Use of Novel Feed Additives in Beef Cattle Production

Jon P. Schoonmaker[1]
Department of Animal Sciences, Purdue University

Introduction

Feed costs represent the largest input cost to produce beef (estimated to be 40-60%). When used strategically, feed additives have the potential to enhance feed efficiency, improve animal health, and/or add value by improving beef quality. Feed additives are defined as dietary ingredients that produce a desirable response in animals in a non-nutritive role. Several feed additives contain nutrients, however, they are not fed to meet a nutritional requirement, rather, they are fed to alter ruminal or post-ruminal metabolism in order to enhance nutrient utilization, animal productivity, or meat quality. Although many feed additives are effective, their practical implementation has been hindered by the variability in animal responses under experimental conditions, increased dosage, handling requirements, and increased cost. Producers should evaluate potential strategies for use of feed additives under specific feeding and economic conditions.

Updates on Selected Feed Additives

Microalgae

Microalgae are microscopic algal bodies that are rich in lipid (> 30% of DM) and omega-3 fatty acids (> 10% of DM). New technology allows for heterotrophic production of microalgae in bulk fermenters that do not require the lighting and electricity previously needed for phototrophic microalgae growth (Harel et al., 2002). Heterotrophic microalgae use organic carbon as an energy source and are easily grown, harvested daily, and can be cultivated using less space relative to typical animal feed ingredients. Algal lipids are used for a myriad of purposes including biofuel production and as a natural omega-3 fatty acid supplements for human food. The microalgae used in animal feed can be the de-oiled by-product of algae oil production (microalgae meal) or can be the high oil microalgae itself.

De-oiled microalgae meal provides protein, carbohydrate, vitamins, and minerals. Stokes et al. (2016) reported that a de-oiled microalgae meal + soybean hull product (43:57) fed up to 42% of the diet DM linearly increased DMI, did not impact ADG, and decreased fat thickness, KPH%, and yield grade in feedlot steers fed a 10% hay diet. At Purdue University, we have investigated feeding 100 g/d of high oil microalgae (ForPLUS; DHA-rich microalgae *Aurantiochytrium limacinum*; 63.6% fat; 17.9% DHA; 30 mg/kg Sel-Plex; Alltech Inc.) in order to increase the healthy omega-3 (**n-3**) long-chain polyunsaturated fatty acid (**PUFA**) content of beef. Feeding 100 g/d of ForPLUS

[1] Contact: 915 W. State St. West Lafayette, IN 47907. 765-494-4860. jschoonm@purdue.edu

more than doubled n-3 fatty acids in beef, produced a 4-fold increase in eicosapentaenoic acid (**EPA**; 20:5n-3) and over a 6-fold increase docosahexaenoic acid (**DHA**; 22:6n-3) (Carvalho et al., 2015). Research at Kansas State University has similarly demonstrated that high-oil microalgae will increase the omega-3 fatty acid content of beef (Phelps et al., 2016). In our study, ForPLUS also increased circulating glucose and decreased circulating insulin after a glucose tolerance test, indicating that whole body glucose metabolism was altered. High-oil microalgae decreased intake but did not statistically impact daily gain. Supplemental microalgae effectively increased the omega-3 content of beef and may be economical if producers are able to produce for a value-added market. Further research on health and metabolic impacts are needed.

Prebiotics

Prebiotics have been described as non-digestible food substances that selectively stimulate the growth of favorable species of bacteria in the gut, thereby benefitting the host (Gibson and Roberfroid, 1995). Examples of prebiotics include oligosaccharides found in yeast cell wall (**YCW**) components and clay minerals.

Yeast Cell Wall

Mannoproteins and β-glucans are the primary components derived from the YCW and have shown promise in keeping receiving cattle healthier (Spring et al., 2000; Volman et al., 2008). Yeast cell wall components adhere to bacteria and prevent their colonization in the gastrointestinal tract (Davis et al., 2004), leading to enhancement of the immune system (Ganter et al., 2003). In general, YCW products are thought to have greater efficacy than live yeast products due to the concentration of cellular components (Burdick Sanchez et al., 2014).

At Purdue University, we fed a proprietary blend of specialized mannan-rich fractions and glucan-rich fractions of yeast (Select TC™, Alltech Inc.). Cattle were fed a high-forage receiving diet and the proprietary blend at a rate of 13 g/d for the first 56 d of the feedlot period, and we observed an improvement in their immune status during a bacterial endotoxin challenge (Pukrop et al., 2017). Interleukin 6 (**IL-6**) is a cytokine associated with tissue degradation, energy mobilization, fever, and a decrease in voluntary feed intake (Johnson, 1997). We noted that receiving cattle fed Select-TC had lower circulating concentrations of IL-6, lower concentrations of non-esterified fatty acids (**NEFA**), and lower rectal temperatures following a bacterial endotoxin challenge. Interferon-γ is an important mediator of macrophage activation and contributes to the resistance of intracellular pathogens (Flynn et al., 1993). We observed an increase in serum IFN-γ concentrations after an endotoxin challenge in steers fed Select-TC compared to control suggesting that steers fed Select-TC had a stronger pro-inflammatory response relative to controls, which may allow for a greater ability to fight disease through identification and elimination of pathogens. Select-TC did not change serum cortisol, glucose, insulin, or blood urea nitrogen relative to controls during an endotoxin challenge.

Others have reported similar responses in beef cattle fed YCW products. Burdick Sanchez et al. (2013) observed that supplementing with YCW products decreased serum IL-6 concentrations, but had no effect on serum IFN-γ. Burdick Sanchez et al. (2014) observed that one YCW product did not affect serum NEFA, but increased serum BUN concentrations, while a second YCW product decreased serum NEFA and did not affect BUN. Buntyn et al. (2016b) found no differences in serum IL-6, an increase in serum IFN-γ, and a decrease in serum NEFA and BUN during an endotoxin challenge in steers supplemented with an active dried yeast compared with non-supplemented steers. Buntyn et al. (2016a) reported that serum concentrations of both IL-6 and IFN-γ were lower in steers receiving 5.0 g/d of a live yeast compared with steers that were not fed yeast.

Although immunologically, cattle fed a YCW product appear to be able to handle possible pathogenic challenges better than controls, the 46% drop in morbidity that we observed was not statistically different during the 56 d study and animal performance was not altered. However, animal health cost savings could be significant. Others (Burdick-Sanchez et al., 2014; Finck et al., 2014; Buntyn et al., 2016b) have similarly reported little statistical response of YCW on morbidity and performance. Source of yeast and YCW products, as well as the condition of calves when they received these products, likely influence efficacy. It has been reported that beneficial effects of yeast product supplementation are more pronounced under stress versus normal conditions (Arambel and Kent, 1990; Cole et al., 1992).

Clay mineral

Because of their physical and chemical structures, clay minerals are frequently used in the livestock industry as binding agents in the production of pelleted feeds, adsorbents for many toxins, and storage and release of microelements (Slamova et al., 2011). Clays are the products of silicate rocks that have been subjected to weathering processes for thousands of years (Buckman and Brady, 1969). The specific term “silicate” is used to describe these clays and the main classification is phyllosilicates. Phyllosilicates consist of many subcategories which are based on chemical composition: kaolinite, smectites, chlorites, and micas (Adamis and Williams, 2005). Smectite clays are 2:1 hydrated sodium calcium aluminosilicate (**HSCAS**) minerals organized in a sheet structure (phyllosilicate) that because of their physical and chemical structures can absorb mycotoxins, tannins, heavy metals, bacteria, and viruses and expel them from the body (Williams and Haydel, 2010). Bentonite is a common smectite clay mineral fed to livestock for this purpose. Zeolites, which are also used in livestock nutrition have properties similar to smectite clays, but form tubes or cage-like structures that can incorporate a variety of molecules and ions. Major advantages of clay mineral adsorbents are that they are relatively inexpensive, generally recognized as safe (**GRAS**), and can be easily added to animal feeds.

Our results with smectite clay (Antonelo et al., 2017) and results of others (Chestnut et al., 1992; Phillips et al., 1988; Moschini et al., 2008) indicate that smectite clays can adsorb mycotoxins in the normal physiological range of ruminal pH. In vitro toxin binding assays don't always translate to in vivo conditions (Phillips et al., 1988), however, studies have demonstrated that the addition of smectite clays to dairy cattle diets resulted in a 40 to 48% reduction in milk aflatoxin M_1 concentration and a 43 to 46% decrease in aflatoxin M_1 excretion in cows fed diets containing significant aflatoxin concentrations (Harvey et al., 1991; Stroud, 2006; Kutz et al., 2009).

Antonelo et al. (2017) observed that the addition of 1% of the diet DM as clay mineral to a 10% roughage feedlot cattle diet had a positive effect on feedlot performance during the first 30 d, but this advantage was not sustained throughout the feeding period. Huntington et al. (1977a,b) similarly observed an improvement in performance during the initial 21 to 30-d of the feeding period when sodium bentonite was added to the diet of lambs fed a high concentrate diet. In contrast, some have observed improvements over the entire feeding period for ADG and DMI (Walz et al., 1998) or just DMI (Huntington et al., 1977b) in lambs fed bentonite. Others have found little improvement (Chestnut et al., 1992) or possible negative effects (Jacques et al., 1986; Rindsig and Schultz, 1970) of smectite clay on growth and intake.

Clay minerals appear to be effective in dietary transition periods or when mycotoxin content of the diet is elevated.

Alkalizers and buffers

Numerous physical treatments have been applied to roughages, including crop residues, in an attempt to increase digestibility. The bonds between lignin and structural carbohydrates are alkaline soluble, thus alkaline treatments can partially break these bonds and increase microbial fermentation (Jung and Deetz, 1993). Chemically treating crop residues with sodium hydroxide, urea, ammonia, calcium oxide (**CaO**), or calcium hydroxide (**$Ca(OH)_2$**) has been shown to increase nutritive value of these feeds and improve animal performance (Berger et al., 1994; Russell et al., 2011). However, none of these methods is widely used because of the capital and energy intensive nature of these methods as well as the cost and corrosive and/or hazardous nature of chemicals (FAO, 2011).

Our approach at Purdue University has been to investigate the addition of alkalizing agents ($Ca(OH)_2$ or CaO) or buffers such as potassium carbonate (**K_2CO_3**) to the total mixed ration (**TMR**) just prior to feeding as a so-called feed additive. This strategy decreases labor and time commitments, and simplifies implementation compared to chemical pre-treatment. The alkali and buffers serve to increase ruminal pH to a value that facilitates increased fiber digestion. Our research indicates that CaO is the most effective alkaline compound for improving cattle performance, increasing ADG by nearly 20% relative to cattle not fed an alkali or buffer (Lancaster, 2017). Calcium hydroxide, K_2CO_3, and a combination of $Ca(OH)_2$ and K_2CO_3 produced gains intermediate to control and CaO-fed cattle. Our initial research into this area suggests that 0.8 to 1.6% of the diet (DM basis) is optimal for improved fiber digestibility and animal gain (Nunez et al., 2014). Further, some of our recent data suggests that a CaO feed additive is most effective when dry, low quality forage is utilized (20% of diet DM as stover) in corn-based diets containing 30% dry distillers grains plus solubles (DDGS; Muegge et al., 2015; Lancaster, 2017). We observed a 13.9% increase in NDF apparent digestibility, a 15% increase in daily gain, no change in dry matter intake, and a 10% increase in gain:feed (Lancaster, 2017). However, replacement of a portion of the corn with soybean hulls, a highly fermentable fiber source, also improved fiber digestibility and performance of cattle, and the inclusion of CaO combined with soybean hulls provided no benefit (Lancaster, 2017).

Addition of strong alkaline substances directly to the TMR is an effective strategy to improve fiber digestibility and performance of beef cattle, thus eliminating the need for labor intensive processing and handling methods of low quality forage pre-treatment.

Summary

Overall, there is evidence of the beneficial effects of feed additives on performance of cattle. However, inconsistent responses may arise from a variety of inherent factors such as interaction with dietary ingredients, ruminal environment of host animal, intake, fiber and/or starch content, length of feeding period and cattle management. Further, in a recent review, Kenney-Rambo et al. (2016) pointed out that characteristics of a feed additive beyond its efficacy may be the greatest obstacle limiting its application in the future. Shelf life (in storage and mixed in a TMR), regulatory oversight, particle size, ability to deliver, and dose size are examples of obstacles that may need to be overcome. Dose size in particular could have serious implications because at present the most widely used feed additives are based on low inclusion (400 mg/hd daily) rates (Kenney-Rambo et al., 2016). Most of the feed additives mentioned in this review and ones that are heavily considered for use in the industry require greater doses. Larger inclusion doses may require 3- to 90-fold greater production, storage, transfer and delivery capacity by the industry (Kenney-Rambo et al., 2016).

References

Antonelo, D.S., N.A. Lancaster, S. Melnichenko, C.R. Muegge, and J.P. Schoonmaker. 2017. Effects of clay on toxin binding capacity, ruminal fermentation, diet digestibility and growth of steers fed high concentrate diets. J. Anim. Sci. 95:4658-4667.

Adamis, Z., and R. B. Williams. 2005. Bentonite, Kaolin, and Selected Clay Minerals. Environmental Health Criteria 231. World Health Organization, Geneva, Switzerland.

Arambel, M. J and B. A. Kent. 1990. Effect of yeast culture on nutrient digestibility and milk yield response in early- to midlactation dairy cows. J. Dairy Sci. 73:1560-1563.

Berger, L.L.*, G.C.* Fahey, Jr*, L.D.* Bourquin, and E.C. Titgemeyer. 1994. Modification of forage quality after harvest*. In Forage Quality, Evaluation, and Utilization ed. Fahey, J.G.C., Jr. pp. 922–966. Madison: American Society of Agronomy, Inc.*

Buntyn, J. O., J. A. Carroll, N. C. Burdick Sanchez, S. E. Sieren, C. J. Bittner, D. B. Burken, G. E. Erickson, S. J. Jones and T. B. Schmidt. 2016a. Yeast

supplementation alters the immune response in feedlot steers. Nebr. Beef Cattle Report. p. 99-101.
Buntyn, J. O., S. E. Sieren, C. J. Bittner, D. B. Burken, G. E. Erickson, N. C. Burdick Sanchez, J. A. Carroll, S. J. Jones, T. B. Schmidt, K. C. Dehann, T. J. Wistuba. 2016b. Effects of feeding OmniGen-AF on immune function, performance, and carcass characteristics during the feeding period. Nebr. Beef Cattle Report. p. 96-98.
Burdick Sanchez, N. C., T. R. Young, J. A. Carroll, J. R. Corley, R. J. Rathmann, and B. J. Johnson. 2013. Yeast cell wall supplementation alters aspects of the physiological and acute phase responses of crossbred heifers to an endotoxin challenge. Innate Immun. 19:411-419.
Burdick Sanchez, N. C., T. R. Young, J. A. Carroll, J. R. Corley, R. J. Rathmann, and B. J. Johnson. 2014. Yeast cell wall supplementation alters the metabolic responses of crossbred heifers to an endotoxin challenge. Innate Immun. 20:104-112.
Buckman, H. O., and N. C. Brady. 1969. The Nature and Properties of Soils. 7th ed. MacMillan, New York, NY.
Cole, N. A., C. W. Purdy and D. P. Hutcheson. 1992. Influence of yeast culture on feeder calves and lambs. J. Anim. Sci. 70:1682-1690.
Carvalho, J. R. R., K. M. Brennan, and J. P. Schoonmaker. 2015. Effect of supplementing feedlot steers with DHA-rich microalgae meal on performance, insulin sensitivity, and meat quality. J. Anim. Sci. 93(Suppl. 2):152.
Chestnut, A. B., P. D. Anderson, M. A. Cochran, H. A. Fribourg, and K. D. Gwinn. 1992. Effects of hydrated sodium calcium aluminosilicate on fescue toxicosis and mineral absorption. J. Anim. Sci. 70:2838–2846. https://doi.org/10.2527/1992.7092838x
Davis, M. E., C. V. Maxwell, G. F. Erf, D. C. Brown and T. J. Wistuba. 2004. Dietary supplementation with phosphorylated mannans improves growth response and modulates immune function of weanling pigs. J. Anim. Sci. 82:1882-1891.
Finck, D., F. Ribeiro, F., N. Burdick, S. Parr, S., J. Carroll, T. Young, B. Bernhard, J. Corley, A. Estefan, and R. Rathmann. 2014. Yeast supplementation alters the performance and health status of receiving cattle. Prof. Anim. Sci. 30:333–341.
Flynn, J. L., J. Chan, K. J. Triebold, D. K. Dalton, T. A. Steward and B. R. Bloom. 1993. An essential role for interferon gamma in resistance to Mycobacterium tuberculosis infection. J. Exp. Med. 178:2249-2254.
Food and Agriculture Organization of the United Nations (FAO). 2011. Successes and failures with animal nutrition practices and technologies in developing countries. Proceedings of the FAO Electronic Conference, 1–30 September 2010, Rome, Italy. H. P. S. Makkar, editor. FAO Animal Production and Health Proceedings. No. 11. FAO, Rome, Italy.
Ganter, B. N., R. M. Simmons, S. J. Canavera, S. Akira and D. M. Underhill. 2003. Collaborative induction of inflammatory responses by Dectin-1 and Toll-like receptor 2. J. Exp. Med. 197:1107-1117.
Gibson, G. R., and M. B. Roberfroid. 1995. Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. J. Nutr. 125:1401-1412.

Harel, M., W. Koven, I. Lein, Y. Bar, P. Behrens, J. Stubblefield, Y. Zohar, and A. R. Place. 2002. Advanced DHA, EPA and ArA enrichment materials for marine aquaculture using single cell heterotrophs. Aquaculture 213:347–362.

Harvey, R. B., T. D. Phillips, J. A. Ellis, L. F. Kubena, W. E. Huff, and H. D. Peterson. 1991. Effects on aflatoxin M1 residues in milk by addition of hydrated sodium calcium aluminosilicate to aflatoxin contaminated diets of dairy cows. Am. J. Vet. Res. 52:1556–1559.

Huntington, G. B., R. J. Emerick and L. B. Embry. 1977a. Sodium bentonite effects when fed at various levels with high concentrate diets to lambs. J. Anim. Sci. 45:119-125. https://doi.org/10.2527/jas1977.451119x

Huntington, G. B., R. J. Emerick and L. B. Embry. 1977b. Sodium bentonite or sodium bicarbonate as aids in feeding high-concentrate diets to lambs. J. Anim. Sci. 45:804-811. https://doi.org/10.2527/jas1977.454804x

Jacques, K. A., D. E. Axe, T. R. Harris, D. L. Harmon, K. K. Bolsen, and D. E. Johnson. 1986. Effect of sodium bicarbonate and sodium bentonite on digestion, solid and liquid flow, and ruminal fermentation characteristics of forage sorghum silage based diets fed to steers. J. Anim. Sci. 63:923–932. https://doi.org/10.2527/jas1986.633923x

Johnson, R. W. 1997. Inhibition of growth by pro-inflammatory cytokines: An integrated view. J. Anim. Sci. 75:1244-1255.

Jung, H.G., and D. A. Deetz. 1993. Cell wall lignification and degradability. In: Jung, H.G., Buxton, D.R., Hatfield, R.D., Ralph, J. (Eds.), Forage Cell Wall Structure and Digestibility. ASA, CSSA and SSSA, Madison, WI, pp. 315–346.

Kenney-Rambo, N., K. Nenn, and A. DiCostanzo. 2016. Eubiotic Feeding Strategies (EFS) in the feedlot: Review of effects on performance, and mechanisms of action. In: The Plains Nutrition Council Spring Conference. Texas A&M AgriLife Extension Service. San Antonio, TX. April 14-15. pp. 28-43.

Kutz, R. E., J. D. Sampson, L. B. Pompeu, D. R. Ledoux, J. N. Spain, M. Vazquez-Anon, and G. E. Rottinghaus. 2009. Efficacy of Solis, NovasilPlus, and MTB-100 to reduce aflatoxin M1 levels in milk of early to mid lactation dairy cows fed aflatoxin B1. J. Dairy Sci. 92:3959–3963. https://doi.org/10.3168/jds.2009-2031

Lancaster, N. A. 2017. Evaluation of alkalis, buffers, and complementary fiber feeds to increase digestibility and performance in feedlot steers fed corn stover. M.S. Thesis. Purdue Univ., West Lafayette.

Moschini, M., A. Gallo, G. Piva, and F. Masoero. 2008. The effects of rumen fluid on the in vitro aflatoxin binding capacity of different sequestering agents and in vivo release of the sequestered toxin. Anim. Feed Sci. Technol. 147:292–309. https://doi.org/10.1016/j.anifeedsci.2008.01.010

Muegge, C. R. and J. P. Schoonmaker. 2015. Effect of the addition of calcium oxide in soybean hull and non-soybean hull based beef diets on feedlot performance and carcass characterstics. J. Anim. Sci. 93(Suppl. 2):92.

Nunez, A. J. C., T. L. Felix, R. P. Lemenager, and J. P. Schoonmaker*. 2014. Effect of calcium oxide inclusion in beef feedlot diets containing 60% dried distillers grains with solubles on rumen fermentation, nutrient digestibility, and performance. J. Anim. Sci. 92:3954-3965.

Phelps, K.J., J.S. Drouillard, T.G. O'Quinn, D.D. Burnett, T.L. Blackmon, J.E. Axman, C.L. Van Bibber-Krueger, and J.M. Gonzalez. 2016. Feeding microalgae meal (All-G Rich™; *Schizochytrium limacinum* CCAP 4087/2) to beef heifers. I: Effects on longissimus lumborum steak color and palatability. J. Anim. Sci. 94:4016-4029.

Phillips, T. D. L. F. Kubena, R. B. Harvey, D. R. Taylor, and N.D. Heidelbaugh. 1988. Hydrated sodium calcium aluminosilicate: A high affinity sorbent for aflatoxin. Poult. Sci. 67:243-247. https://doi.org/10.3382/ps.0670243

Pukrop, J.R. 2017. Inclusion of antibiotic alternatives in feedlot cattle diets: Impact on health status, cattle performance and meat quality. M.S. Thesis. Purdue Univ., West Lafayette.

Rindsig, R. B. and L. H. Schultz. 1970. Effect of bentonite on nitrogen and mineral balances and ration digestibility of high-grain rations fed to lactating dairy cows. J. Dairy Sci. 53:888-892. https://doi.org/10.3168/jds.S0022-0302(70)86313-5

Russell, J. R., D. D. Loy, J. Anderson, and M. Cecava. 2011. Potential of chemically treated corn stover and modified distiller grains as a partial replacement for corn grain in feedlot diets. Animal Industry Report 657: 10.

Slamova, R., M. Trckova, H. Vondruskova, Z. Zraly, and I. Pavlik. 2011. Clay minerals in animal nutrition. Appl. Clay Sci. 51:395-398. https://doi.org/10.1016/j.clay.2011.01.005

Spring, P., C. Wenk, A. K. Dawson, and E. K. Newman. 2000. The effects of dietary mannanoligosaccharides on cecal parameters and the concentrations of enteric bacteria in the ceca of *Salmonella*-challenged broiler chicks. Poult. Sci. 79:205-211.

Stokes, R.S., D.D. Loy, and S.L. Hansen. 2016. Effects of increased inclusion of algae meal on finishing steer performance and carcass characteristics. J. Anim. Sci. 94:687-696.

Stroud, J. S. 2006. The effect of feed additives on aflatoxin in milk of dairy cows fed aflatoxin-contaminated diets. MSc Thesis. North Carolina State University, Raleigh.

Volman, J. J., J. D. Ramakers and J. Plat. 2008. Dietary modulation of immune function by β-glucans. Physiol. Behav. 94:276-284.

Walz, L. S., T. W. White, J. M. Fernandez, L. R. Gemtry, D. C. Blouin, M. A. Froetschel, T. F. Brown, C. J. Lupton and A. M. Chapa. 1998. Effect of fish meal and sodium bentonite on daily gain, wool growth, carcass characteristics, and ruminal and blood characteristics of lambs fed concentrate diets. J. Anim. Sci. 76:2025-2031. https://doi.org/10.2527/1998.7682025x

Williams, L. B., and S. E. Haydel. 2010. Evaluation of the medicinal use of clay minerals as antibacterial agents. Int. Geol. Rev. 52:745-770. https://doi.org/10.1080/00206811003679737

SESSION NOTES