6.0 in the reticulum (Kröger et al., 2017). Supplementation of DA in

the same study also decreased concentrations of plasma LPS, histamine, pyrrolidine, and spermine compared to the non-supplemented control group (Humer et al., 2018). However, data on the impact of this additive on finishing beef cattle fed high-grain diets are lacking.

The purpose of this study was to evaluate the effect of DA on growth performance, feed intake behavior, carcass traits, fatty acid profiles, and the incidence of liver abscesses of finishing cattle receiving standard, ionophore-containing feedlot diets. On the basis of the findings that DA alleviated the negative impact of an abrupt transition of dairy cows from hay to a diet containing 65% concentrate and improve feed intake and ADG in calves, we hypothesized that DA could as well improve growth performance or modulate feed intake of beef cattle exposed to high-grain diets during finishing.

## MATERIAL AND METHODS

This experiment was conducted at the Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre. The experimental protocol was reviewed and approved by the institutional animal care committee. Cattle were cared for in accordance with the guidelines of the Canadian Council on Animal Care (CCAC, 2009).

### *Experimental Design*

This study was conducted between September 2017 and January 2018 over a period of 110 d. One hundred and twenty Angus × Charolais crossbred, yearling steers ( $488 \pm 26.5$  kg initial unshrunk body weight [BW]) were blocked by weight and randomly assigned to 12 outdoor feedlot pens so that each pen housing 10 steers had similar BW at the beginning of the experiment. Each pen was allocated to one of three treatments, resulting in four pens per treatment. To monitor feeding behavior, two pens for each treatment were equipped with an automated system for monitoring individual feed intake and feed intake behavior (GrowSafe Systems Ltd, Calgary, AB, Canada).

### *Cattle and Housing*

Thirty-three days before the onset of the experiment, steers were vaccinated against Bovine Rhinotracheitis-Virus Diarrhea (Express yearling, Boehringer Ingelheim Ltd. Burlington, ON, Canada), clostridial agents and Histophilus somni (Ultrabac 7/Somubac, Zoetis Canada Inc.,

Kirkland, QC, Canada). Nine days before starting the experiment, steers were implanted with Component TE-100 (Elanco Animal Health, Guelph, ON, Canada). Medical treatments were documented for all steers over the entire feeding period. Steers were fitted with a radio frequency transponder located in the upper base of their right ear (Allflex USA, Dallas–Fort Worth, TX).

Pens were identical in size (17 × 12.7 m), fitted with automatic waters and separated by wooden porosity fences on two sides. Six pens were equipped with industry standard concrete bunks. Steers in the remaining six pens were offered feed through the GrowSafe system.

### Diets and Feeding

The steers were transitioned from a high-forage diet containing approximately 60% barley silage to a high-grain diet (90% concentrate; both DM basis) over the course of 4 weeks. One week before the beginning of the experiment all steers received the basal diet offered throughout the experiment. The basal diet was a typical Western Canadian finishing diet and consisted of 86.5% dry-rolled barley grain, 10% barley silage, and 3.5% pelleted vitamin and mineral supplement (DM basis; Table 1]. DA is a phytogenic product containing a blend consisting primarily of licorice, caraway, vanilla, essential oil of clove, salt, and silicon dioxide (Biomin,

Getzersdorf, Austria). DA was added to the pelleted vitamin and mineral supplement at inclusion rates of 0, 1.41, and 2.82 g/kg to achieve concentrations of 0, 0.05, and 0.1 g DA/kg complete diet (DM basis) and average daily intakes of 0 g (control), 0.5 g (LowDA) or 1.0 g DA (HighDA) per steer, respectively. Concentrations of DA in the diet were chosen based on manufacturer recommendation. The diets were prepared once daily as a total mixed ration using a feed truck (model: 414-14B; Roto-Mix, Dodge City, KS) equipped with a horizontal reel mixer and digital scale. Diets were formulated according to the recommendations of NASEM (2016) for finishing feedlot steers and offered ad libitum with a targeted feed refusal of 2% (as fed basis). The quantity of offered feed was recorded daily for each pen. Monensin sodium (Elanco Animal Health, Greenfield, IN) was included in all diets at 25 mg/kg complete diet (DM basis). Other synthetic feed additives were not included.

### Data Collection and Sampling

Initial and final BW were based on two consecutive weights on subsequent days at the beginning and the end of the experiment. Over the course of the study, steers were weighed once every 28 d resulting in 4 subsequent weigh periods. To reduce the variation in BW caused by differences in gut fill, steers were always weighed directly before feeding

**Table 1.** Ingredient and chemical composition of experimental diets

Item	Treatment		
	Control	LowDA	HighDA
Ingredient, % of diet DM			
Barley silage <sup>1</sup>	10.0	10.0	10.0
Barley grain, dry-rolled <sup>2</sup>	86.5	86.5	86.5
Control pellet <sup>3</sup>	3.5	—	—
LowDA pellet <sup>4</sup>	—	3.5	—
HighDA pellet <sup>5</sup>	—	—	3.5
Chemical composition, % of DM			
DM, %	78.5	79.1	78.6
OM	97.6	97.1	96.6
CP	12.8	12.3	12.4
NDF	14.3	15.8	15.1
ADF	3.9	4.7	4.4

<sup>1</sup>Contained: 34.5% DM, 10.7% CP DM basis (based on  $n = 4$ ; samples were composited by period).

<sup>2</sup>Contained: 90.7% DM, 12.5% CP DM basis (based on  $n = 4$ ; samples were composited by period).

<sup>3</sup>Contained: 549.1-g barley grain, 100-g canola meal, 250-g calcium carbonate, 25-g molasses, 30-g salt, 10-g mineral premix, 20-g urea, 0.66-g vitamin E premix, 10-g canola oil, and 3.85-g Rumensin premix (Elanco Animal Health, Greenfield, IN, USA; all values per kg pellet DM). Rumensin premix supplied 25 ppm of monensin sodium to the complete diet (DM basis).

<sup>4</sup>Composition of the LowDA pellet was identical to the control pellet, except that 1.41 g of barley grain was replaced by DA (Biomin, Getzersdorf, Austria) to supply 0.05-g DA per kg complete diet (DM basis).

<sup>5</sup>Composition of the HighDA pellet was identical to the control pellet, except that 2.82 g of barley grain was replaced by DA (Biomin, Getzersdorf, Austria) to supply 0.1-g DA per kg complete diet (DM basis).

time. Weights were reported as shrunk weights ( $BW \times 0.96$ ) to account for gut fill. ADG was calculated based on the shrunk BW gain of two consecutive weighings, divided by the days on feed (final BW – initial BW/d on feed). Weekly feed refusals were removed from all feed bunks, weighed, and subsampled separately for each pen. The diets were also subsampled on the same day. Weekly refusal and diet samples were oven-dried (55 °C) for at least 72 h to calculate the dry matter intake (DMI) of each pen. For calculating gain:feed ratio (G:F), ADG was divided by the DMI.

### **Feeding Behavior Measurements**

Feeding behavior was assessed in 6 pens (20 steers in 2 pens per diet) equipped with the GrowSafe system. Each GrowSafe pen was equipped with two plastic-feed tubs ( $0.38 \times 0.53 \times 0.91$  m) suspended on load cells. An antenna surrounding the tub was designed to activate the radio frequency ear transponders when the distance between antenna and transponder tag was  $\leq 50$  cm. The transponder transmitted an electronic identification number specific to each individual steer back to the system. Scale readings (kg) from each feed tub were transmitted every second to the computer system using data acquisition software (DAQ 3000, GrowSafe Systems Ltd).

The system recorded the bunk attendance of each steer, the length of each bunk visitation and the weight of feed withdrawn from the bunks at each visit. On the basis of these data, eating rate (g/min), duration of each visit (min/meal), meal frequency (meals/d), meal size (kg/meal), and meal interval (min) were calculated. As high-grain diets can induce digestive disorders such as sub-acute and acute acidosis, and those disorders are commonly associated with low or fluctuating feed intake (Owens et al., 1998), we furthermore calculated the daily variation in DMI (DVI). DVI was defined as difference in DMI of a steer between two consecutive days. Bunk visitations that were less than 5 min apart for the same steer were considered to be the same meal. If a meal took place over midnight, the meal was assigned to the day on which the greater duration of the meal occurred. A meal was only considered a meal when the feed consumption exceeded 100 g (as fed basis). Otherwise, it was assumed that the steer only browsed through the feeder without the intention of consuming feed.

Validation of the GrowSafe system was performed throughout the experiment. The function

of the load cells and antenna was checked at least weekly as described by Schwartzkopf-Genswein et al. (2011). Load cells were calibrated by placing a 20 kg weight in each tub and confirming that the computer recorded the correct corresponding weight. Antennas were checked using an unassigned transponder by holding it within the read range of each antenna. Subsequently, the data were checked to ensure that the transponder had been detected at the correct feed tub and time.

### **Slaughter, Carcass Traits, and Liver Scores**

Steers were commercially slaughtered at the Cargill beef processing facility (High River, AB, Canada). At the facility, hot carcass weight (kg) with kidneys removed, back fat thickness (mm), longissimus muscle (LM) area ( $\text{cm}^2$ ) and saleable meat yield (%) were recorded for each steer. Dressing percentage (%) was calculated by dividing the carcass weight by shrunk live BW. Beef quality grades were determined according to the Canadian Beef Grading Agency (2009). Livers were categorized as not abscessed, abscessed (one or two inactive or scarred abscesses) or severely abscessed (one or more active abscess  $>2.5$ -cm diameter and inflammation of the surrounding tissue) by a trained employee of the Lethbridge Research and Development Centre.

To test if DA altered the fatty acid composition of beef, samples (1 kg) from the *pars costalis diaphragmatis* (PCD) were taken from five randomly chosen steers previously kept in each of the 12 pens, resulting in samples from 20 steers within each treatment. Samples were frozen at  $-80$  °C until analyzed.

### **Laboratory Analysis**

Diets and orts were sampled weekly, oven dried for at least 72 h at 55 °C and composited by weigh period. For further analysis, the composited samples were ground through a 1-mm screen (4 Wiley mill; Philadelphia, PA) and dried at 135 °C for 2 h to determine analytical DM (AOAC, 2005; method 930.15). The organic matter (OM) content was calculated as the difference between 100 and percentage of ash (500 °C for 5 h; AOAC, 2005; method 942.05). Neutral detergent fiber was determined as described by Van Soest et al. (1991) using heat-stable  $\alpha$ -amylase and sodium sulfite. Acid detergent fiber was determined according to AOAC (2005; method 973.18). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) values were

expressed inclusive of residual ash. The N content was analyzed from ball-ground subsamples (Retsch MM 400; Retsch Inc., Newtown, PA) by flash combustion with thermal conductivity detection (Carlo Erba Instruments, Milan, Italy). Total N content was expressed on crude protein (CP)-basis ( $N \times 6.25$ ).

Meat samples for fatty acid analysis were subsampled (1 g) and homogenized with distilled water, isopropanol, and hexane. The homogenate extract was mixed with nonadecanoic acid methyl ester (19:0) as an internal standard. Nitrogen gas was then used to evaporate the hexane and sodium methoxide and boron trifluoride were added for methylation. Fatty acid methyl esters (FAME) were quantified using a gas chromatograph (Hewlett Packard GC System 6890, Mississauga, ON, Canada) as described previously (He et al., 2012).

### Statistical Analysis

The experiment was analyzed as a completely randomized design with three dietary treatments (control, LowDA, and HighDA). Pen was considered the experimental unit for all growth performance parameters (ADG, G:F), DMI, carcass traits, liver abscesses, and fatty acid content of the PCD. Data were analyzed using Mixed procedure of SAS (version 9.1; SAS Institute, Inc., Cary, NC). The model used to analyze the growth performance parameters over the entire length of the trial including the fixed effects of diet, weighing period and the interaction of diet and period. Period was included as repeated measure and pen was included as random effect. For the analysis of repeated measures, the best-fitting covariate structure (first order autoregressive) was selected based on the smallest Akaike's information and Bayesian information criteria. Denominator degrees of freedom were determined using the Kenward–Roger option. The effect of increasing concentration of DA in the diet was examined through linear and quadratic orthogonal contrasts. To test the effect of DA on growth performance within each period, period and the interaction of diet and period were removed as fixed effects.

Individual steer was considered the experimental unit for GrowSafe data (i.e. feed intake behavior;  $n = 20$ ). The model for feed intake behavior-related parameters included the fixed effects of diet, period and the interaction of diet and period. Individual steers were included as random effect and period as a repeated measure. Denominator

degrees of freedom were determined using the Kenward–Roger option and contrasts were performed as described earlier.

Carcass quality grades and liver abscess score data were analyzed using GLIMMIX (SAS, version 9.1; SAS Institute, Inc.) with a binomial error structure and logit data transformation. Diet was included as fixed effect. Percentage of carcasses graded as “A” or “prime” was not analyzed, as no carcasses met the “A” classification and only two carcasses were classified as “prime” (one in the control and one in the HighDA group). Liver scores were expressed as a percent of total for abscessed and severely abscessed livers. For all parameters, significance was declared at  $P < 0.05$  with trends discussed at  $0.05 \leq P \leq 0.10$ .

## RESULTS

The chemical composition of the diets is presented in Table 1. Initial BW did not differ among treatments (Table 2). Supplementation of DA tended to linearly increase BW in periods 2 and 3 ( $P = 0.06$ ). In period 2, feeding DA also linearly increased ADG ( $P = 0.003$ ) with no impact in periods 1, 3, and 4 ( $P > 0.10$ ). Over the entire length of the study, increasing concentration of DA tended to linearly increase ADG ( $P = 0.09$ ). Similarly to BW and ADG, DMI ( $P = 0.06$ ) and G:F ( $P = 0.05$ ) tended to linearly increase in response to DA in period 2. A trend for a quadratic response to increasing levels of DA was observed for G:F with lowest G:F ratio for LowDA LowDA in period 3 ( $P = 0.07$ ). DMI and G:F over the complete length of the study were not affected by DA.

Feeding behavior parameters were not influenced by DA (Table 3;  $P > 0.10$ ). Dressing percentage decreased linearly in response to DA ( $P < 0.01$ ; Table 4). Supplementation of DA quadratically affected LM area ( $\text{cm}^2$ ;  $P = 0.05$ ), with the largest area observed for LowDA carcasses ( $90.8 \text{ cm}^2$ ). No carcasses were classified as A and only two as prime (one in the control and one in HighDA). Consequently, only percentages of AA and AAA carcasses were statistically analyzed. Diets had no effect on quality grades (AAA:  $P = 0.21$ ; AA:  $P = 0.29$ ), but feeding LowDA tended to increase percentage of AAA (92.3%) compared to control (77.5%;  $P = 0.08$ ). Percentage of abscessed livers (mean of diets: 56%) was not affected by diet ( $P = 0.92$ ). Similarly, percentage of severely abscessed livers (% of total livers;  $P = 0.23$ ) was not affected by DA even though numerical differences

**Table 2.** Effects of DA on growth performance of finishing beef steers

Item	Treatment			SEM	P-value <sup>1</sup>	
	Control	LowDA	HighDA		L	Q
Growth performance						
Live body weight <sup>2</sup> , kg						
Initial	468	469	468	4.1	0.99	0.89
Period 1	536	538	536	5.1	0.96	0.65
Period 2	578	594	595	6.1	0.06	0.35
Period 3	638	649	656	6.6	0.06	0.84
Final	664	671	675	7.1	0.27	0.99
ADG <sup>3</sup> , kg/d						
Period 1	2.49	2.57	2.50	0.09	0.93	0.46
Period 2	1.59	2.11	2.17	0.10	0.003	0.10
Period 3	2.05	1.90	2.12	0.09	0.63	0.14
Period 4	1.13	0.96	0.99	0.09	0.28	0.37
Overall	1.82	1.87	1.95	0.05	0.09	0.81
DMI, kg						
Period 1	9.96	10.22	10.02	0.51	0.94	0.72
Period 2	8.33	9.62	9.46	0.38	0.06	0.15
Period 3	9.87	10.36	10.31	0.51	0.56	0.68
Period 4	8.00	7.92	8.02	0.40	0.97	0.85
Overall	9.04	9.53	9.45	0.30	0.36	0.46
Gain:feed ratio, kg/kg						
Period 1	0.252	0.249	0.255	0.014	0.96	0.96
Period 2	0.193	0.211	0.234	0.013	0.05	0.95
Period 3	0.214	0.193	0.215	0.009	0.94	0.07
Period 4	0.145	0.119	0.116	0.011	0.22	0.40
Overall	0.205	0.199	0.205	0.006	0.50	0.25

<sup>1</sup>L, linear effects; Q, quadratic effects.

<sup>2</sup>BW were reported as shrunk weight (BW × 0.96) to compensate for gut fill.

<sup>3</sup>ADG was calculated based on shrunk BW gain (final BW – initial BW).

**Table 3.** Effects of DA on feeding behavior of finishing beef steers

Item	Treatment			SEM	P-value <sup>1</sup>	
	Control	LowDA	HighDA		L	Q
DVI <sup>2</sup> , kg DM	1.89	1.81	1.84	0.06	0.55	0.44
Bunk attendance duration, min/d	96.9	99.5	93.7	2.92	0.44	0.24
Bunk attendance frequency, events/d	9.3	9.7	9.1	0.28	0.50	0.16
Eating rate, g DM/min	112	114	117	3.59	0.29	0.87
Meal frequency <sup>3</sup> , meals/d	8.8	9.0	8.5	0.26	0.54	0.30
Eating duration, min/meal	11.2	11.1	11.1	0.48	0.89	0.91
Meal size, kg DM/meal	1.26	1.28	1.30	0.09	0.72	0.99
Meal interval, min	172	167	177	5.24	0.49	0.25

<sup>1</sup>L, linear effects; Q, quadratic effects.

<sup>2</sup>DVI = daily variation in DMI, defined as difference in DMI between two consecutive days.

<sup>3</sup>Bunk attendance intervals between visits shorter than 5 min were considered to be the same meal.

between control and LowDA (50% vs. 30.8%;  $P = 0.09$ ) were observed.

Supplementation of DA tended to result in a quadratic response in palmitic acid (C16:0;  $P = 0.07$ ) and total proportion of saturated fatty acids (SFA;  $P = 0.06$ ); with steers fed LowDA containing the lowest proportions (% of total FAME; Table 5). Steers fed LowDA had higher C18:1 t9 ( $P < 0.05$ )

and C18:1 t10 ( $P < 0.05$ ) compared with HighDA and control steers, resulting in a quadratic response and a tendency for a quadratic response in C18:1 t6-8 content ( $P = 0.06$ ). In contrast, C18:1 t11, linolenic acid (18:3), CLA c9t11, and CLA+TVA linearly decreased with increasing level of DA in the diet ( $P < 0.05$ ). The share of unsaturated fatty acids (USFA) and monounsaturated fatty acids (both

**Table 4.** Effects of DA on carcass traits and liver scores of finishing beef steers

Item	Treatment			SEM	P-value <sup>1</sup>	
	Control	LowDA	HighDA		L	Q
Carcass characteristics						
Carcass weight, kg	402	404	404	4.45	0.82	0.84
Dressing percentage, %	60.6	60.2	59.8	0.21	0.01	0.95
Back fat, mm	19.0	17.59	18.0	0.74	0.36	0.27
LM area, cm <sup>2</sup>	88.4	90.8	86.2	1.48	0.28	0.05
Saleable meat yield <sup>2</sup> , %	51.6	53.1	51.8	0.67	0.85	0.09
AAA <sup>3</sup> , %	77.5	92.3*	85.0	—	0.21	
AA <sup>3</sup> , %	20.0	7.7	12.5	—	0.29	
Liver scores						
Abscessed livers, %	55.0	59.0	55.0	—	0.92	
Severely abscessed <sup>4</sup> , %	50.0	30.8**	42.5	—	0.23	

<sup>1</sup>L, linear effects; Q, quadratic effects.

<sup>2</sup>Proportion of the carcass that can be processed and sold to the consumer.

<sup>3</sup>Quality grades were determined according to Canadian Beef Grading Agency and expressed as percentage of total carcasses.

<sup>4</sup>Percentage of livers classified as A+ (1 or more active abscess >2.5 cm diameter with inflammation of surrounding tissue).

\*Trend for an increase in AAA carcasses; LowDA vs. control ( $P = 0.08$ ).

\*\*Trend for less severely abscessed livers; LowDA vs. control ( $P = 0.09$ ).

% of total FAME) tended ( $P = 0.06$ ) to respond quadratically to DA. Percentage of polyunsaturated fatty acids was low (average of all diets:  $2.72 \pm 0.1\%$ ) and not affected by DA.

## DISCUSSION

The tested additive is a blend of essential oils, herbs, and spices primarily licorice, caraway, vanilla, and essential oil of clove beside salt and silicon dioxide. Liquorice contains, among other secondary plant compounds, triterpenoids and flavonoids which have anti-inflammatory and antimicrobial properties (Ramos-Morales et al., 2018). Caraway acts as a spasmolytic and is described to modulate digestive upsets (Runjaić-Antić et al., 2010). Vanilla extract has positive impact on feed palatability (Harper et al., 2016). Clove oil promotes muscle relaxation and has antimicrobial as well as antioxidant properties (Dorman and Deans, 2000; Dragland et al., 2003). Complex mixtures of plant bioactives such as those in DA make it impossible to attribute observed responses to any singular component in the formulation.

As in the current study, the effect of phytochemicals on growth performance of cattle seems to vary depending on plant source, active ingredients and bioavailability. In addition, phytochemicals might interact with the composition of the basal diet or bioactive plant compounds naturally contained in other diet ingredients. A similar study examining the effect of cinnamaldehyde, a frequently tested phytochemical, reported that ADG of steers fed an almost

identical barley-based high-grain diet was not affected by 400, 800, or 1600 mg of cinnamaldehyde per steer/d (Yang et al., 2010). Similarly, Benchaar et al. (2006) reported that a mixture of essential oils from thymol, eugenol, vanillin, and limonene had no effect on DMI, ADG, or G:F of beef cattle fed a growing diet containing 75% mixed grass silage (DM basis). Meyer et al. (2009) compared finishing steers provided with 1 g/d of an essential oil mixture similar to that of Benchaar's to those receiving a mixture containing guaiacol, linalool, and  $\alpha$ -pinene (1 g/d) and reported that ADG, DMI, and G:F of both essential oils did not differ from the control. Ornaghi et al. (2017) supplemented bulls fed a high-grain diet (79% cracked corn; DM basis) with 0, 3.5, and 7.0 g of essential oil from clove or cinnamon (g/d complete diet; DM basis) and found that supplemented bulls had higher DMI and ADG whereas G:F was unaffected. A study on crossbred bulls fed a corn-silage-based diet (45% corn silage, 40% concentrate; DM basis) supplemented with 3 g of cashew and castor essential oils per bull reported higher final weight, ADG, and G:F compared to the control diet (Valero et al., 2014).

Even though DA tended to increase overall ADG, its impact was not consistent throughout the experiment. Driven by an increase in DMI and G:F, ADG increased during the second period of the experiment but not during periods 1, 3, and 4. Ambient temperature was extremely low during periods 3 and 4 (i.e.  $-30\text{ }^{\circ}\text{C}$ ) an outcome that could have negated responses to DA. This suggests that DA is able to improve growth performance, but its effectiveness

**Table 5.** Effects of DA on the fatty acid profile of the *pars costalis diaphragmatis* of fattened beef steers

Fatty acids, % FAME	Treatment			SEM	P-value <sup>1</sup>	
	Control	LowDA	HighDA		L	Q
C10	0.071	0.064	0.067	0.003	0.23	0.11
C12	0.068	0.064	0.065	0.003	0.39	0.52
C14	2.80	2.67	2.74	0.11	0.70	0.49
C14:1 t9	0.11	0.10	0.10	0.01	0.19	0.22
C14:1 c9	0.48	0.51	0.48	0.03	0.88	0.32
C15	0.50	0.49	0.51	0.02	0.68	0.58
C16	24.7	23.7	24.5	0.40	0.75	0.07
C16:1 c9	2.62	2.65	2.70	0.08	0.51	0.94
C17	1.81	1.86	1.89	0.06	0.34	0.90
C18	18.2	17.3	18.0	0.44	0.79	0.13
C18:1 t6-8	0.12	0.13	0.11	0.01	0.58	0.06
C18:1 t9	0.18	0.20	0.18	0.01	0.71	0.04
C18:1 t10	0.95	1.22	1.07	0.08	0.27	0.03
C18:1 t11	0.70	0.55	0.52	0.05	0.01	0.40
C18:1 c9	41.8	43.4	42.3	0.73	0.65	0.12
C18:1 c11	1.76	1.88	1.83	0.05	0.30	0.13
C18:2 c9c12	1.70	1.75	1.62	0.09	0.47	0.39
C20	0.12	0.11	0.11	0.004	0.41	0.26
C20:1 c11	0.30	0.36	0.32	0.02	0.52	0.09
C18:3	0.29	0.28	0.24	0.02	0.03	0.62
CLA c9t11	0.29	0.28	0.24	0.02	0.02	0.48
C20:4	0.32	0.29	0.30	0.02	0.66	0.56
C20:5	0.04	0.04	0.04	0.004	0.35	0.32
C22:5	0.15	0.14	0.14	0.01	0.61	0.71
SFA	48.2	46.2	47.9	0.77	0.77	0.06
USFA	51.8	53.8	52.2	0.77	0.77	0.06
MUFA	49.0	51.0	49.6	0.75	0.61	0.06
PUFA	2.80	2.78	2.58	0.13	0.24	0.57
CLA+TVA <sup>2</sup>	0.99	0.83	0.75	0.06	0.01	0.63
n-3FA	0.49	0.46	0.42	0.03	0.11	0.92
n-6/n-3	4.33	4.62	4.64	0.22	0.32	0.63

MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

<sup>1</sup>L, linear effects; Q, quadratic effects.

<sup>2</sup>CLA + TVA, conjugated linoleic acid + trans-vaccenic acid.

may depend on the level of biotic or abiotic stress. Another possibility is that responses to DA may vary with shifts in the rumen microbiome, or that the dosage of DA should be adjusted to changes in weather or other external stressors. The hypothesis that the effectiveness of a phytogetic additive might depend on the level of stress cattle is exposed to is supported by [Yang et al \(2010\)](#), who supplemented steers with different levels of cinnamaldehyde and reported increased DMI relative to the control and a linear increase in G:F only over the first 28 d of a feedlot study, when stress is typically increased, but not the rest of the experiment.

Similar to the present study, [Ornaghi et al. \(2017\)](#) reported that essential oils did not affect feed intake behavior. [Segabinazzi et al. \(2011\)](#) fed a blend (5 g/cow daily) of rosemary and soap tree (*Quillaja saponaria*) extract, thyme and garlic oil to confined

cows and found that it had no impact on the number of meals per day. Both studies agree with our finding that DA did not alter feeding behavior. However, the fact that there were no differences in feeding behavior among supplementation levels could indicate that the targeted maximum intake of 1 g DA/d was too low to alter the smell or taste of the diets. Owing to variation in DMI, mean DA intake was not uniform but varied between 0.39 and 0.51 g/d for steers fed LowDA and 0.79 and 1.02 g/d for steers fed HighDA. [Schwartzkopf-Genswein et al. \(2011\)](#) reported a mean DMI of 8.35 kg/d and mean bunk attendance durations between 65.9 and 79.4 min/d for cattle fed similar barley-based diets. This is lower compared to the average DMI of 9.34 kg/d and shorter compared to the mean bunk attendance duration of more than 90 min/d in the current study. Mean DVI in the same study was 3.05 kg ([Schwartzkopf-Genswein et al.,](#)



2011), which is substantially higher compared to 1.85 kg (both DM basis) in this study. Since prolonged bouts of acidosis are commonly associated with low and fluctuating feed intake (Owens et al., 1998), it can be assumed that the steers in the current study were able to cope relatively well with the expected decrease in ruminal pH due to the exposure to high-grain diets.

Data about the impact of phytochemicals on beef quality are scarce and foremost available from experiments that supplemented single essential oils as opposed to blends containing other secondary plant compounds. Yang et al. (2010) found that the carcass characteristics of finishing steers were not affected by different dietary concentrations of cinnamaldehyde. Supplementation of feedlot heifers with eugenol, thymol, and vanillin did not affect carcass quality (de Oliveira Monteschio et al., 2017). Similarly, muscle, fat and bone percentages, and LM area of fattening bulls did not differ between those that received essential oils from cloves or cinnamon (Ornaghi et al., 2017). The reason for the quadratic response in LM area in our study is unknown. Since the *longissimus dorsi* provides an indication of the relative muscularity of the complete carcass, it is justified to suspect that LowDA steers deposited more muscle tissue relative to the other two treatments. This is somewhat supported by numerically lower AA and numerically higher number of AAA carcasses for steers receiving DA as compared to the control. However, dressing percentage decreased linearly in response to DA, which contradicts the hypothesis that inclusion of DA would lead to more muscle tissue aggregation. Even though the percentage of total abscessed livers was not different among treatments, it is still noteworthy that LowDA decreased the occurrence of severely abscessed livers by 38.4% compared to the control. However, the fact that feeding HighDA did not lead to a reduction of severely abscessed livers does not support that DA is effective against the occurrence of severely abscessed livers. The fact that this large difference was not statistically significant is due to the limited number of steers per treatment. The reason for this substantial numerical decline, particularly in response to LowDA, might be due to changes in rumen fermentation that led to a reduction in acidotic bouts in the rumen. Sustained low rumen pH and subsequent rumenitis predispose cattle to the development of liver abscesses (Amachawadi and Nagaraja, 2016). Supplementation of DA could also have reduced the growth of bacteria that are causative for the formation of abscesses in the liver. However, both of these explanations are speculative, as rumen pH and the composition of the rumen microbiome

were not investigated in the current study. Kröger et al. (2017), who supplemented dairy cows with DA reported shorter average duration of reticular pH below the threshold for subacute ruminal acidosis. Other ruminal pH data in response to DA are, to our knowledge, not available. The fact that rumen fermentation and pH were not assessed in our study is a limitation, as we can only speculate about the impact of DA on rumen fermentation.

The finding that DA modified fatty acid composition in the PCD muscle was unlike results reported for other essential oils that were administered to finishing cattle. He et al. (2015) tested cinnamaldehyde in fattening feedlot steers and reported that it had no effect on the fatty acid profiles of the PCD. Rivaroli et al. (2016) studied the impact of an essential oil blend that consisted, among other constituents, of oregano and garlic oil, on the fatty acid composition of feedlot bulls and concluded that the fatty acid composition was not affected. However, the results of this experiment show that LowDA in particular, reduced SFA, but increased USFA content. This suggests that DA modulated the biohydrogenation potential in the rumen and possibly the microbiome. Ingested fats are hydrolyzed through microbes in the rumen and subsequently biohydrogenated (Raes et al., 2004).

In conclusion, supplementation of a high-grain diet with DA tended to increase overall ADG. However, the response varied among days on-feed. Feeding behavior-related parameters such as bunk attendance or meal size were not affected by DA. In contrast, supplementation with DA quadratically increased LM area, with the largest area for steers fed LowDA. However, the dressing percentage was negatively affected by DA. Percentage of severely abscessed livers tended to be reduced for LowDA but not for HighDA compared to control. LowDA also tended to lead to the lowest SFA and highest USFA content in the PCD, suggesting that it may alter ruminal biohydrogenation. To confirm the observed response in growth performance, further larger scale feeding studies should be executed. In addition, the mode of action and impact of DA on rumen fermentation requires further investigation.

## ACKNOWLEDGMENTS

This study was conducted with funding from Biomin Holding GmbH (Getzersdorf, Austria). T.B. received a travel bursary from the Faculty of Agriculture (University of Goettingen, Germany). We thank A. Furtado (sampling and laboratory analysis), and D. Vedres (chromatography). We also

thank the barn staff of the Lethbridge Research and Development Centre for the care and management of the steers. We acknowledge support by the German Research Foundation and the Open Access Publication Funds of the Göttingen University.

*Conflict of interest statement.* None declared.

## LITERATURE CITED

- Abaker, J. A., T. L. Xu, D. Jin, G. J. Chang, K. Zhang, and X. Z. Shen. 2017. Lipopolysaccharide derived from the digestive tract provokes oxidative stress in the liver of dairy cows fed a high-grain diet. *J. Dairy Sci.* 100:666–678. doi:10.3168/jds.2016-10871
- AOAC. 2005. Official methods of analysis, 18th ed. Gaithersburg (MD): AOAC Int.
- Akbarian-Tefaghi, M., E. Ghasemi, and M. Khorvash. 2018. Performance, rumen fermentation and blood metabolites of dairy calves fed starter mixtures supplemented with herbal plants, essential oils or monensin. *J. Anim. Physiol. Anim. Nutr. (Berl.)* 102:630–638. doi:10.1111/jpn.12842
- Amachawadi, R. G., and T. G. Nagaraja. 2016. Liver abscesses in cattle: a review of incidence in holsteins and of bacteriology and vaccine approaches to control in feedlot cattle. *J. Anim. Sci.* 94:1620–1632. doi:10.2527/jas.2015-0261
- Benchaar, C., J. L. Duynisveld, and E. Charmley. 2006. Effects of monensin and increasing dose levels of a mixture of essential oil compounds on intake, digestion and growth performance of beef cattle. *Can. J. Ani. Sci.* 86:91–96. doi:10.4141/A05-027
- Canadian Beef Grading Agency. 2009. Canadian beef grading standards. Available from <http://www.beefgradingagency.ca/#grades> [accessed May 31, 2018].
- Canadian Council on Animal Care (CCAC). 2009. CCAC guidelines on: the care and use of farm animals in research, teaching and testing. Ottawa ON Canada. Available from <https://www.ccac.ca/en/standards/guidelines> [accessed April 10, 2018].
- Dorman, H. J., and S. G. Deans. 2000. Antimicrobial agents from plants: antibacterial activity of plant volatile oils. *J. Appl. Microbiol.* 88:308–316. doi:10.1046/j.1365-2672.2000.00969.x
- Dragland, S., H. Senoo, K. Wake, K. Holte, and R. Blomhoff. 2003. Several culinary and medicinal herbs are important sources of dietary antioxidants. *J. Nutr.* 133:1286–1290. doi:10.1093/jn/133.5.1286
- European Union. 2003. Regulation 1831/2003/EC on additives for use in animal nutrition, replacing Directive 70/524/EEC on additives in feeding-stuffs. Available from <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32003R1831> [accessed July 30, 2018].
- Harper, M. T., J. Oh, F. Giallongo, J. C. Lopes, H. L. Weeks, J. Faugeron, and A. N. Hristov. 2016. Preference for flavored concentrate premixes by dairy cows. *J. Dairy Sci.* 99:6585–6589. doi:10.3168/jds.2016-11001
- He, M., J. Jia, and W. Yang. 2015. Comparison on the fatty acid profiles of liver, subcutaneous fat and muscle from feedlot steers finished on diets supplemented with or without cinnamaldehyde or monensin. *J. Sci. Food Agric.* 95:576–582. doi:10.1002/jsfa.6786
- He, M. L., T. A. McAllister, J. P. Kastelic, P. S. Mir, J. L. Aalhus, M. E. Dugan, N. Aldai, and J. J. McKinnon. 2012. Feeding flaxseed in grass hay and barley silage diets to beef cows increases alpha-linolenic acid and its biohydrogenation intermediates in subcutaneous fat. *J. Anim. Sci.* 90:592–604. doi:10.2527/jas.2011-4281
- Humer, E., I. Kröger, V. Neubauer, K. Schedle, N. Reisinger, and Q. Zebeli. 2018. Supplementing phytogetic compounds or autolyzed yeast modulates ruminal biogenic amines and plasma metabolome in dry cows experiencing subacute ruminal acidosis. *J. Dairy Sci.* 101:9559–9574. doi:10.3168/jds.2018-14744
- Kröger, I., E. Humer, V. Neubauer, N. Reisinger, S. Aditya, and Q. Zebeli. 2017. Modulation of chewing behavior and reticular pH in nonlactating cows challenged with concentrate-rich diets supplemented with phytogetic compounds and autolyzed yeast. *J. Dairy Sci.* 100:9702–9714. doi:10.3168/jds.2017-12755
- Meyer, N. F., G. E. Erickson, T. J. Klopfenstein, M. A. Greenquist, M. K. Luebke, P. Williams, and M. A. Engstrom. 2009. Effect of essential oils, tylosin, and monensin on finishing steer performance, carcass characteristics, liver abscesses, ruminal fermentation, and digestibility. *J. Anim. Sci.* 87:2346–2354. doi:10.2527/jas.2008-1493
- National Academies of Sciences, Engineering, and Medicine (NASEM). 2016. Nutrient requirements of beef cattle, 8th rev. edn. Washington, DC: The National Academies Press. doi:10.17226/19014
- de Oliveira Monteschio, J., K. A. de Souza, A. C. P. Vital, A. Guerrero, M. V. Valero, E. M. B. C. Kempinski, V. C. Barcelos, K. F. Nascimento, and I. N. do Prado. 2017. Clove and rosemary essential oils and encapsulated active principles (eugenol, thymol and vanillin blend) on meat quality of feedlot-finished heifers. *Meat Sci.* 130:50–57. doi:10.1016/j.meatsci.2017.04.002
- Ornaghi, M. G., R. A. Passetti, J. A. Torrecilhas, C. Mottin, A. C. P. Vital, A. Guerrero, and I. N. Prado. 2017. Essential oils in the diet of young bulls: effect on animal performance, digestibility, temperament, feeding behaviour and carcass characteristics. *Anim. Feed Sci. Technol.* 234:274–283. doi:10.1016/j.anifeeds.2017.10.008
- Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. *J. Anim. Sci.* 76:275–286. doi:10.2527/1998.761275x
- Raes, K., S. De Smet, and D. Demeyer. 2004. Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in lamb, beef and pork meat: a review. *Anim. Feed Sci. Technol.* 113:199–221. doi:10.1016/j.anifeeds.2003.09.001
- Ramos-Morales, E., G. Rossi, M. Cattin, E. Jones, R. Braganca, and C. J. Newbold. 2018. The effect of an isoflavonoid-rich liquorice extract on fermentation, methanogenesis and the microbiome in the rumen simulation technique. *FEMS Microbiol. Ecol.* 94:1–11. doi:10.1093/femsec/fiy009
- Rivaroli, D. C., A. Guerrero, M. Velandia Valero, F. Zawadzki, C. E. Eiras, M. D. M. Campo, C. Sañudo, A. Mendes Jorge, and I. Nunes do Prado. 2016. Effect of essential oils on meat and fat qualities of crossbred young bulls finished in feedlots. *Meat Sci.* 121:278–284. doi:10.1016/j.meatsci.2016.06.017
- Runjaić-Antić, D., S. Pavkov, and J. Lević. 2010. Herbs in a sustainable animal nutrition. *Biotechnol. Anim. Husbandry.* 26:203–214. doi:10.2298/BAH1004203R

- Schieder, C., T. Steiner, and M. Friedrichkeit. 2014. Effect of phytogetic feed additives on performance parameters and health of bull calves under commercial conditions. *J. Anim. Sci.* 92 (E-Suppl. 2/J). *Dairy Sci.* 97 (E-Suppl. 1):863. (Abstr.).
- Schwartzkopf-Genswein, K. S., D. D. Hickman, M. A. Shah, C. R. Krehbiel, B. M. Genswein, R. Silasi, D. G. Gibb, D. H. Crews, and T. A. McAllister. 2011. Relationship between feeding behavior and performance of feedlot steers fed barley-based diets. *J. Anim. Sci.* 89:1180–1192. doi:10.2527/jas.2010-3007
- Segabinazzi, L. R., J. Viégas, L. D. S. Freitas, I. L. Brondani, F. M. Argenta, and J. Binotto. 2011. Behavior patterns of cows with Charolais or Nellore breed predominance fed diets with plant extract or monensin sodium. *Rev. Bras. Zootecn.* 40:2954–2962. doi:10.1590/S1516-35982011001200044
- Smith-Palmer, A., J. Stewart, and L. Fyfe. 1998. Antimicrobial properties of plant essential oils and essences against five important food-borne pathogens. *Lett. Appl. Microbiol.* 26:118–122. doi:10.1046/j.1472-765X.1998.00303.x
- Valero, M. V., R. M. D. Prado, F. Zawadzki, C. E. Eiras, G. S. Madrona, and I. N. D. Prado. 2014. Propolis and essential oils additives in the diets improved animal performance and feed efficiency of bulls finished in feedlot. *Acta Sci. Anim. Sci.* 36:419–426. doi:10.4025/actascianimsci.v36i4.23856
- Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:473–481.
- Wei, A., and T. Shibamoto. 2007. Antioxidant activities and volatile constituents of various essential oils. *J. Agric. Food Chem.* 55:1737–1742. doi:10.1021/jf062959x
- Windisch, W., K. Schedle, C. Plitzner, and A. Kroismayr. 2008. Use of phytogetic products as feed additives for swine and poultry. *J. Anim. Sci.* 86 (Suppl. 14):E140–E148. doi:10.2527/jas.2007-0459
- Yang, W. Z., B. N. Ametaj, C. Benchaar, M. L. He, and K. A. Beauchemin. 2010. Cinnamaldehyde in feedlot cattle diets: intake, growth performance, carcass characteristics, and blood metabolites. *J. Anim. Sci.* 88:1082–1092. doi:10.2527/jas.2008-1608
- Yang, C., M. A. Chowdhury, Y. Huo, and J. Gong. 2015. Phytogetic compounds as alternatives to in-feed antibiotics: potentials and challenges in application. *Pathogens* 4:137–156. doi:10.3390/pathogens4010137