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Effects of functional oils and monensin on cattle finishing programs[1]

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ABSTRACT

The use of functional oils (FO; Essential) and ionophores on cattle feedlot performance, carcass characteristics, and economic analysis was evaluated. Angus and Angus crossbred steers were assigned to 5 treatments: control (CON); monensin (MON); monensin + FO low dosage (MON+FL); FO low dosage (FL); and FO high dosage (FH; $n = 48$/treatment; 6/rep). Daily DMI was not affected ($P > 0.05$) by FO, and MON improved ADG and G:F when compared with FL and FH ($P < 0.05$). Dressing percentage for the FH treatment was larger than for MON and FL ($P < 0.05$). Longissimus muscle area of FH cattle was the largest of all treatments and differed from that of MON ($P < 0.05$). Backfat thickness was not different ($P > 0.05$) among treatments. Cattle on the MON+FL treatment yielded the best cutability and differed from MON ($P < 0.05$). Quality grade was not different ($P > 0.05$) among treatments. Diets with FO increased the percentage of Choice and Prime carcasses, and FH yielded the largest percentage of Prime grade carcasses, differing from CON and MON+FL ($P < 0.05$) but not from MON and FL ($P > 0.05$). Sensory panel evaluations were unaffected by treatments ($P > 0.05$). Using actual costs and prices, profitability was numerically highest for MON+FL. In annual and seasonal price scenarios, profitability favored FH. Carcass price provided the greatest effect on profitability. Thus, the use of FO may provide a viable alternative to ionophores in feedlot cattle.

Key words: feedlot cattle, functional oil, ionophore, performance, profit

INTRODUCTION

Public concern over routine use of antibiotics in livestock nutrition has resulted in certain countries banning their use in animal feeds. Consequently, a considerable amount of effort has been devoted toward developing alternatives to antibiotics that modulate ruminal fermentation. These alternatives include the use of yeasts, organic acids, plant extracts and oils, probiotics, and antibodies.

Research on the use of essential oils, as feed additives to improve the efficiency of ruminal fermentation, decrease methane production, reduce nutritional stress, and improve animal health and productivity, has been published extensively (Wallace, 2004; Benchaar et al., 2007; Calsamiglia et al., 2007). However, some plant oils and extracts cannot be classified as essential oils because they are not derived either from essences or from spices. These products have been previously defined as functional oils (**FO**; Murakami et al., 2009) because they have activities beyond their energy value. Cashew nut shell liquid and castor oil are examples of FO. Cashew nut shell liquid activities include antitumor, antimicrobial, and antioxidant activities (Himejima and Kubo, 1991) as well as decreases in in vitro methane production (Watanabe et al., 2010). Ricinoleic acid, the main fatty acid found in castor oil, has been shown to be active against some gram-positive bacteria and fungi (Novak et al., 1961) and to decrease methane production in vitro (Van Nevel et al., 1971). Unfortunately, castor oil is a laxative when used orally, thereby precluding its oral use. However, when combined with cashew nut shell liquid, castor oil is biologically active at dosages below the level at which it acts as a laxative, making it safe for oral use.

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The overall objective of this experiment is to evaluate the effects of a commercial mix of castor oil and cashew nut shell liquid called Essential (Patent Pending, Oligo Basics Agroindustrial Ltd., Cascavel, PR, Brazil), with and without ionophores, on feedlot finishing programs and to compare feeder cattle live performance, carcass characteristics, blood parameters, and production economics.

MATERIALS AND METHODS

Animals and Dietary Treatments

All procedures involving animals were approved by the Institutional Animal Care and Use Committee at Iowa State University. Two blocks using 120 spring-born steers (Angus and Angus crossbred) per block (322 and 344 ± 10 kg of initial BW, respectively) were obtained from a common source and used in a completely randomized design feeding experiment. Approximately 48 h after arrival, steers were given an individually numbered ear tag, implanted with Compudose E-S growth implants (VetLife Inc., Overland Park, KS), injected with Dectomax (Pfizer Inc., New York, NY), treated with Cydectin pour-on (Fort Dodge Animal Health, Fort Dodge, IA) to control external and internal parasites, and provided with a second insecticide and miticide ear tag (Cutter Blue, Bayer Health Care LLC, Shawnee Mission, KS), which was replaced at d 56.

About a week after arrival and following acclimation, the steers were gradually adapted to an 82% concentrate diet containing whole shelled corn, tall fescue hay, and wet distillers grain along with a vitamin and mineral supplementation (Table 1) that was delivered once daily at 0800 h. The steers were adapted during 2 wk to the pens before starting the experiment and randomly assigned to 1 of 5 treatments so that the BW, color, and temperament of the steers were uniformly distributed among the treatments (6 steers/pen, 8 pens/treatment). All treatments were fed the same diets, differing only in the type of additive supplemented. The 5 treatments were control (**CON**), no additive provided; monensin only (**MON**; 223 mg/steer per day of monensin; Rumensin, Elanco Animal Health, Indianapolis, IN); monensin + FO low (**MON+FL**; 223 mg/steer per day of monensin + 250 mg/kg of DMI of Essential; Oligo Basics USA LLC, Wilmington, DE); FO low (**FL**; 250 mg/kg of DMI of Essential); and FO high (**FH**; 500 mg/kg of DMI of Essential). All animals were reimplanted with Component TE-S (VetLife Inc.) approximately 60 d before slaughter.

The feed allotment was determined daily before the morning feeding. The amount of feed was increased when the bunks, in approximately one-half of the pens of a treatment, were completely empty at 0800 h before the morning feeding. Feed samples were collected once weekly for DM determination. The pens of steers were fed for an average of 169 and 161 d for the first and second blocks, respectively.

Steers were weighed individually at 28-d intervals before feeding to calculate ADG. The amount of daily DM fed to the steers was determined by obtaining ingredient samples, before being loaded onto the feed-wagon, approximately every 5 d. The samples were weighed, placed in a conventional oven (Campbell Scientific, Logan, UT) at 105°C for a minimum of 48 h, and reweighed. Feed samples were weekly analyzed by Dairyland Laboratories Inc. (Arcadia, WI) for feed quality, molds, and mycotoxins.

Table 1. Composition of diet fed to feedlot steers

Feed ingredient	% of dietary DM
Dry-rolled corn	60.4
Tall fescue	18.2
Wet distillers grain	18.4
Liquid molasses	0.4
Calcium carbonate	1.9
Salt	0.5
Vitamin A	0.1
Trace mineral premix[1]	0.1
Total	100.0

[1]Trace mineral premix analysis (air-dry basis): 11.84 to 14.21% Ca (calcium carbonate); >1.50% Cu (copper sulfate); >10.00% Fe (ferrous carbonate and ferrous sulfate); >8.0% Mn (manganous oxide); 12.0% Zn (zinc oxide); 1,000 mg/kg Co (cobalt carbonate); and 2,000 mg/kg I (ethylenediamine dihydroiodide).

Blood Samples and Carcass Data Collection

Blood samples were collected from 120 randomly selected steers (3 steers/pen) at the beginning and at the end of each block. Samples were collected via jugular venipuncture into 10-mL sodium heparinized BD Vacutainer tubes using a Vacutainer blood-collection needle (Becton Dickinson, Franklin Lakes, NJ) and placed on ice. Complete blood counts were performed using a new generation hematology analyzer Advia 120 (Bayer, Tarrytown, NY). The analyzer was calibrated and maintained according to the manufacturer's instructions.

The final BW was obtained in the morning, and pens of steers were loaded and transported by treatment groups to Tyson Fresh Meats Inc., a commercial abattoir located in Denison, Iowa, at a uniform end weight determined to optimize YG and QG. Carcass weights and liver abscess scores were determined by the USDA inspectors at the time of slaughter. After 24-h postmortem chilling, 12th-rib backfat thickness and longissimus muscle area (LM area) measurements were recorded by trained personnel at the same facility in Denison, Iowa. Estimated percentages of KPH were recorded for each carcass, and carcass DP were calculated by dividing HCW by final BW. The USDA Meat Grading Service graders at the packing plant determined the KPH, YG, and QG. The QG were estimated to the nearest one-third of a grade and were converted to numerical values for evaluation purposes.

Sensory-Panel Evaluations

A previously trained 9-member sensory evaluation panel evaluated steaks from 120 steers total (3 steers/pen) and recorded their observations using Compusense software (Compusense Inc., Guelph, Ontario, Canada). Steaks were chosen based on the initial BW of the steer: light, middle, and heavy. Sample preparation and guidelines for cooking procedures were done according to *Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat* (AMSA, 1995).

Economic Analysis

The economic analysis was conducted using 3 scenarios. The first scenario (actual) involved using actual prices paid for the feeder cattle and feed components and prices received for carcasses (2007–2009). In the second scenario (annual) it was assumed that all the cattle received the same feeder and fed cattle prices and feed costs were based on a 10-yr average (1999–2009). The third scenario (seasonal) used the same criteria as the second scenario except prices for feed components and feeder and fed cattle prices were derived from the 10-yr averages for corresponding months. These scenarios took into account variations in the prices, measured in US dollars, of beef cattle over the course of time of production and cycles that roughly span 10 yr (Aadland, 2004). They also allowed for the determination of changes in profitability and other variables upon time.

All values for feeder and live finished cattle, as well as carcass grades and corn and hay, were obtained from the Chartbook from Iowa State University Extension. A budgeting worksheet, which was derived from the 2009 Livestock Enterprise Budgets for Iowa (Ellis et al., 2010), was used as a template and modified to drylot systems based on the "Finishing Yearling Steers" budget calculations. All costs were individually calculated for the period of time each steer was fed.

The feeder price was obtained using the Oklahoma City medium-framed 227- to 272-kg steers. The annual purchase value was determined by multiplying the initial BW by the 10-yr average feeder price. Similarly, the live finished cattle price was determined by multiplying the final BW by the 10-yr average Nebraska live steer price index. For the carcass value, the individual price was established by taking the HCW and multiplying it by the 10-yr average beef price for Prime, Choice, or Select, depending on the QG of each animal. It was assumed that 100% of the money spent to purchase the cattle was borrowed with an 8% interest rate. Days on feed were calculated from the day cattle started on test through the day they were weighed and shipped to the commercial abattoir.

Corn and hay prices were obtained from the Chartbook; monensin and wet distillers grain prices were obtained from "Feedstuffs" (Minnetonka, MN) magazine. The FO price was obtained from Oligo Basics USA LLC, Wilmington, Delaware. The annual feed costs were determined by multiplying the 10-yr average price for each feed ingredient by the amount of feed fed per feeding period and summed to obtain a total feed cost per pen. The seasonal feed costs were obtained by multiplying the 10-yr average prices for the corresponding months for each feed ingredient by the amount of feed fed per feeding period and summed to obtain a total feed cost per pen. Variable and fixed costs were obtained using values reported from the 2009 Livestock Enterprise Budgets for Iowa.

The income over variable cost was the result of the subtraction of the total variable costs from the gross income. The profit was obtained by subtracting all total costs from the gross income. The gross income was necessary so that the income was adjusted to reflect a standard 1% death loss. The breakeven price for live and carcass prices was calculated by taking the sum of all costs per animal divided by the final BW or HCW multiplied by 100. For the price sensitivity analysis, the effect of a ±5% in feeder, carcass and corn prices were determined to assess their effects on profitability and on the breakeven price.

Statistical Analysis

Data were analyzed using the PROC MIXED procedures (Littell et al., 1998) of SAS (SAS Institute Inc., Cary, NC). Steers were assigned to pens of 6 steers/pen. There were 5 treatments, each with 8 pens/treatment (4 from block 1 and 4 from block 2). The experimental design was a randomized complete block design; therefore, we used pen as the experimental unit throughout the experiment. The pairwise comparisons between the treatments least significant differences were found using Tukey-Kramer's multiple pairwise comparison method for means and declared at $P < 0.05$ (Rafter et al., 2002).

RESULTS AND DISCUSSION

Growth Performance and Carcass Composition

There were no differences in the final BW or in the daily DMI (609.8 kg and 13.27 kg/d across treatments, respectively; Table 2). The steers supplemented only with monensin gained more BW ($P < 0.05$) than did those supplemented either with the high or low dose of FO. No other differences were seen in ADG. Feed efficiencies for cattle fed MON were better ($P < 0.05$) than those of cattle fed CON, FL, and FH. Although Benchaar et al. (2007) reported that monensin did not influence ADG and feed efficiency, several reviews (Goodrich et al., 1984; Potter et al., 1985; Raun, 1990) concluded that in grain-based feedlot diets, supplementation of monensin improves feed efficiency by reducing DMI with little or no effect on ADG.

Surprisingly, all the advantage of MON in feed efficiency was lost when the carcasses were evaluated. Not only were carcass weights not differ-

Table 2. Effects of monensin and functional oil on feedlot performance[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
Initial BW, kg	331.40	332.50	330.90	331.60	332.70	4.31	0.22
Final BW, kg	608.90	612.40	610.70	603.30	604.70	5.99	0.68
Daily DMI, kg/d	13.33	13.10	13.18	13.37	13.67	0.23	0.52
ADG, kg/d	1.63[ab]	1.71[a]	1.68[ab]	1.62[b]	1.60[b]	0.04	0.01
G:F[2]	0.124[ab]	0.131[c]	0.128[bc]	0.124[ab]	0.119[a]	0.00	0.05

[a–c]Means within the same row with different superscripts differ ($P < 0.05$).

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

[2]Feed efficiency ADG/DMI.

ent (369.78 kg across treatments), but DP was lower ($P < 0.05$) for the MON treatment when compared with those of all the other treatments other than FL and LM area was also smaller than for the FH treatment (83.81 and 87.74 cm^2, respectively; Table 3). Although the backfat thickness was not different among the treatments, cattle fed MON had a higher KPH percentage and differed from MON+FL (2.58 and 2.35%, respectively, $P < 0.05$) but not from CON, FL, or FH. Correspondingly, cattle fed MON+FL had a similar KPH percentage to CON, FL, or FH ($P > 0.05$). Our results disagree with those of Schaake et al. (1993), who reported a positive relationship between backfat thickness and KPH percentage, but tend to agree with those observed by Sainz et al. (1995), who found that backfat thickness decreased as KPH percentage increased. The cattle fed MON+FL yielded a better YG and differed from MON ($P < 0.05$; Table 3); however, YG was not different for the cattle fed CON, FL, or FH. Cattle fed MON showed the worst YG but did not differ from CON, FL, or FH.

The QG was not different among the 5 treatments ($P > 0.05$; Table 3). However, numerically, cattle fed FH showed a slightly higher QG than did the cattle fed CON (7.07, Choice vs. 6.77, Select, respectively). The QG distributions were different ($P < 0.05$) in the Prime and high Choice percentiles (Table 3). The cattle fed FH yielded the most Prime QG and differed from CON and MON+FL ($P < 0.05$) but not from MON and FL. The MON+FL treatment yielded the most high Choice QG carcasses and differed from FL and FH ($P < 0.05$) but not from CON and MON treatments. However, other QG such as average and low Choice and Select did not differ. In general, in most beef-cattle studies, ionophores had little or no effect on carcass characteristics such as marbling score and YG (Goodrich et al., 1984), so it was unexpected to find an effect of MON on these characteristics.

Cattle fed FH had a higher percentage of liver abscesses ($P < 0.05$) compared with the cattle fed MON. The steers fed MON, MON+FL, and FL treatments did not differ ($P > 0.05$) from the steers fed CON. Generally, the liver-abscess incidence in drylot cattle ranges from 1 to 95%, with most feedlots averaging between 12 to 32% (Brink et al., 1990). Our results disagree with those of Devant et al. (2012), who reported a tendency for a decreased number of liver abscesses in Holstein bulls supplemented with FO.

In this experiment, feed efficiency favored the 2 monensin treatments (MON and MON+FL). Feeding monensin is known to increase the molar proportions of propionate and decrease the molar proportions of acetate and butyrate in the rumen. This fact results in an increased efficiency of energy metabolism of the rumen and of the animal. However, although the effect of FO on the molar proportions in ruminal VFA has not been thoroughly studied, Coneglian (2009) showed that the inclusion of FO in high-concentrate diets also changed the molar proportions and amounts of ruminal VFA in a similar way to monensin. No VFA samples were taken in this experiment, but if the VFA proportions were similar in the FO and MON treatments, the differences in efficiency could not be attributed to VFA differences. However, differences in body composition may explain the differences in feed efficiency. Monensin and FO affected the carcass characteristics of the supplemented animals differently in this experiment, and increases in backfat thickness or carcass grade have been previously shown to be correlated to decreases in feed efficiency (Nkrumah et al., 2004). Recent research has shown that supplementing FO to chicken diets increased dietary ME around 4% (Bess et al., 2012). If FO supplementation were also to increase ME in ruminant diets, the excess energy would be deposited as fat, which could affect backfat thickness, carcass grade, and feed efficiency.

No differences ($P > 0.05$) were observed for juiciness, tenderness, or beef flavor (Table 3). The FO supplements evaluated in this experiment did not alter the sensory properties of the meat.

Blood Analysis

Our steers were healthy and had no clinical health issues. According to Kramer (2000), the complete blood count may be used to suggest certain

Table 3. Effects of monensin and functional oil on cattle carcass characteristics[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
Liver abscesses,[2] %	10.42[ab]	6.25[b]	10.42[ab]	10.42[ab]	18.75[a]	2.10	0.05
DP	61.03[ab]	60.01[c]	60.97[ab]	60.64[bc]	61.47[a]	0.17	0.01
HCW, kg	371.60	366.60	373.10	365.90	371.10	4.24	0.41
LM area,[3] cm^2	86.26[ab]	83.81[b]	84.77[ab]	84.64[ab]	87.74[a]	0.09	0.02
12th-rib fat thickness, cm	1.35	1.24	1.27	1.32	1.35	0.01	0.66
KPH, %	2.49[ab]	2.58[a]	2.35[b]	2.55[ab]	2.55[ab]	0.03	0.02
YG	2.73[ab]	2.75[a]	2.50[b]	2.74[ab]	2.70[ab]	0.04	0.03
YG, %							
1	0.00	2.08	2.08	2.08	0.00	0.70	0.74
2	29.17	29.17	41.67	25.00	29.17	3.61	0.63
3	68.75	62.50	54.17	70.83	70.83	3.70	0.62
4	2.08	4.17	2.08	2.08	0.00	0.88	0.68
5	0.00	2.08	0.00	0.00	0.00	0.42	0.42
QG[4]	6.77	6.85	6.93	6.87	7.07	0.10	0.15
QG, %							
Prime	0.00[b]	2.08[ab]	0.00[b]	2.08[ab]	6.25[a]	0.88	0.02
Choice+	4.17[ab]	10.42[ab]	12.50[a]	2.08[b]	2.08[b]	1.86	0.002
Choice	22.92	12.50	10.42	22.92	20.83	2.82	0.23
Choice−	41.67	43.75	47.92	47.92	47.92	3.71	0.97
Select	31.25	31.25	29.17	25.00	22.92	3.12	0.87
Sensory-panel evaluation							
Juiciness[5]	8.97	9.05	9.55	9.42	9.61	0.31	0.71
Tenderness[5]	7.19	6.93	8.04	6.87	7.10	0.42	0.47
Beef flavor[5]	6.97	6.70	6.76	6.92	6.57	0.23	0.91
Off flavor[5]	0.13	0.35	0.29	0.13	0.39	0.12	0.48

[a–c]Means within the same row with different superscripts differ ($P < 0.05$).

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

[2]Least squares means pen values.

[3]Longissimus muscle area.

[4]High Select = 6, Low Choice = 7.

[5]Increasing numerical score = not juicy to juicy; not tender to tender; no beef flavor to intense beef flavor; no off flavor to intense off flavor.

disease processes when physical-examination findings do not indicate any health problems. We collected blood samples to check for health problems. The white blood cell, hemoglobin, red blood cell, and sorbitol dehydrogenase results were not different ($P > 0.05$) among the treatments (Table 4). The white blood cell count ranged from 9.97 to 10.95 × 10^3/μL. The red blood cell count ranged from 8.52 to 8.93 × 10^6/μL. The hemoglobin count was toward the upper boundary. The hemoglobin ranged from 12.06 to 14.39 g/dL. The sorbitol dehydrogenase activity ranged from 6.13 to 29.88 U/L. The blood tests of our sample indicate that the levels of different substances in the blood were within the normal range. Therefore, one can conclude that the cattle did not have any mild or severe health issues that hematology would detect and that supplementation of FO did not have any deleterious effects.

Economic Analysis

In the actual analysis there were no differences ($P > 0.05$) among the treatment groups for carcass value (Table 5), which represents the most significant component of the final breakeven cost of the cattle. The same feeder price was applied to all the steers, because the cattle were purchased at the same time. The total feed cost and corn costs were numerically higher for the cattle fed FH, mainly because of the cost of FO supplementation.

The cost of gain eliminates the effect of purchase value on profitability and reflects the cost of production associated with performance of the cattle in the drylot (Table 5). The cost of gain was lower for cattle fed MON and FL ($P < 0.05$) than for cattle fed FH. However, because FH cattle had the highest percentage of Choice and Prime carcasses, they compensated for their higher feed costs, and thus their profit was relatively competitive to the other treatments.

The breakeven prices for live and carcass price were not different among treatments. The profit was numeri-

Table 4. Effects of monensin and functional oil on blood cells, hemoglobin, and sorbitol dehydrogenase[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
White blood cell, × 10^3/μL							
Initial	9.97	10.67	10.47	10.95	10.27	0.29	0.79
Final	10.39	10.04	10.76	9.87	10.30	0.18	0.56
Hemoglobin, g/dL							
Initial	12.17	12.66	12.44	12.22	12.06	0.14	0.69
Final	14.17	14.17	14.39	14.15	14.12	0.09	0.92
Red blood cell, × 10^6/μL							
Initial	8.93	8.88	8.88	8.65	8.52	0.12	0.64
Final	8.93	8.85	8.82	8.58	8.70	0.07	0.66
SDH,[2] U/L							
Initial	29.83	26.18	29.88	23.31	17.93	2.20	0.42
Final	9.80	12.05	10.68	8.22	6.13	0.01	0.43

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

[2]Sorbitol dehydrogenase (or L-serine dehydratase).

cally higher for MON+FL steers compared with MON. The MON steers yielded the lowest profit because of their unexpected lower percentage of Choice and Prime carcasses. From these results, one might suggest that the use of FO with an ionophore such as monensin or FO at higher levels in a drylot finishing system might be the most profitable among the studied treatments. However, more research on the economics of FO use is needed to be able to draw this conclusion with certainty.

In the annual analysis the carcass value was numerically highest for the FH and lowest for the MON treatment (Table 6). There were no differences for feeder price, purchase value, and total feed cost ($P > 0.05$). The cost of gain of cattle on the FH treatment was different ($P < 0.05$) from the cost of gain of cattle on the MON treatment. However, the 2 monensin treatments (MON and MON+FL) and 2 FO treatments (FL and FH) were not different ($P > 0.05$) between each other. The breakeven prices for live and carcass price were not different ($P > 0.05$) among treatments. Although the profit was not different ($P > 0.05$) among treatments, numerically the general trend changed when

Table 5. Effects of monensin and functional oil on economic variables for actual prices, in US dollars[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
Initial BW, kg	331.44	332.48	330.98	331.63	332.67	4.31	0.22
Final BW, kg	608.95	612.35	610.69	603.25	604.65	5.99	0.68
Feeder price, $/45.4 kg	103.21	103.21	103.21	103.21	103.21	—	—
Purchase value, $/steer	753.05	754.16	754.32	753.90	755.86	0.73	0.79
Fed price, $/45.4 kg	87.79	87.79	87.79	87.79	87.79	—	—
HCW, kg	371.62	366.58	373.07	365.94	371.67	4.24	0.41
Carcass value, $/steer	1,198.39	1,185.33	1,205.25	1,184.81	1,209.24	20.25	0.48
Total feed cost, $/steer	318.54	313.17	310.47	308.34	321.77	4.18	0.51
Corn cost, $/steer	233.93	225.87	227.78	226.47	236.57	3.89	0.35
Interest on cattle, $/steer	27.23	27.27	27.28	27.27	27.34	0.03	0.79
Total variable cost, $/steer	1,167.66	1,160.73	1,163.60	1,158.34	1,173.80	3.99	0.51
Total cost, $/steer	1,181.66	1,174.73	1,177.60	1,172.34	1,187.80	3.99	0.51
Cost of gain, $/45.4 kg	71.57^{ab}	68.71^{b}	71.67^{ab}	70.52^{b}	74.35^{a}	2.35	0.03
Breakeven price live BW, $/45.4 kg	87.37	86.45	86.50	87.35	88.24	0.55	0.32
Breakeven price HCW, $/45.4 kg	143.21	144.11	142.16	144.02	143.65	1.02	0.83
Profit, $/steer	4.74	(1.26)	15.60	0.63	9.34	22.69	0.87

[a,b]Means within the same row with different superscripts differ ($P < 0.05$).

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

Table 6. Effects of monensin and functional oil on economic variables for annual prices, in US dollars[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
Initial BW, kg	331.44	332.48	330.98	331.63	332.67	4.31	0.22
Final BW, kg	608.95	612.35	610.69	603.25	604.65	5.99	0.68
Feeder price, $/45.4 kg	98.96	98.96	98.96	98.96	98.96	—	—
Purchase value, $/steer	723.11	724.19	724.40	723.94	725.79	4.37	0.81
Fed price, $/45.4 kg	81.58	81.58	81.58	81.58	81.58	—	—
HCW, kg	371.62	366.58	373.07	365.94	371.67	4.24	0.41
Carcass value, $/steer	1,103.70	1,092.36	1,109.12	1,094.07	1,118.96	6.60	0.66
Total feed cost, $/steer	219.55	214.65	217.18	211.05	221.10	3.22	0.48
Corn cost, $/steer	153.73	148.10	149.98	147.50	154.90	2.45	0.30
Interest on cattle, $/steer	26.15	26.19	26.20	26.18	26.25	0.16	0.81
Total variable cost, $/steer	1,037.61	1,033.86	1,036.60	1,029.97	1,041.94	2.79	0.51
Total cost, $/steer	1,051.61	1,047.86	1,050.60	1,043.97	1,055.94	2.79	0.51
Cost of gain, $/45.4 kg	61.81[ab]	59.20[b]	61.86[ab]	61.34[ab]	64.85[a]	0.86	0.01
Breakeven price live BW, $/45.4 kg	77.62	76.98	77.05	77.64	78.32	0.44	0.50
Breakeven price HCW, $/45.4 kg	127.22	128.32	126.62	128.02	127.49	0.83	0.84
Profit, $/steer	41.05	33.57	47.43	39.16	51.83	7.45	0.89

[a,b]Means within the same row with different superscripts differ ($P < 0.05$).

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

compared with the previous actual analysis. Most favorable was for cattle fed FH and least favorable was for cattle fed MON ($51.83 and $33.57/steer, respectively).

The seasonal price patterns for feeder cattle are quite regular and persistent but are modified by short-term market trends and may be muted or exaggerated by the longer-term cattle cycle (Peel, 2006). Because this calculation was done by 10-yr average seasonal prices, there were no differences for fed and feeder price and purchase value ($P > 0.05$; Table 7). The carcass value was numerically highest for FH and lowest for MON. The cost of gain in cattle fed FH was the highest and differed ($P < 0.05$) from MON but not from CON, MON+FL, and FL ($P > 0.05$); however, the

Table 7. Effects of monensin and functional oil on economic variables for seasonal price, in US dollars[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
Initial BW, kg	331.44	332.48	330.98	331.63	332.67	4.31	0.22
Final BW, kg	608.95	612.35	610.69	603.25	604.65	5.99	0.68
Feeder price, $/45.4 kg	100.72	100.72	100.72	100.72	100.72	—	—
Purchase value, $/steer	736.20	737.31	737.54	737.05	738.93	5.47	0.81
Fed price, $/45.4 kg	81.82	81.82	81.82	81.82	81.82	—	—
HCW, kg	371.62	366.58	373.07	365.94	371.67	4.24	0.41
Carcass value, $/steer	1,109.51	1,098.13	1,115.47	1,101.19	1,127.24	6.95	0.56
Total feed cost, $/steer	216.69	211.87	214.27	208.21	218.17	3.45	0.48
Corn cost, $/steer	150.29	144.76	146.64	144.11	151.40	2.65	0.30
Interest on cattle, $/steer	26.62	26.67	26.67	26.65	26.72	0.20	0.80
Total variable cost, $/steer	1,048.32	1,044.68	1,047.30	1,040.71	1,052.62	3.41	0.51
Total cost, $/steer	1,062.32	1,058.68	1,061.30	1,054.71	1,066.62	3.41	0.51
Cost of gain, $/45.4 kg	60.45[ab]	57.85[b]	60.5[ab]	60.11[ab]	63.90[a]	1.08	0.01
Breakeven price live BW, $/45.4 kg	78.42	77.79	77.85	78.46	79.13	0.50	0.51
Breakeven price HCW, $/45.4 kg	128.54	129.68	127.94	129.37	128.81	0.93	0.83
Profit, $/steer	36.09	28.47	43.01	35.47	49.34	8.66	0.84

[a,b]Means within the same row with different superscripts differ ($P < 0.05$).

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

Table 8. Effects of monensin and functional oil on sensitivity of the mean return to management to changes in economic variables, in US dollars[1]

Item	CON	MON	MON+FL	FL	FH	SEM	*P*-value
Base actual profit, $/steer	4.74	(1.26)	15.60	0.63	9.34	22.69	0.87
Corn price increase 5%, $/steer	(6.95)	(12.55)	4.21	(10.69)	(2.49)	22.82	0.88
Corn price decrease 5%, $/steer	16.44	9.96	26.99	11.95	21.17	22.49	0.86
Feeder price increase 5%, $/steer	(34.28)	(40.34)	(23.49)	(38.44)	(29.83)	22.63	0.87
Feeder price decrease 5%, $/steer	43.76	37.81	54.68	39.69	48.50	22.67	0.87
Carcass price increase 5%, $/steer	64.07	57.42	75.26	59.28	69.21	22.65	0.87
Carcass price decrease 5%, $/steer	(54.57)	(59.93)	(44.06)	(58.02)	(50.51)	21.66	0.88

[1]CON = control; MON = monensin; MON+FL = monensin plus functional oil; FL = functional oil low dose; FH = functional oil high dose.

2 monensin treatments (MON and MON+FL) and 2 FO treatments (FL and FH) were not different ($P > 0.05$) between each other. The breakeven prices for live and carcass price were not different ($P > 0.05$) among treatments. Again, although the profit was not different ($P > 0.05$) among treatments, the general trend was similar to the annual scenario and unlike the actual scenario analyses. From the 10-yr seasonal price calculation, the use of a high dose of FO in a drylot finishing system was the most profitable compared with some other systems. Lawrence and Ibarburu (2007) used meta-analysis to combine more than 170 research trials evaluating pharmaceutical technologies in the cow-calf, stocker, and feedlot systems of beef production. In the feedlot systems, they concluded that using ionophores would reduce feeding costs by approximately $12.00 to $13.00/steer or about 1.2%. However, in our experiment we did not find such a difference.

Increasing and decreasing the corn price naturally affects feed costs and other costs associated with production (Table 8). When corn price increased and decreased by 5% from the actual base profit, the average profitability across treatments decreased $11.49/steer and increased $11.51/steer, respectively. Changes in feeder price are reflected in breakeven price for carcass and profit. When feeder price increased and decreased 5%, the average profitability across treatments decreased $39.09/steer and increased $39.08/steer, respectively. The average profitability across treatments increased $59.32/steer and decreased $59.21/steer when the carcass values were increased and decreased by 5%. This analysis shows the importance of carcass value on profitability. Because the carcass is the end product that brings in revenue, the price received highly affects overall profitability.

Langemeier et al. (1992) found that in cattle, finishing, feeder, carcass, and corn prices had the most effect on profit variability over time. The movement in fed cattle prices explained roughly 50% of the variability over time in cattle feeding profits. In addition, the changes in corn prices contributed up to 22% of the variability in profits. Similar results were observed in an experiment done by Koknaroglu et al. (2005). They investigated the factors affecting beef cattle performance and profitability and concluded that 50% of the variation in profit was caused by fed and feeder price. These results show the importance of marketing time on profitability.

IMPLICATIONS

The steers provided FO in their diets showed similar ADG and inferior G:F compared with steers fed diets with monensin and produced carcasses with acceptable YG and a higher percentage of Prime and Choice QG. The use of a low dose of FO with an ionophore such as monensin or a high dose of FO without monensin in a cattle drylot finishing system was the most profitable feeding system in this experiment, at least when compared with other dietary treatments used in these comparisons. Thus FO, which are natural products, may have potential for replacing synthetic products, such as the ionophores now used in cattle feedlot supplements, without hindering profitability if these results are repeated in other experiments.

LITERATURE CITED

Aadland, D. 2004. Cattle cycles, heterogeneous expectations and the age distribution of capital. J. Econ. Dyn. Control 28:1977–2002.

AMSA. 1995. Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat. Am. Meat Sci. Assoc. Nat. Livest. Meat Board, Chicago, IL.

Benchaar, C., H. V. Petit, R. Berthiaume, D. R. Ouellet, J. Chiquette, and P. Y. Chouinard. 2007. Effects of essential oils on digestion, ruminal fermentation, rumen microbial populations, milk production, and milk composition in dairy cows fed alfalfa silage or corn silage. J. Dairy Sci. 90:886–897.

Bess, F., A. Favero, S. L. Vieira, and J. Torrent. 2012. Effects of functional oils on broiler diets of varying energy levels. J. Appl. Poult. Res. 21:567–578.

Brink, D. R., S. R. Lowry, R. A. Stock, and J. C. Parrot. 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. J. Anim. Sci. 68:1201–1207.

Calsamiglia, S., M. Busquet, P. W. Cardozo, L. Castillejos, and A. Ferret. 2007. Invited review: Essential oils as modifiers of rumen microbial fermentation. J. Dairy Sci. 90:2580–2595.

Coneglian, S. M. 2009. The use of cashew nut shell liquid and castor oil in bovine diets. PhD Diss. Univ. Estadual de Maringa, Brazil.

Devant, M., A. Aris, A. Bach, and J. Torrent. 2012. Effect of a blend of castor oil and cashew nut shell liquid on performance, eating pattern, rumen health and carcass quality in bulls fed high concentrate diets. J. Anim. Sci. 90(Suppl. 3):243. (Abstr.)

Ellis, S., W. Edwards, J. Lawrence, and A. Johanns. 2010. Livestock Enterprise Budgets for Iowa 2009. Ag Decision Maker, Iowa State Univ., Ames.

Goodrich, R. D., J. E. Garrett, D. R. Gast, M. A. Kirick, D. A. Larson, and J. C. Meiske. 1984. Influence of monensin on the performance of cattle. J. Anim. Sci. 58:1484–1498.

Himejima, M., and I. Kubo. 1991. Antibacterial agents from the cashew *Anacardium occidentale* (Anacardiaceae) nut shell oil. J. Agric. Food Chem. 39:418–421.

Koknaroglu, H., D. D. Loy, D. E. Wilson, M. P. Hoffman, and J. D. Lawrence. 2005. Factors affecting beef cattle performance and profitability. Prof. Anim. Sci. 21:286–296.

Kramer, J. W. 2000. Normal Hematology of Cattle, Sheep, and Goats. Schalm's Veterinary Hematology. 5th ed. Lippincott, Williams Wilkins, Philadelphia, PA.

Langemeier, M., T. Schroeder, and J. Mintert. 1992. Determinants of cattle finishing profitability. S. J. Agric. Econ. 24:41–47.

Lawrence, J. D., and M. A. Ibarburu. 2007. Economic analysis of pharmaceutical technologies in modern beef production. Proc. NCCC-134 Conf. Appl. Commod. Price Anal., Forecasting, Market Risk Manage., Chicago, IL.

Littell, R. C., P. R. Henry, and C. B. Ammerman. 1998. Statistical analysis of repeated measures data using SAS procedures. J. Anim. Sci. 76:1216–1231.

Murakami, A. E., L. M. G. Souza, J. C. Faveri, and J. Torrent. 2009. Effects of functional oils on chickens challenged with coccidiosis. J. Anim. Sci. 87(Suppl. 2):39. (Abstr.)

Nkrumah, J. D., J. A. Basarab, M. A. Price, E. K. Okine, A. Ammoura, S. Guercio, C. Hansen, C. Li, B. Benkel, B. Murdoch, and S. S. Moore. 2004. Different measures of energetic efficiency and their phenotypic relationships with growth, feed intake, and ultrasound and carcass merit in hybrid cattle. J. Anim. Sci. 82:2451–2459.

Novak, A., G. Clark, and H. Dupuy. 1961. Antimicrobial activity of some ricinoleic acid and oleic acid derivatives. J. Am. Oil Chem. Soc. 38:321–324.

Peel, D. S. 2006. Economics of stocker production. Vet. Clin. North Am. Food Anim. Pract. 22:271–296.

Potter, E. L., M. I. Wray, R. D. Muller, H. P. Grueter, J. McAskill, and D. C. Young. 1985. Effect of monensin and tylosin on average daily gain, feed efficiency and liver abscess incidence in feedlot cattle. J. Anim. Sci. 61:1058–1065.

Rafter, J. A., M. L. Abell, and J. P. Braselton. 2002. Multiple comparison methods for means. SIAM Rev. 44:259–278.

Raun, A. P. 1990. Rumensin "Then and Now." Rumensin in the 1990s. Elanco Anim. Health, Denver, CO, pages A1–A20.

Sainz, R. D., F. De la Torre, and J. W. Oltjen. 1995. Compensatory growth and carcass quality in growth-restricted and refed beef steers. J. Anim. Sci. 73:2971–2979.

Schaake, S. L., G. C. Skelley, E. Halpin, L. W. Grimes, R. B. Brown, D. L. Cross, and C. E. Thompson. 1993. Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. J. Anim. Sci. 71:3199–3205.

Van Nevel, C. J., D. I. Demeyer, and H. K. Henderickx. 1971. Effect of fatty acid derivatives on rumen methane and propionate in vitro. Appl. Microbiol. 21:365–366.

Wallace, R. J. 2004. Antimicrobial properties of plant secondary metabolites. Proc. Nutr. Soc. 63:621–629.

Watanabe, Y., R. Suzuki, S. Koike, K. Nagashima, M. Mochizuki, R. J. Forster, and Y. Kobayashi. 2010. In vitro evaluation of cashew nut shell liquid as a methane-inhibiting and propionate-enhancing agent for ruminants. J. Dairy Sci. 93:5258–5267.