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RESEARCH ARTICLE

# Using Phosphorylated Mannan Oligosaccharide and Fibrolytic Enzyme as Natural Feed Additive Substitutes for Growth-Enhancing Technologies in Sustainable Beef Production [1]

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## Summary

The study objective was to determine the effect on beef production sustainability when growth-enhancing technologies (GET) were substituted with the natural feed additives (NFA) phosphorylated mannan oligosaccharide (Bio-MOS®-(MOS)) and fibrolytic enzyme (Fibrozyme®-(FIB)). Angus x Hereford x Gelbvieh steers, after weaning (n=80; BW=279.6±3 kg), were used in an 84-day backgrounding study (4 treatments; 4 pen replicates/treatment) that was followed by a 122-day finishing study. A control (C) treatment with GET (Revelor-IS® and Rumensin®) was compared to NFA (10 mg/head/day): MOS, FIB, and MOS+FIB. Data were analyzed using mixed procedure of SAS. The backgrounding C steers end weight, weight gain, and average daily gain (ADG) were greater (P<0.01) compared to MOS, FIB, and MOS+FIB. Feed efficiency ratio did not differ (P=0.198). Feed cost/kg of gain was lower for the C treatment (P<0.01). The C treatment net return was 45.9% greater than the average of MOS, FIB, and MOS+FIB treatments. For finishing, the C treatment ADG was greater (P<0.05) compared to MOS, FIB, and MOS+FIB. In addition, the C treatment harvest weight and hot carcass weight were greater (P<0.01) and were harvested 5 days earlier. However, other carcass measurements did not differ (P>0.10). Ending net return was $54.22, -$33.62, -$20.65, and -48.69 for the C, MOS, FIB, and MOS+FIB, respectively. The NFA were less profitable during backgrounding, but not profitable for finishing.

***Keywords:*** *Fibrolytic enzyme, Monensin sodium, Phosphorylated mannan oligosaccharide, Steroid implant, Sustainable beef production*

# Sürdürülebilir Sığır Eti Üretiminde Büyümeyi Artırıcı Teknolojilere İkame Olarak Doğal Yem Katkı Maddesi Fosforile Mannan Oligosakkarit ve Fibrolitik Enzim Kullanımı

## Özet

Bu çalışmanın amacı sürdürülebilir sığır eti üretiminde büyümeyi arttırıcı teknolojilere (GET) ikame olarak doğal yem katkı maddeleri (NFA) phosphorylated mannan oligosaccharide (Bio-MOS®-(MOS)) ve fibrolitik enzimin (Fibrozyme®-(FIB)) etkisini belirlemektir. 84 günlük büyütme ve bunu izleyen 122 günlük bitirme çalışmasında sütten kesilmiş Angus x Hereford x Gelbvieh melez kastre edilmiş tosunları (n=80; BW=279.6±3 kg) kullanılmıştır (4 grup; 4 tekrar/grup). GET içerikli (Revelor-IS® ve Rumensin®) kontrol (C) grubu NFA içerikli (10 mg/head/day): MOS, FIB ve MOS+FIB gruplar ile karşılaştırılmıştır. Veriler SAS istatistik programı kullanılarak analiz edilmiştir. Büyüme döneminde; C grubu tosunlarda son ağırlık, ağırlık artışı ve ortalama günlük artış (ADG) diğer MOS, FIB ve MOS+FIB gruplarına göre daha yüksektir (P<0.01). Yemden yararlanma oranı bakımından gruplar arasında farklılık bulunmamıştır (P=0.198). Birim ağırlık artışı için yem maliyeti C grubunda daha düşüktür (P<0.01). Büyüme dönemi net kazancı C grubunda diger MOS, FIB ve MOS+FIB grup ortalamalarından %45.9 daha yüksektir. Bitirme döneminde; C grubu ADG diğer MOS, FIB ve MOS+ FIB gruplardan daha yüksektir (P<0.05). Ayrıca, C grubu kesim ağırlığı ve sıcak karkas ağırlığıda diğer gruplardan daha yüksek bulunmuştur (P<0.01) ve C grubu tosunları 5 gün önce kesilmiştir. Ancak, diğer karkas parametrelerinde farklılık görülmemiştir (P>0.10). Araştırma sonunda C, MOS, FIB ve MOS+FIB gruplarında net kazanç sırasıyla 54.22$, -33.62$, -20.65$ ve -48.69$ olarak tespit edilmiştir. NFA büyüme döneminde az da olsa kârlı iken bitirme döneminde zarar etmiştir.

***Anahtar sözcükler:*** *Fibrolitik enzim, Monensin sodyum, Fosforile mannan oligosakkarit, Steroid implant, Sürdürülebilir sığır eti üretimi*

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# INTRODUCTION

The USA cattle industry has experienced significant growth in "natural beef" as cattle producers respond to increasing consumer concerns over the use of growth promoting hormones, ionophores, and antibiotics in their meat; however, growth-promoting technologies improve animal performance and reduce environmental impact [1]. These compounds have the potential to be replaced with phosphorylated mannan oligosaccharide and fibrolytic enzymes that in separate research investigations have been shown to reduce stress, enhance immune response, inhibit intestinal binding, improve fiber digestion, increase feed intake, gain, and feed efficiency [2-4]. Enzyme preparations with cellulase and xylanase activity have been shown to improve fiber and dry matter digestion and growth performance in cattle [5-8].

The research objective of this field study was to determine beef production sustainability when using (NFA) mannan oligosaccharide and a fibrolytic enzyme as replacements for growth-enhancing technology (GET), during the backgrounding period, and to document the subsequent carryover effect on finishing feedlot performance, carcass traits, and economics.

# MATERIAL and METHODS

This research was conducted in accordance with guidelines approved by the North Dakota State University Institutional Animal Care and Use Committee (Approval number A0610)

March-April born crossbred steers (Angus x Hereford x Gelbvieh; n=80; w=279.6 kg, age=7.4 months) were weaned the first week of November and fed in an 84-day backgrounding period study using a complete randomized design consisting of four treatments and four pen replicates with five steers per replicate (n=20 per treatment). The investigation was conducted using sixteen 9.75 m x 34.1 m pens at the Dickinson Research Extension Center feedlot located southwest of Manning, North Dakota, USA. Feedlot pens were affixed with steel fencing, anti-siphoning frost-free water fountains, slotted windbreak, with a three-row tree windbreak oriented northwest of the study area. The experimental treatments were:

1. Growth-Enhancing Technology (GET), Control (C) - (Revelor-IS® implant: Trenbolone acetate (80 mg) + estradiol benzoate (16 mg) + monensin sodium (30 g/ton) - (Rumensin®))

2. Natural Feed Additive (NFA), Fibrolytic Enzyme (FIB) (Fibrozyme® 10 g/head/day)

3. Natural Feed Additive (NFA), Mannan Oligosaccharide (MOS) (Bio-MOS® 10 g/head/day)

4. Natural Feed Additive (NFA), Bio-MOS® + Fibrozyme® (MOS+FIB) (10 g+10 g/head/day)

The experimental diets were formulated according to National Research Council specifications for steers estimated to gain 1.4-1.6 kg/head/day [9]. Two feed supplements were prepared that were top-dressed over medium quality alfalfa-bromegrass hay (*Medicago sativa*, *Bromus inermis:* CP=9.1%; ADF=35.0%; NDF=59.9%; TDN=57.4%; NEm Mcal/kg=1.37; NEg Mcal/kg=0.68). The natural feed additives MOS, FIB and MOS+FIB (Alltech Biotechnology Inc., Nicholasville, KY, USA) were blended with cracked corn, shredded beet pulp, corn oil, and molasses in meal form as a carrier *(Table 1)*, for the first supplement, and were fed at the rate of 454 g/head/day to provide 10 g/head/day of each feed additive. For the second supplement, a fortified protein-energy backgrounding feed was prepared as a pelleted complete feed *(Table 2)*. The C steers were

***Table 1.*** *Feed additive supplement ingredient composition and analysis (DM)*
***Tablo 1.*** *Yem katkısı içerikli karma yemin hammadde kompozisyonu ve analizi (DM)*

| **İngredient Composition** | **C** | **MOS** | **FIB** | **FIB+MOS** |
|---|---|---|---|---|
| Cracked Corn, % | 46.0 | 44.9 | 44.9 | 43.8 |
| Shredded Beef Pulp, % | 46.0 | 44.9 | 44.9 | 43.8 |
| Corn Oil, % | 3.0 | 3.0 | 3.0 | 3.0 |
| Molasses, % | 5.0 | 5.0 | 5.0 | 5.0 |
| Bio-MOS, % | --- | 2.2 | --- | 2.2 |
| Fibrozyme, % | --- | --- | 2.2 | 2.2 |
| **Analysis** | | | | |
| CP, % | 9.34 | 10.2 | 9.33 | 10.2 |
| TDN, % | 85.3 | 85.1 | 85.4 | 85.1 |
| Fat, % | 5.46 | 5.42 | 5.5 | 5.5 |
| Acid Detergent Fiber, % | 14.3 | 13.9 | 14.3 | 13.9 |
| NEm, Mcal/kg | 2.15 | 2.15 | 2.15 | 2.15 |
| NEg, Mcal/kg | 1.38 | 1.38 | 1.38 | 1.38 |

implanted once with Revelor-IS® and fed Rumensin® (35.3 mg/kg/supplement) throughout the study. At the end of the 84-day backgrounding period, the steers were moved to the Decatur County Feed Yard, Oberlin, Kansas, USA for a feedlot finishing period and final harvest to determine the subsequent carryover effect of the 84-day backgrounding period treatment on finishing feedlot performance, carcass traits, and overall production economics. During the feedlot finishing period, GET and NFA were not used. Harvest end point for the steers was based on back fat depth and determined using MicroBeef Technologies' Electronic Cattle Management system in use at the Decatur County Feed Yard [10] and were slaughtered at Cargill Meat Solutions, Ft. Morgan, Colorado, and sold on the Angus America grid.

*Table 2.* Protein-energy supplement ingredient composition and analysis (DM)

*Tablo 2.* Protein-enerji ilaveli karma yemin hammadde kompozisyonu ve analizi (DM)

| Ingredient Composition | C | MOS, FIB and MOS+FIB |
|---|---|---|
| Soybean Hull, % | 30.753 | 30.80 |
| Field Pea, % | 20.00 | 20.00 |
| Corn, % | 15.00 | 15.00 |
| Barley Malt Sprout, % | 10.00 | 10.00 |
| Wheat Middling, % | 10.00 | 10.00 |
| Distillers Dried Grain with Solubles, % | 8.00 | 8.00 |
| Decoquinate (6.0 %), % | 0.027 | - |
| Monensin (36.3 gm/kg), % | 0.02 | - |
| Other*, % | 6.20 | 6.20 |
| **Analysis** | | |
| CP, % | 15.10 | 15.1 |
| TDN, % | 70.20 | 70.25 |
| Fat, % | 2.65 | 2.65 |
| Acid Detergent Fiber, % | 18.03 | 18.05 |
| NEm, Mcal/kg | 1.73 | 1.73 |
| NEg, Mcal/kg | 1.16 | 1.16 |

** Beet Molasses, 5.0%; Calcium Carbonate, 0.50%; Salt, 0.50%; Dicalcium Phosphate 21%, 0.10%; Feedlot Trace Mineral Premix, 0.075%; Feedlot Vitamin Premix, 0.025%*

Backgrounding and finishing period data were analyzed using pen as the experimental unit for both growth and carcass closeout data. The mixed procedure of SAS was used to separate means [11]. In the model, diet served as the fixed effect and block served as a random effect. Differences between the treatments were considered significant at P<0.05 and a trend at P<0.10.

## RESULTS

The 84-day backgrounding period performance, feed efficiency, and partial feeding economics are shown in *Table 3*. The control treatment steers, which were implanted with Revelor-IS® and fed diets containing Rumensin® medication, gained 0.31 kg faster (P<0.01) than the average gain of steers fed MOS, FIB, and MOS+FIB. This was an 18.9% improvement in average daily gain, or an average of 32.3 kg more per C treatment steer during the 84-day backgrounding period compared to the average gain of the treatments fed the NFA. However, daily feed intake (P=0.85), feed to gain (P=0.20), and daily feed cost per steer (P=0.60) did not differ. The C treatment steers consumed a numerically smaller amount of feed per kg of gain, but the difference was not significant (P=0.198). However, when feed cost/kg of gain was determined, the numerically lower quantity of feed consumed by the C steers contrasted with the significantly greater rate of gain

*Table 3.* Backgrounding period performance

*Tablo 3.* Büyüme dönemi performansı

| Animal Performance | C | MOS | FIB | FIB+MOS | SEM | P-Value |
|---|---|---|---|---|---|---|
| Number of Steers | 20 | 20 | 20 | 20 | | |
| Number of days Fed | 84 | 84 | 84 | 84 | | |
| Start Backgrounding Wt, kg | 284.2 | 278.8 | 277.8 | 278.0 | 3.16 | 0.43 |
| End Backgrounding Wt., kg | 423.4$^{a}$ | 390.8$^{b}$ | 393.1$^{b}$ | 389.3$^{b}$ | 4.63 | <0.01 |
| Gain, kg | 139.1$^{a}$ | 112.0$^{b}$ | 115.3$^{b}$ | 111.3$^{b}$ | 3.44 | <0.01 |
| ADG, kg | 1.66$^{a}$ | 1.33$^{b}$ | 1.38$^{b}$ | 1.33$^{b}$ | 0.041 | <0.01 |
| Dry Matter Intake/Head/Day, kg | 10.03 | 9.49 | 9.41 | 9.45 | 0.57 | 0.85 |
| Protein-Energy Suppl./Head/day, kg | 4.74 | 4.77 | 4.77 | 4.77 | 0.57 | 0.43 |
| Alfalfa-Brome Hay/Head/Day, kg | 4.83 | 4.27 | 4.19 | 4.23 | 0.57 | 0.84 |
| Feed Additive Suppl./Head/Day, kg | 0.454 | 0.454 | 0.454 | 0.454 | | |
| Feed: Gain, kg/kg | 6.04 | 7.14 | 6.86 | 7.11 | 0.371 | 0.20 |
| Feed Cost/Head/Day, $ | 1.388 | 1.377 | 1.380 | 1.425 | 0.0275 | 0.60 |
| Feed Cost/kg of Gain, $ | 0.8361$^{a}$ | 1.035$^{b}$ | 1.00$^{b}$ | 1.071$^{b}$ | 0.0088 | <0.01 |

***a-b:** Means with different superscripts within a line are significantly different (P<0.05)* among the C steers resulted in a significantly lower feed cost/kg of gain among the C steers compared to the steers that were fed MOS, FIB, and MOS+FIB additives. When comparing estimated profitability potential between treatments at the end of the 84-day backgrounding period, all treatments were profitable, but treatments fed the natural feed additives were an average 45.9% less profitable *(Table 6)*. The research assumption was that any profitability realized among treatments at the end of the backgrounding period would carry over into the finishing period.

The subsequent carryover effect on finishing feedlot performance following the 84-day backgrounding period is shown in *Table 4*. The significant weight advantage that the C treatment steers gained during the backgrounding period carried over through the finishing feedlot period, which was not anticipated, because GET were removed for finishing. The C treatment steers continued to gain at a faster rate during the finishing feedlot period reducing the number of days on feed to final harvest by 5 days. There appeared to be a carryover effect from the use of GET in the C treatment during the 84-day backgrounding period, because the C treatment steers gained faster ($P<0.05$), consumed more feed ($P<0.01$), and live harvest and hot carcass weights were heavier ($P<0.01$) than steers previously backgrounded with MOS, FIB, and MOS+FIB *(Table 5)*. Except for hot carcass weight ($P<0.01$), all of the other carcass measurements did not differ: fat depth ($P=0.54$), ribeye area ($P=0.53$), yield grade ($P=0.79$), quality grade ($P=0.21$), and percent grading choice or greater ($P=0.81$). Total carcass value and marketing analysis *(Table 6)* of the treatment comparisons resulted in a profit of $54.22 per head for the C treatment steers compared to net losses of -$33.62, -$20.65, and -$48.69 per carcass for MOS, FIB,

***Table 4.*** *Finishing feedlot period performance*
***Tablo 4.*** *Bitirme Feedlot dönemi performansı*

| Animal Performance | C | MOS | FIB | FIB+MOS | SEM | P-Value |
|---|---|---|---|---|---|---|
| Number of Days Fed | 116.3 | 122.2 | 120.1 | 121.2 | | |
| Start Finish Weight, kg | 410.3$^a$ | 381.3$^b$ | 383.6$^b$ | 376.3$^b$ | 18.50 | <0.01 |
| Harvest Weight, kg | 615.1$^a$ | 576.0$^b$ | 583.7$^b$ | 572.4$^b$ | 15.67 | <0.01 |
| Gain, kg | 204.8 | 194.7 | 200.1 | 196.1 | 5.80 | 0.32 |
| ADG, kg | 1.76$^a$ | 1.59$^b$ | 1.67$^b$ | 1.62$^b$ | 0.399 | .022 |
| Dry Matter Intake/Head/Day, kg | 9.95$^a$ | 9.64$^b$ | 9.60$^b$ | 9.55$^b$ | 0.170 | <0.01 |
| Feed:Gain, kg | 5.65 | 6.06 | 5.75 | 5.90 | 0.122 | 0.23 |

***a-b:*** *Means with different superscripts within a lines significantly different (P<0.05)*

***Table 5.*** *Carcass measurement*
***Tablo 5.*** *Karkas parametreleri*

| Carcass Measurement | C | MOS | FIB | FIB+MOS | SEM | P-Value |
|---|---|---|---|---|---|---|
| Hot Carcass Weight, kg | 390.4$^a$ | 361.8$^b$ | 366.8$^b$ | 362.2$^b$ | 9.83 | <0.01 |
| Fat Depth, cm | 1.32 | 1.32 | 1.32 | 1.27 | 1.04 | 0.54 |
| Ribeye Area, cm$^2$ | 84.6 | 80.0 | 79.9 | 81.5 | 2.61 | 0.53 |
| Yield Grade | 2.95 | 2.80 | 3.05 | 2.80 | 0.2508 | 0.79 |
| Quality Grade | 4.35 | 3.4 | 4.8 | 5.05 | 0.8091 | 0.21 |
| Percent Choice, % | 75.0 | 70.0 | 65.0 | 58.8 | 12.26 | 0.81 |

***a-b:*** *Means with different superscripts within a line are significantly different (P<0.05)*

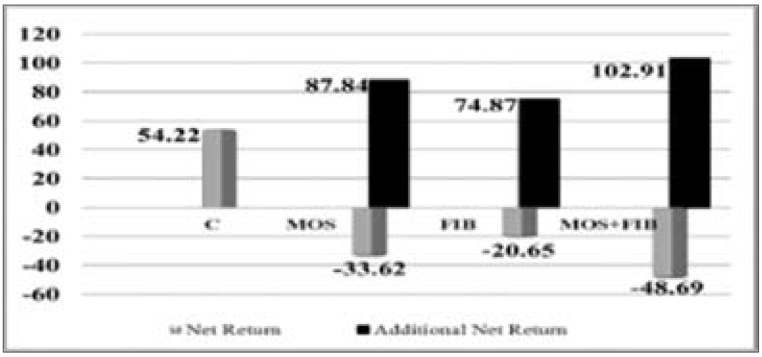


**Fig 1.** Additional net return needed from NFA to equal the control treatment

**Şekil 1.** Kontrol grubu kârına eşit olması için NFA grubuna gerekli ilave net kazanç

***Table 6.*** *Beef production economic analysis*
***Tablo 6.*** *Sığır eti üretiminde ekonomik analiz*

| Economic Analysis | C | MOS | FIB | FIB+MOS | SEM | P-Value |
|---|---|---|---|---|---|---|
| **84-Day Backgrounding Economics** | | | | | | |
| Weight sold with 3.0% shrink, kg | 410.37 | 378.84 | 381.07 | 377.35 | | |
| Price/kg, $* | 2.089 | 2.182 | 2.183 | 2.183 | | |
| Gross Return, $ | 857.20 | 826.65 | 831.70 | 823.58 | | |
| Feeder Calf Cost, $ | 680.77 | 667.73 | 665.55 | 665.55 | | |
| Feed Cost, $ | 116.65 | 115.69 | 115.93 | 119.71 | | |
| Yardage Cost, $ | 25.20 | 25.20 | 25.20 | 25.20 | | |
| 84-Day Backgrounding Net Return, $ | 34.58 | 18.03 | 25.02 | 13.12 | | |
| **Total Beef Production Economics** | | | | | | |
| Total Carcass Value, $** | 1243.55[a] | 1149.52[b] | 1153.66[b] | 1130.98[b] | 3.58 | <0.01 |
| Feeder Calf Cost, $ | 680.77 | 667.73 | 665.55 | 665.55 | | |
| Backgrounding Feed and Yardage, $ | 141.85 | 140.89 | 141.13 | 144.91 | | |
| Feedlot Feed and Yardage Cost/Head, $ | 325.71 | 333.52 | 326.63 | 328.21 | 6.73 | 0.78 |
| Transportation, $*** | 41.00 | 41.00 | 41.00 | 41.00 | | |
| Total Net Return, $ | 54.22 | -33.62 | -20.65 | -48.69 | | |

** Backgrounding economics prices are from Stockmen's Livestock Exchange, Dickinson, North Dakota, ** Total carcass value amount paid by Cargill Meat Solutions based on the Angus America value grid, *** Transportation from Dickinson, North Dakota to Oberlin, Kansas,* ***a-b:*** *Means with different superscripts within a line are significantly different, (P<0.05)*

and MOS+FIB additives, respectively. Although there was no difference between treatments in the percentage of carcasses grading choice, steers fed natural additives during backgrounding returned significantly less gross return/carcass that affected total net return.

# DISCUSSION

Growth-enhancing technology (steroid hormones and feed antibiotics) is used extensively in the USA cattle feeding industry to increase muscle accretion, alter rumen volatile fatty acid production, and improve gain, and feed efficiency However, the consuming public is becoming increasingly more concerned about the use of hormones and antibiotics, and buying habits are changing as evidenced by meat sale increases for natural and organically grown meat [12]. This consumer message must be taken seriously. The NFA, mannan oligosaccharides and fibrolytic enzymes (cellulase and xylanase activity) have been evaluated in separate investigations, but research comparing the two additives fed together as replacements for GET is limited. The research objective was to determine whether comparable animal response can be realized when feeding the NFA separately or in combination as alternatives to using GET.

Mannan oligosaccharides (MOS) used commercially are products containing a minimum of 28% glucomanno-protein from *S. cerevisiae* and have been mostly evaluated as dietary alternatives for antibiotics in simple stomach food producing animals [13-16]. Feeding supplemental MOS resulted in comparable performance when compared to feeding antibiotics. However, to a lesser extent in ruminant animals. In growing-finishing cattle, steers fed 85% concentrate diets with MOS were compared to steers fed a conventional diet regime that included the feed antibiotic Rumensin® [2]. No difference was measured in growth rate, days on feed, feed efficiency, fat thickness, ribeye area, yield grade, or quality grade, suggesting MOS was an effective replacement for feed grade antibiotic. In the current study that included a steroid implant and the feed additive Rumensin, our results show that feeding MOS alone or in combination with Fibrozyme® (FIB+MOS) did not differ from the C for total daily feed intake, feed required per kg of gain, and feed cost per steer per day. The results of the current study agree with the reported feed efficiency and carcass data [2], but do not agree with the reported growth performance [2], because using the steroid implant in this study significantly increased ADG.

Increasing fiber digestion is the main reason for feeding enzymatic products that have been shown to improve forage digestion, resulting in improved milk production and growth performance in beef cattle [5-7,10,17,18]. The effectiveness of enzyme additives can be variable due to the additive formulation and the enzymes present, forage variability, and feeding level [7]. Considering the results of others [5-7,10,17,18], steer response to NFA in the present study was encouraging in the fact that DMI, feed efficiency, and the resultant feed cost/steer/day during the 84-day backgrounding period was similar to the C treatment. In fact, had ADG among the NFA treatments not averaged 18.9% less/day, the bottom line feed cost/kg of gain would have been more favorable for the NFA treatments. The depression in ADG is certainly understandable, since the mode of action for GET and the NFA is very different. Overall, since steer performance with FIB, MOS and MOS+FIB was the same, there is no production advantage for feeding MOS and FIB together.

Economics for NFA compared to employing GET in this study suggest that there is no economic advantage for feeding MOS or FIB individually or in combination during the 84-day backgrounding period and there was no economic carryover advantage during the feedlot finishing period. Combining the two additives added to the cost of production *(Fig. 1)*. Therefore, feedlot managers would be advised not to feed the two additives together. Using GET in the C treatment contributed to significantly improved growth performance and lowered feed cost per kg of gain resulting in improved overall productivity and a large net return advantage, which has also been documented by others [19-21].

Since the human population is socially responsible to reduce impact from resource inputs and waste outputs, deterministic models [22,23] have shown that reduced production efficiency increases the amount of feed, land, and water necessary to produce a kg of beef [23].

In conclusion, NFA were less profitable during backgrounding and unprofitable for finishing. Producers growing cattle for NFA markets without the use of GET will need to feed cattle longer, commit more feed, land and water resources, and obtain additional net return from natural markets to capture unrealized revenue.

## REFERENCES

**1. Basarab J, Baron V, Lopez-Campos O, Aalhus J, Haugen-Kozyra K, Okine E:** Greenhouse gas emissions from calf- and yearling-fed beef production systems, with and without the use of growth promotants. *Animals,* 2 (2): 195-220, 2012.

**2. Anderson VL, Schoonmaker J:** Evaluation of performance and carcass quality of finishing beef with natural feeding practices in North Dakota. **In,** *NDSU Carrington Research Extension Center Crop and Livestock Review,* 45, 22-23, 2004.

**3. Spring P, Wenk C, Dawson KA, Newman KE:** The effects of dietary mannan oligosaccharides on cecal parameters and the concentrations of enteric bacteria in the ceca of Salmonella-challenged broiler chicks. *Poult Sci,* 79-205-211, 2000.

**4. Newman K:** Mannan-oligosaccharides natural polymers with significant impact on the gastrointestinal microflora and the immune system. **In,** Lyons TP, Jacques KA (Eds): Biotechnology in the Feed Industry: Proceeding from Alltech's 10th Annual Synposium, Nottingham Press University, Nottingham, UK, 167-174, 1994.

**5. Beauchemin KA, Rode LM, Sewalt VJH:** Fibrolytic enzymes increase fiber digestibility and growth rate of steers fed dry forages. *CJAS,* 75, 641-644, 1995.

**6. Beauchemin KA, Jones SDM, Rode LM, Sewalt VJH:** Effects of Fibrolytic enzymes in corn or barley diets on performance and carcass characteristics of feedlot cattle. *CJAS,* 77, 645-653, 1997.

**7. Beauchemin KA, Colombatto D, Morgavi DP, Yang WZ:** Use of exogenous fibrolytic enzymes to improve feed utilization by ruminants. *J Anim Sci,* 81 (E. Suppl. 2): E37-E47, 2003.

**8. Lewis GE, Hunt CW, Sanchez WK, Treacher R, Pritchard GT, Feng P:** Effects of direct fed fibrolytic enzymes on the digestive characteristics of a forage-based diet fed to beef steers. *J Anim Sci,* 75, 3020, 1996.

**9. NRC:** Nutrient Requirements of Beef Cattle. 7th Rev ed., Natl Acad Sci, Washington, DC, 1996.

**10. ACCU-TRAC:** Electronic Cattle Management System, Micro Beef Technologies, Amarillo, Texas. http://www.microbeef.com/ *Accessed:* 09.03.2013.

**11. SAS:** SAS/STAT Inst Inc Cary, NC, 27513, 2008.

**12. Loe ER, Melroe TA:** Conventional, natural, and organic beef production and consumption. South Dakota State University Extension Extra ExEx2059, http://agbiopubs.sdstate.edu/articles/ExEx2059.pdf. *Accessed*: 10.09.2013.

**13. Funderburke DW:** Effects of dietary supplementation with mannan oligosaccharides on performance of commercial sows and their litters. **In,** Lyons TP, Jacques KA (Eds): Proceeding from Alltech's 18th Annual Symposium, Nottingham Press University, Nottighham, UK, 407, 2002.

**14. Heinrichs AJ, Jones CM, Heinrichs BS:** Effects of mannan oligosaccharide or antibiotics in neonatal diets on health and growth of dairy calves. *J Dairy Sci,* 86, 4064-4069, 2003.

**15. Ferket PR, Parks CW, Grimes JL:** Mannan oligosaccharides versus antibiotics for turkeys. **In,** Lyons TP, Jacques KA (Eds): Nutritional Biotechnology in the Feed and food Industries: Proceeding from Alltech's 18th Annual Synposium, Nottingham Press University, Nottingham, UK, pp.43, 2002.

**16. LeMieux FM, Southern LL, Bidner TD:** Effect of mannan oligosaccharides on growth performance of weanling pigs. *J Anim Sci,* 81, 2482-2487, 2003.

**17. McAllister TA, Oosting SJ, Poop JD, Mir Z, Yanke LJ, Hristov AN, Treacher RJ, Cheng KJ:** Effect of exogenous enzymes on digestibility of barley silage and growth performance of feedlot cattle. *CJAS,* 79, 353-360, 1999.

**18. Romero JJ, Zarate MA, Querioz OCM, Han JH, Shin JH, Staples CR Brown WF, Adesogan AT:** Fibrolytic enzyme and ammonia application effects on the nutritive value, intake, and digestion kinetics of bermudagrass hay in beef cattle. *J Anim Sci,* 91, 4345-4356, 2013.

**19. Foutz CP, Dolezal HG, Gardner TL, Gill DR, Hensley JL, Morgan JB:** Anabolic implant effects on steer performance, carcass traits, subprimal yields, and longissimus muscle properties. *J Anim Sci,* 75, 1256-1265, 1997.

**20. Herschler RC, Olmsted AW, Edwards AJ, Hale RL Montgomery T, Preston RL, Bartle SJ, Sheldon JJ:** Production responses to various doses and ratios of estradiol benzoate and trenbolone acetate implants in steers and heifers. *J Anim Sci,* 73, 2873-2881, 1995.

**21. Berthiaume R, Mandell I, Faucitano L, Lafreniere C:** Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 1. Feedlot performance, carcass quality, and production costs. *J Anim Sci,* 84, 2168-2177, 2006.

**22. Capper JL:** The environmental impact of beef production in the United States: 1997 compared with 2007. *J Anim Sci,* 89, 4249-4261, 2001.

**23. Capper JL, Hayes DJ:** The environmental and economic impact of removing growth-enhancing technologies from U.S. beef production. *J Anim Sci,* 90, 3527-3537, 2012.