NEW TECHNOLOGIES IN THE FIELD OF LOW-MOISTURE BLOCK MANUFACTURING AND SUPPLEMENTATION

by

KEVIN ALAN MILLER

B. S., KANSAS STATE UNIVERSITY, 2006

A THESIS

Submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

College of Agriculture

Kansas State University

Manhattan, Kansas

2012

Approved by:

_____

Major Professor
J. S. Drouillard

Abstract

Three studies were conducted to investigate alternative ingredients and processing methods for manufacturing low-moisture blocks. Study 1 was designed to determine if ruminal lactate could be transiently increased by feeding fructose-based blocks to heifers fed prairie hay, thus providing substrate for establishment of lactate utilizing microbes. Low-moisture blocks comprised of 96% fructose and 4% vegetable oil (DM basis) were manufactured and dosed via ruminal fistulas. Administration of fructose blocks resulted in transient increases in ruminal lactate ($P < 0.05$), accompanied by transient decreases in pH ($P < 0.05$). Ruminal fluid incubated with semi-defined lactate medium became more turbid ($P < 0.05$) as a result of prior exposure to fructose blocks suggesting greater capacity for lactate metabolism. In study 2 a portion of the molasses was replaced by corn steep liquor (CSL) or condensed corn distiller's solubles (CCDS). Heifers were fed a forage-based diet and supplemented with 1 of 4 supplement blocks. Supplements were a 30% CP molasses block manufactured at ambient pressure and high temperatures (Mol-30). The remaining treatments were manufactured at reduced pressure and temperature and were a 30% CP block with 36% CSL (CSL-30); a 40% CP block with 40% CSL (CSL-40); or a 40% CP block with 25% CCDS (CCDS-40). Supplementing with Mol-30 and CSL-40 resulted in greater DMI (%BW) than with CCDS-40 ($P < 0.05$). Supplementing with CSL-30 improved efficiency and ADG compared to Mol-30 ($P < 0.01$). Study 3 evaluated the affect of cooking temperature on blocks containing CSL fed to heifers receiving a forage-based diet. Heifers were offered no supplement (Control) or a 15% CSL block manufactured at ambient pressure and high temperature (HT-15). The remaining treatments were manufactured at reduced pressure and temperature and were a

15% CSL block (LT-15); or 40% CSL block (LT-40). Control heifers had the lowest DMI and LT-40 had the greatest ($P < 0.05$). Feeding heifers LT-15 or LT-40 improved ADG compared to heifers fed HT-15 or no supplement ($P < 0.05$). Heifers fed LT-40 tended to be more efficient than those fed HT-15 and Control ($P = 0.07$).

Keywords: Forage, Low-Moisture Blocks, Lactic Acid

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: **A REVIEW OF THE LITERATURE**

Introduction

According to the USDA livestock slaughter 2009 summary there were 33,457,800 cattle slaughtered in the United States in 2009 (USDA, 2010). The Baseline Reference of Feedlot Management Practices reported that, of feedlots surveyed, 63.7% started cattle out on diets containing greater than 35% concentrate, 32.8% started cattle on diets comprised of 56% or greater concentrate, and 18.8% started cattle on diets containing greater than 75% concentrates (APHIS, 2000). As animals are transitioned from a forage-based diet to a concentrate-based diet, microbial populations within the rumen must be adapted from forage digestion to concentrate digestion. This change in diet composition may result in acidosis if not managed properly. Acidosis is a digestive disorder which adversely impacts animal performance and heath. When cattle are not adapted to concentrate diets or concentrates are consumed in excess, lactic acid accumulates in the rumen resulting in decreased ruminal pH. To decrease incidence of acidosis, microbial populations must be adapted to concentrate diets gradually to prevent rapid production and accumulation of lactic acid.

According to the 2007 USDA census of agriculture, there were approximately 408,832,116 acres of permanent pasture and rangeland and approximately 35,771,154 acres of cropland utilized for grazing. The beef cattle industry relies heavily on grazing to sustain production throughout its various segments, such as seedstock production, backgrounding, and stocker grazing. Cattle are capable of utilizing these resources; however, nutrient profiles of these feedstuffs change throughout the year

and producers may need to provide additional nutrients in the form of supplement. Nutrients can be provided in a free-choice manner or fed at a specific level and frequency depending on the availability and cost of labor and supplements. Supplementation programs change input cost and animal performance. Providing supplement on a daily basis may improve animal performance over less frequent supplementation (Farmer et al., 2001). Increasing the frequency of supplementation increases vehicle maintenance, fuel, and labor cost. Supplements delivered less frequently in bulk may result in overconsumption which increases supplement cost and provides more nutrients than are necessary (Bowman and Sowell, 1997). Low-moisture blocks have a unique characteristic that limits intake, and can therefore be delivered less frequently while avoiding overconsumption. These blocks are comprised primarily of molasses, with ingredients that supply nutrients such as fat, protein, minerals, and vitamins suspended within the molasses. These blocks are manufactured by removing moisture from the molasses through a high temperature evaporative process, resulting in a hard, amorphous mass that has deliquescent properties. This property limits intake to approximately 0.23-0.45 kg per head per animal daily. Moisture from the atmosphere is absorbed by sugars in the block, resulting in the formation of a syrup layer that is readily consumed by livestock. Once the syrup has been consumed, animals must wait for a new layer to form before consumption can resume. Recent increases in molasses prices have increased the cost of low-moisture block production, resulting in an increased interest in alternatives to molasses. Relatively inexpensive and readily available by-products such as corn steep liquor and condensed distiller's solubles are effective as supplements for

grazing livestock. These ingredients contain reducing sugars and proteins, which predisposes them to Maillard reactions when processed at the high temperatures normally used for production of low-moisture blocks. Utilization of these by-products will require changes in the manufacturing process to facilitate reduced processing temperatures.

Acidosis

Acidosis is a major concern when cattle are transitioned from forage-based diets to grain-based diets. Acidosis most commonly occurs when cattle are placed in a feedlot and placed onto high-concentrate finishing diets or when dairy cows are transitioned to lactation diets. Acidosis can occur any time large amounts of grain are consumed or during changes in intake or to diet composition. Ruminal microbes ferment feedstuffs, producing VFA (lactic acid), CO_2, and CH_4.These VFA are used for microbial and host growth.

Ruminal bacteria can be broadly categorized as fiberolytic or amylolytic based on their preferred substrates. When large amounts of starch are introduced into the diet, microbial populations shift from predominantly fibrolytic to predominantly amylolytic species and this change often is coupled with increased rate of fermentation and increased production of VFA and lactic acid (Owens et al., 1998). In animals adapted to grain diets, the increase in organic acid production is counterbalanced by decreased pH. This results in increased VFA absorption and metabolism of lactic acid by lactate-utilizing bacteria and prevents the accumulation of these end products (Schwartzkopf-Genswein et al., 2003; Nagaraja and Titgemeyer, 2007). In cattle not adapted to high-grain diets, ruminal concentrations

of organic acids may increase due to inadequate populations of lactate-utilizing bacteria or an under-developed ruminal epithelium. During the shift in microbial populations, there is a disproportional growth rate between lactic-producing and lactic-utilizing populations.

Average growth rates over a pH range of 5.0 to 6.75 in a glucose media for *Streptococcus bovis* (lactic-acid producing) and *Megasphaera elsdenii* (lactic acid utilizing) were 1.45 and 0.46 h^{-1} respectively (Therion et al., 1982). The proportionally faster growth rates of lactate-producing bacteria compared to lactate-utilizing bacteria results in accumulation of lactic acid and the subsequent reduction in ruminal pH, which can have deleterious effects on the ruminal environment. Some of these effects are decreased rumen motility, increased osmolality, inhibited bacterial growth, decreased VFA production, decreased DMI, and poor performance (Huber et al., 1976; Slyter, 1976). Various methods have been employed to prevent this digestive disturbance in order to maintain animal health and performance. The most common method for decreasing the incidence of acidosis is to gradually introduce grains into the diet over a period of time, thus allowing the microbial population within the gut to adapt to the new diet. In a survey of 42 feedlot nutritionists, Vasconcelos and Galyean (2007) found that 76% utilized multiple step-up rations, averaging 3 rations for 7 d each. Approximately 14% of consultants used a two-ration blending program with an average of 21 d to the final diet.

Mackie and Gilchrist (1979) adapted sheep from a 10% concentrate diet to a 71% concentrate diet over a 21-d period with a series of 3 intermediate diets. Amylolytic bacterial populations increased rapidly with each diet change, while

growth of lactate-utilizing populations was lagged behind amlylolytic bacteria growth rates. During the step-up period the dominant populations of lactate-utilizing bacteria changed with ruminal pH. When concentrate levels were below 40% of the diet, *Veillonella* and *Selenomonas* were the dominant lactate utilizers. When concentrate levels exceeded 40% more acid-tolerant lactate utilizers (*Anaerovibrio* and *Propionibacterium)* became the dominant genus. The greatest increase in amylolytic bacteria occurred during the final step to 71% concentrate, coinciding with what was the largest increase in lactate-utilizing bacteria. With each diet change lactic acid accumulation was avoided and only transient increases in lactic acid were observed. Tremere et al., (1968) found that dairy heifers could be adapted to concentrate diets over a 3-wk period without reduced intake if daily increases in concentrate were less than $7g/BW^{0.75}$. If heifers were adapted at faster rates, they experienced digestive upset and decreased DMI. Direct-fed microbial (DFM) feed additives have had little efficacy for preventing ruminal acidosis (Ghorbani et al., 2002; and Beauchemin et al., 2005; Yang et al., 2004). *Selenomonas ruminantium* and *Propionibacteria* have both been evaluated as DFM, but *S. ruminantium* is not well suited for the low ruminal pH associated with high intakes of concentrate. *Propionibacteria* has greater impact on propionate production then on lactate use (Krehbiel et al., 2003). During the adaptation process and subsequent feeding of high concentrate diets *Selenomonas ruminantium* increased 3.8- fold, *Veillonella* spp remained unchanged, and *Megasphaera elsdenii* increased 21–fold suggesting that *Megasphaera* is more well suited to flourish at lower ruminal pH (Slyter, 1976). Direct ruminal inoculation with *Megasphaera elsdenii* has been effective at preventing ruminal acidosis. Lambs

abruptly transitioned from a forage diet to a high concentrate diet and dosed with 10^{11} cfu/animal of *Megasphaera elsdenii* had greater DMI than lambs receiving a placebo of water (Henning et al., 2010). Henning et al. (2010) also observed greater DMI and lower ruminal lactate concentrations in steers receiving *Megasphaera elsdenii* compared to control steers. Robinson et al. (1992) abruptly switched steers from a 50% concentrate diet to a 90% concentrate diet and observed greater intake, higher ruminal pH, and lower ruminal lactate concentrations when steers where inoculated with *Megasphaera elsdenii*.

Fructose

Fructose is a monosaccharide simple sugar that is found in many common feedstuffs. Fructose is readily fermented by ruminal micro-organisms producing VFA, including lactic acid. *In vitro* studies utilizing fructose as a substrate in ruminal fluid collected from cattle fed forage-based diets (Cullen et al., 1986; Sutton, 1968) and concentrate diets (Sutton, 1969) showed decreases in culture pH and increasing production of VFA including lactic acid. Sutton (1968) reported a decrease in pH and molar proportion of acetic acid and an increase in lactic acid and molar proportions of propionic and butyric acid when two Friesian cows fed 70% meadow hay and 30% concentrate cubes were supplemented with fructose. Heldt et al. (1999) conducted two experiments to evaluate effects of supplemental carbohydrate source and DIP level on prairie hay utilization by steers. In experiment 1, steers weighing 448 kg were supplemented with starch, glucose, fructose, or sucrose at 0.3% BW/d and DIP at 0.031% BW/d. In experiment 2, steers weighing 450 kg received the same carbohydrate sources at similar levels but, DIP was fed at 0.122% BW/d. In

experiment 1, NDF digestion was decreased as a result of carbohydrate supplementation but in experiment 2, with greater DIP levels, NDF digestion increased with supplementation. In both experiments, ruminal pH decreased in response to supplementation of carbohydrates. Molar proportions of acetate decreased as a result of supplementation and molar proportions of propionate and butyrate increased. Lactate was also increased as a result of supplementation, with fructose resulting in a greater increase than glucose.

Effect of low-moisture blocks on forage intake and digestion

Low-moisture blocks (LMB) are an effective means of providing supplemental nutrients to cattle consuming low quality forages. Supplementing steers fed prairie hay (5.9% CP) with 417 g/d of a 30% CP LMB made with beet molasses, cane molasses, or concentrated separator by-product increased forage OM, N, and NDF intake. Organic matter and NDF digestibility were increased with supplementation but LMB made with beet molasses increased digestibility of OM and NDF to a slightly greater extent than the other LMB (Greenwood et al., 2000). Titgemeyer et al. (2004) supplemented heifers fed prairie hay (5.2% CP) or prairie hay plus 1.96 kg/d alfalfa (18.6% CP) with LMB containing either 14.4 or 27.5% CP. Low-moisture blocks did not affect forage intake when compared to either the prairie hay or prairie hay plus alfalfa control group. When only prairie hay was fed, supplementing with the 27.5% CP LMB resulted in greater forage intakes compared to supplementing with the 14.4% CP block. Supplementation with either block resulted in increased digestibility when prairie hay alone was fed, but blocks did not increase digestibility when heifers were fed prairie hay plus alfalfa. In trial 2, steers

were fed brome hay (8.4% CP) or alfalfa hay (19.31% CP) and supplemented with LMB (33.2% CP). There was no impact on forage intake (Titgemeyer et al., 2004). The authors noted that the alfalfa hay provided adequate amounts of DIP; therefore, DIP in the form of a LMB provided no benefits to digestion. Leupp et al. (2005) supplemented LMB to cannulated steers fed switch grass (6.0% CP); LMB had either no or contained additives, fermentation extract or brown seaweed meal. Crude protein contents of the blocks were 40.5, 31.1, and 36.9% for LMB containing no additives, fermentation extract, or brown seaweed meal, respectively. Steers receiving the LMB supplement, regardless of composition, consumed more hay and total OM than steers that did not receive a LMB. Supplementation resulted in increased ruminal DM, total-tract DM, and total-tract CP digestion and increased ruminal ammonia concentrations. Greenwood et al. (1998) reported increases in forage and total OM intake when steers fed prairie hay were supplemented with LMB. Organic matter digestibility was numerically greater for supplemented steers but was not statistically different. Increases in forage and OM intake when LMB were fed were associated with increased NDF digestibility when LMB were fed. The efficiency of low-quality forage utilization by cattle can be increased by supplementing low-moisture blocks due to increased forage intake and digestibility.

Processing factors can impact the availability of LMB nutrients. Trater et al. (2003) evaluated the impacts of pH, addition of fructose and glucose, storage conditions, and time of urea addition on ammonia release *in vitro*. When urea was added at the start of cooking or in the middle of the process, ammonia release was decreased compared to adding urea at the end of the process. Conversely, the benefit

of adding urea at the end of the process was reduced when the LMB were stored at 66° C for 12 or 24 h. Adding urea earlier in the process or maintaining the LMB at elevated temperatures after cooking allowed more time for the urea or ammonia to undergo reactions that decreased ammonia release. Ammonia release was decreased when glucose and fructose were added to the LMB. Glucose and fructose are reducing sugars that react more readily with N than does sucrose. At low pH, sucrose stability was decreased resulting in the conversion of sucrose into reducing sugars (Shallenberger and Birch, 1975). Trater et al. (2003) also observed that low molasses pH decreased NH_3 release.

Methods for Manufacturing Low-Moisture Blocks

Low-moisture blocks are manufactured by heating molasses to evaporate moisture, followed by incorporating dry ingredients (protein, vitamins, and minerals) into the dehydrated molasses. The resulting blend is then cooled, forming a hard, brittle, amorphous mass. These blocks are deliquescent in nature, causing them to absorb moisture from the atmosphere to form a syrup layer on the surface of the block that cattle can consume readily. Once the syrup layer has been exhausted, consumption is dramatically decreased until a new fluid layer is formed. The syrup layer will develop at different rates depending on ambient temperatures and humidity.

McKenzie (1974) patented the first process for manufacturing low-moisture blocks. In this process, molasses was heated at atmospheric pressure to 127 to 140 °C while continuously agitated to reduce burning and foaming. Once the appropriate temperature has been reached, no further heat was added to the process. The molasses was then subjected to a vacuum, evaporating much of the remaining

moisture. Upon completion of this step, dry ingredients were added to produce the desired composition. Incorporation of dry ingredients was the final step before packaging the finished product into a rigid container and allowing it to cool into a solid mass.

Several additional processes have been patented since 1974, making various modifications but with the goal of producing a similar end product. Benton and Patrick (1985) patented a process that incorporated the use of unsaturated free fatty acids in combination with a bivalent base in order to form a soap (Figure 1-1). The unsaturated free fatty acids and bivalent base were incorporated into the molasses before heating. Once these ingredients have been combined, the mixture is heated to remove moisture. After removal of a major portion of water, the mixture is exposed to a vacuum to remove additional moisture. Ingredients are then incorporated into the mixture and the final product is packaged and allowed to cool. The addition of unsaturated fatty acids and the bivalent base form insoluble soaps. The production of insoluble soaps restricts absorption of atmospheric moisture by the exposed surface of the block to a very slow rate.

A continuous flow process was patented by McKenzie et al. (1994) in which molasses and oil were continuously blended and heated to a temperature of 150 to 180 °C (Figure 1-2) in an elongated cooking zone. The cooked blend was then passed through a cyclone separator and vacuumizer tank to remove moisture. A premix of dry ingredients was continuously added and a screw auger mixed the cooked blend with the dry ingredients. Like the McKenzie et al. (1994) patent, Westberg (2002) patented a process describing a continuous flow process (figure 1-

3). Molasses and vegetable fat were mixed and then heated in an elongated cooking zone (i.e., a heat exchanger) to between 130 and 150 °C. The heat exchanger was operated above atmospheric pressure. The superheated fluid mixture was pumped into multiple heated vessels operating at atmospheric pressure. The decrease in pressure upon discharge from the heat exchanger resulted in rapid evaporation and decreased temperature. The vessels were configured to allow for simultaneous filling of some vessels while others were being heated or emptied. Setting up the batch cookers in this fashion allowed the steps before and after the batch cookers to be continuous. After batch processing, the partially dehydrated mixture is passed through a vacuumizer tank to evaporate additional moisture. Dry ingredients are then incorporated into the mixture and the product is packaged into rigid containers. Yet another process utilizing vacuum cooking was patented by Benton and Beintema (1996; Figure 1-4). This process employed a jacketed dehydrator equipped with a ribbon mixer, recirculation pump, condensing collection device, and vacuum system to dehydrate the liquid portion. Molasses made up the majority of the liquid portion along with soap stock, a bivalent base, and optional lecithin. The dehydrator contained a lower jacketed portion for heating the mixture and an upper cooling section in order to condense the vapors and collect the subsequent moisture. The condensing and collection portion of the dehydrator was comprised of cooling coils which condensed the vapors produced by heating the liquid mixture (Figure 1-5). Directly under the cooling coils are baffles which direct the condensate to a collection pan that drained into a collection tank on the exterior of the dehydrator (Figure 1-6). Once the initial liquid mix was weighed and pumped into the dehydrator, the vessel

was subjected to vacuum. When a vacuum of 29 inches of Mercury was achieved, the vacuum was closed providing the dehydrator was sealed. The liquid was continuously mixed by the ribbon mixer and a recycling pump circulated liquid from the bottom of the dehydrator and reintroduced it at the top of the liquid level. Once dehydrated, dry ingredients were incorporated into the dehydrated mixture by the ribbon mixer. Upon completion of the mixing step, the bottom of the dehydrator was opened and the final product was discharged. The final product was molded into rigid containers and allowed to cool.

Molasses

Molasses is a by-product of sugar production from either sugarcane or sugar beets. The initial steps for extraction of sugar differ for sugarcane and sugar beets but the post-extraction steps are similar.

Processing of sugarcane starts with cleaning and grinding of the cane followed by steeping of the cane in water or juice (water-containing sugar from the steeping process). The spent cane (bagasse) is discarded and the juice is strained and clarified using heat and lime. The juice is concentrated using evaporator tanks and the sugar is crystallized in vacuum pans for recovery. The crystals are separated from the liquid portion by centrifugation. The remaining liquid is returned to the evaporators and crystallizers to extract more sugar. This is repeated until no more sugar can be removed. The remaining liquid (molasses) is then used for livestock feed.

Sugarbeet processing has subtle differences from sugarcane processing, though the basic principles are the same. The sugarbeets are cleaned and sliced into thin cosettes before being transported to a diffuser. Once in the diffuser, the cosettes

are conveyed up a slope with hot water flowing in a counter-current manor. The sugar-laden juice flows out of the diffuser and is purified using heat and lime. The remaining process is similar to that of sugar production from sugarcane, in so far as the sugar is crystallized several times before arriving at the final molasses. Beet molasses typically has 3.5% greater DM content and a 3% greater CP content than cane molasses (NRC, 1996).

Historically molasses has been a cost-effective and readily available ingredient for use in the manufacturing of low-moisture blocks. Recent increases in molasses prices have resulted in increased production cost (Figure 1-7). Molasses-price reporting is sparsely documented, as USDA terminated official reporting in 1995; however using several different sources, molasses prices can be tracked over the past decade showing over a 2 fold increase in prices from 2004 to 2010. Chromatographic technologies in the sugar industry have allowed for more complete extraction of the sugar from molasses. Beet molasses is best suited for this process as it typically contains 60% sucrose while cane molasses contains only 40% (DM basis). Several sugar companies in the United States employ this technology, utilizing molasses that historically was available to the livestock feed industry (Asadi, 2007).

Corn Steep Liquor

Corn Steep liquor (CSL) is a byproduct of corn wet milling that corn refiners began to recover as a protein source for animal feeding in the early 1980's. Before this time it had been discarded as a waste product (Corn Refiners Association, 2010a). Corn steep water is the liquid remaining after the corn has been steeped in water for 30 to 40 hours, which facilitates removal of the germ and pericarp. Mild

acids are added to the water during the steeping process in order to prevent bacterial growth and aid in the initial steps of breaking down the gluten bonds to liberate starch. The kernel is removed and the steep water is condensed to form corn steep liquor. (Corn Refiners Association, 2010b).

Corn steep liquor can be utilized as a supplement for cattle. Grazing cattle supplemented with a RDP supplement comprised of 53.5% CSL had increased gains and ruminal NH_3 compared to unsupplemented cattle (Hafley et al., 1993). Wagner et al. (1983) evaluated CSL as a supplement for cows grazing dormant native range and found that CSL supplementation resulted in weight changes similar to those obtained with cottonseed meal and also reduced weight loss compared to a ground corn supplement. Corn steep liquor increased ruminal NH_3 levels compared to both the ground corn and cottonseed meal supplements. Johnson et al. (1962) evaluated CSL in forage-based diets of steers and sheep. Steers fed chopped hay and supplemented CSL had greater ADG than steers supplemented with ground corn and urea. Performance of lambs fed a 60% roughage diet containing soybean meal or CSL was similar and digestibility coefficients were increased for DM, crude fiber, and cellulose when lambs were fed 50% forage diets and supplemented with CSL compared to lambs fed just the 50% forage diet. In a separate trial, these authors fed the same basal diet but added 5% CSL and observed no differences in digestibility coefficients.

Condensed Distiller's Solubles

Condensed distiller's solubles are a byproduct of ethanol production from cereal grains. Once the grain has been fermented and the ethanol has been recovered

through distillation, the remaining mash is centrifuged to remove solids, leaving a low-solids liquid fraction that contains soluble proteins, lipids, and minerals. This fraction is condensed (approximately 30% DM) and sold as condensed distiller's solubles or added to dried distiller's grains or wet distiller's grains. The mixture can be dried to approximately 90% DM to yield dried distiller's grains with solubles (Renewable Fuels Association, 2010). Gilbery et al. (2006) supplemented steers consuming switchgrass hay with 0, 5, 10, or 15% corn condensed distiller's solubles (CCDS). In study 1, CCDS and switchgrass were fed separately and in study 2 they were fed as a TMR. In study 1, hay DMI, OM flow to the small intestine, ruminal digestion, postruminal digestion, and total tract digestion were not affected by treatments. Crude protein intake and digestibility were linearly increased but microbial efficiency was not affected. Digestibility of NDF and ADF were similar among treatments. In study 2, hay DMI increased linearly and ruminal DM fill decreased linearly with increasing CCDS inclusion. Total OM and microbial flow were optimized at the 10% inclusion level. True ruminal OM digestion increased linearly; however, intestinal and total-tract digestibilities were not affected by CCDS inclusion. Total-tract CP digestion increased linearly with feeding level of CCDS. Contradictory to previous findings, Coupe et al. (2008) fed cows CCDS separate from their forage had greater DMI than cows fed CCDS mixed with their forage. Regardless of method of feeding the addition of CCDS increased weight gain of cows fed a forage diet. Chen et al. (1976) conducted several *in vitro* studies to evaluate the effects of distiller's solubles processed by screening or centrifugation on cellulose digestion. Distiller's solubles increased cellulose digestion regardless of processing

method but screen-processed distiller's soluble increased digestion to a greater extent than centrifugation.

Maillard Reaction

The Maillard reaction is a complex set of chemical reactions that occur between reducing sugars and free amino groups. When heated, sugars bind to a free amino group of a protein, forming the first of many structures ultimately resulting in Maillard products (Brands, 2002). The formation of Maillard products has been shown to reduce protein digestibility (Goering et al., 1973; Cleale et al., 1987; Elwakeel et al., 2007). Several factors, such as temperature, duration of heating, pH, and water activity, can impact the rate of reaction (Benzing-Purdie et al., 1985; Brands, 2002). Goering et al. (1973) stored orchardgrass pellets with 10% molasses or alfalfa in flasks containing distilled water (53% moisture) for 0, 2, 4, 8, 16, 32, and 72 hr at 80° C. Storage at elevated temperatures resulted in an increased percentage of N that was insoluble in acid detergent. The longer the forage was heated, the greater the proportion of acid detergent insoluble N. Cleale et al. (1987) found that when moisture and pH were held constant, adding reducing sugars to soybean meal and heating to 150° C resulted in greater suppression of NH_3 release then heating soybean meal alone. Liquid ingredients such as molasses, CSL, and distiller's solubles have been shown to undergo Maillard reactions when heated. Elwakeel et al. (2007) added casein or urea to three different liquid feedstuffs (cane molasses, CSL, or distiller's solubles) and then heated the mixtures. Following heating, they measured *in vitro* nitrogen availability by measuring microbial cytosine to determine

differences in microbial protein synthesis or N availability and found that the N availability was reduced in the heated mixtures compared to the unheated mixtures.

Literature Cited

APHIS. 2000. Baseline reference of feedlot management practices. 1999. http://www.aphis.usda.gov/animal_health/nahms/feedlot/downloads/feedlot99/Feedlot99_dr_PartI.pdf. Accessed Oct. 28, 2010.

Asadi, M. 2007. Beet-sugar handbook. Wiley-Interscience. John Wiley and Sons, Inc. Publication, Hoboken, NJ.

Beauchemin, K. A., W. Z. Yang, D. P. Morgavi, G. R. Ghorbani, W. Kautz, and J. A. Z. Leedle. 2003. Effects of bacterial direct-fed microbials and yeast on site and extent of digestion, blood chemistry, and subclinical ruminal acidosis in feedlot cattle. J. Anim. Sci. 81:1628-1640.

Benton, A. E. and J. Patrick. inventors; Benton Feed Yard, Inc., assignee. 1985. Molasses feed block for animals and method of making the same. U.S. Patent No. 4759578. November 25.

Benton, A. E. and C. D. Beintema, inventors; K.E.S. Associates, assignee. 1996. Feed for animals. U.S. Patent No. 6440478 B1. November 22.

Benzing-Purdie, L. M., J. A. Ripmeester, and C. I. Ratcliffe. 1985. Effects of temperature on Maillard reaction products. J. Agric. Food Chem. 33:31-33.

Bowman J. G. P. and B. F. Sowell. 1997. Delivery method and supplementation consumption by grazing ruminants: A review. J. Anim. Sci. 75:543-550.

Brands, C. M. J. 2002. Kinetic modeling of Maillard reaction between proteins and sugars. Ph.D. Thesis, Wageningen University, The Netherlands.

Chen, M. C., W. M. Beeson, and T. W. Perry. 1976. In vitro studies on the effect of screening processed corn distillers soluble and centrifuge processed corn

distillers soluble on cellulose digestion and microbial protein synthesis. J. Anim. Sci. 43:1280-1285.

Cleale R. M., IV, T. J. Klopfenstein, R. A. Britton, L. D. Satterlee, and S. R. Lowry. 1987. Induced non-enzymatic browning of soybean meal. I. Effects of factors controlling non-enzymatic browning on in vitro ammonia release. J. Anim. Sci. 65:1312-1318.

Corn Refiners Association. A brief history of the corn refining industry. http://www.corn.org/historycornrefining.htm. Retrieved: July 22, 2010a.

Corn Refiners Association. Steeping. http://www.corn.org/web/steep.htm. Retrieved: July 22, 2010b.

Coupe, L. R., G. P. Lardy, A. M. Meyer, B. W. Neville, J. L. Leupp, and J. S. Caton. 2008. Effect of corn condensed distiller's soluble supplementation on performance and dry matter intake of beef cows consuming forage-based diets. Proc. Western Section American Society of Anim. Sci. 59:346-349.

Cullen A. J., D. L. Harmon, and T. G. Nagaraja. 1986. In vitro fermentation of sugars, grains and by-product feeds in relation to initiation of ruminal lactate production. J. Dairy Sci. 69:2616-2621.

Elwakeel E. A., E. C. Titgemeyer, J. S. Drouillard, C. K. Armendariz. 2007. Evaluation of ruminal nitrogen availability in liquid feeds. Anim. Feed Sci. and Tech. 137:163-181.

Farmer C. G., R. C. Cochran, D. D. Simms, E. A. Klevesahl, T. A. Wickersham, and D. E. Johnson. 2001. The effect of supplementation frequencies on forage use

and the performance of beef cattle consuming dormant tallgrass prairie forage. J. Anim. Sci. 79:2276-2285.

Ghorbani, G. R., D. P. Morgavi, K. A. Beauchemin, and J. A. Z. Leedle. 2002. Effect of bacterial direct-fed microbials on ruminal fermentation, blood variables, and the microbial populations of feedlot cattle. J. Anim. Sci. 80:1977-1985.

Gilbery, T. C., G. P. Lardy, S. A. Soto-Navarro, M. L. Bauer and J. S. Caton. 2006. Effects of corn condensed distiller's soluble supplementation on ruminal fermentation, digestion, and in situ disappearance in steers consuming low-quality hay. J. Anim. Sci. 84:1468-1480.

Goering, H. K., P. J. Van Soest and R. W. Hemken. 1973. Relative susceptibility of forages to heat damage as affected by moisture, temperature and pH. J. Dairy Sci. 56:137-143.

Greenwood R. H., E. C. Titgemeyer, C. A. Löest, and J. S. Drouillard. 1998. Effects of supplement strategy on intake and digestion of prairie hay by beef steers and plasma amino acid concentrations. Prof. Anim. Sci. 14:56-61.

Greenwood, R. H., E. C. Titgemeyer, and J. S. Drouillard. 2000. Effect of base ingredients in cooked molasses blocks on intake and digestion of prairie hay by beef steers. J. Anim. Sci. 78:167-172.

Hafley J. L., B. E. Anderson, and T. J. Klopfenstein. 1993. Supplementation of growing cattle grazing warm-season grass with proteins of various ruminal degradabilities. J. Anim. Sci. 71:522-529.

Heldt, J. S., R. C. Cochran, G. L. Stokka, C. G. Farmer, C. P. Mathis, E. C. Titgemeyer, and T. G. Nagaraja. 1999. Effects of different supplemental

sugars and starch fed in combination with degradable intake protein on low-quality forage use by beef steers. J. Anim. Sci. 77:2793-2802.

Henning, P. H., C. H. Horn, K.-J. Leeuw, H. H. Meissner, F. M. Hagg. 2010. Effect of ruminal administration of the lactate-utilizing strain *Megasphaera elsdenii (Me)* NCIMB 41125 on abrupt or gradual transition from forage to concentrate diets. Anim. Feed. Sci. Tech. 157:20-29.

Huber, T. L. 1976. Physiological effects of acidosis on feedlot cattle. J. Anim. Sci. 43:902-909.

Johnson, R. R., E. W. Klosterman and O. G. Bentley. 1962. Energy value of lactic acid and corn steepwater and their effects on digestibility of ruminant rations. J. Anim. Sci. 21:887-897.

Krehbiel, C. R., S. R. Rust, G. Zhang, and S. E. Gilliland. 2003. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. J. Anim. Sci. 81:E120-E132.

Leupp, J. L., J. S. Caton, S. A. Soto-Navarro, and G. P. Lardy. 2005. Effects of cooked molasses blocks and fermentation extract or brown seaweed meal inclusion on intake, digestion and microbial efficiency in steers fed low-quality hay. J. Anim. Sci. 83:2938-2945.

Mackie R. I., and Gilchrist F. M. C. 1979. Changes in lactate-production and lactate-utilizing bacteria in relation to pH in the rumen of sheep during stepwise adaptation to a high-concentrate diet. Appl. Environ. Microbiol. 38:422-430.

McKenzie, G. R., R. P. Hunt, C. H. Jones, inventors. 1994. Continuous process for manufacturing animal feed blocks. US Patent No. 5,482,729. June 16.

McKenzie, C. O, inventor. 1974. Molasses feed block for animals and method of making same. U. S. patent 3,961,081. Mar. 12.

Nagaraja, T. G. and E. C. Titgemeyer. 2007. Ruminal acidosis in beef cattle: The current microbiological and nutritional outlook. J. Dairy Sci. 90(E Suppl.): E17-E38.

NRC. 1996. Nutrient requirements of beef cattle. 7th rev. ed. Natl. Acad. Press, Washington, D. C.

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.

Renewable Fuels Association. How ethanol is made. http://www.ethanolrfa.org/pages/how-ethanol-is-made. Retrieved July 29, 2010.

Robinson, J. A., W. J. Smolenski, R. C. Greening, M. L. Ogilvie, R. L. Bell, K. Barsuhn, and J. P. Peters. 1992. Prevention of acute acidosis and enhancement of feed intake in the bovine by *Megasphaera elsdenii* 407A. J. Anim. Sci. 70(Suppl. 1):310 (Abstr).

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. d. Hickman, M. Streeter and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim. Sci. 81:E149-158.

Shallenberger, R. S. and G. G. Birch. 1975. Sugar Chemistry. The Avi Publishing Company, Inc., Westport, CT.

Slyter, L. L. 1976. Influence of acidosis on rumen function. J. Anim. Sci. 43:910-929.

Sutton J. D. 1968. The fermentation of soluble carbohydrates in rumen contents of cows fed diets containing a large proportion of hay. Br. J. Nutr. 22:689-712.

Sutton J. D. 1969. The fermentation of soluble carbohydrates in rumen contents of cows given diets containing a large proportion of flaked maize. Br. J. Nutr. 23:567-583.

Therion J. J., A. Kistner, and J. H. Kornelius. 1982. Effect of pH on growth rates of rumen amylolytic and lactilytic bacteria. Appl. Environ. Microbiol. 44:428-434.

Titgemeyer E. C., J. S. Drouillard, R. H. Greenwood, J. W. Ringler, D. J. Bindel, R. D. Hunter, and T. Nutsch. 2004. Effect of forage quality on digestion and performance responses of cattle to supplementation with cooked molasses blocks. J. Anim. Sci. 82:487-494.

Trater, A. M., E. C. Titgemeyer, J. S. Drouillard, J. N. Pike. 2003. Effects of processing factors on in vitro ammonia release from cooked molasses blocks containing urea. Anim. Feed Sci. and Tech. 107:173-190.

Tremere, A. W., W. G. Merrill, and J. K. Loosli. 1968. Adaptation to high concentrate feeding as related to acidosis and digestive disturbances in dairy heifers. J. Dairy Sci. 51:1065-1072.

USDA. 2007. 2007 Census of agriculture. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/st99_1_008_008.pdf Accessed Aug. 12, 2010.

USDA. 2010. Livestock slaughter 2009 summary. http://www.aphis.usda.gov/animal_health/nahms/feedlot/downloads/feedlot99/Feedlot99_dr_PartII.pdf. Accessed Oct. 28, 2010.

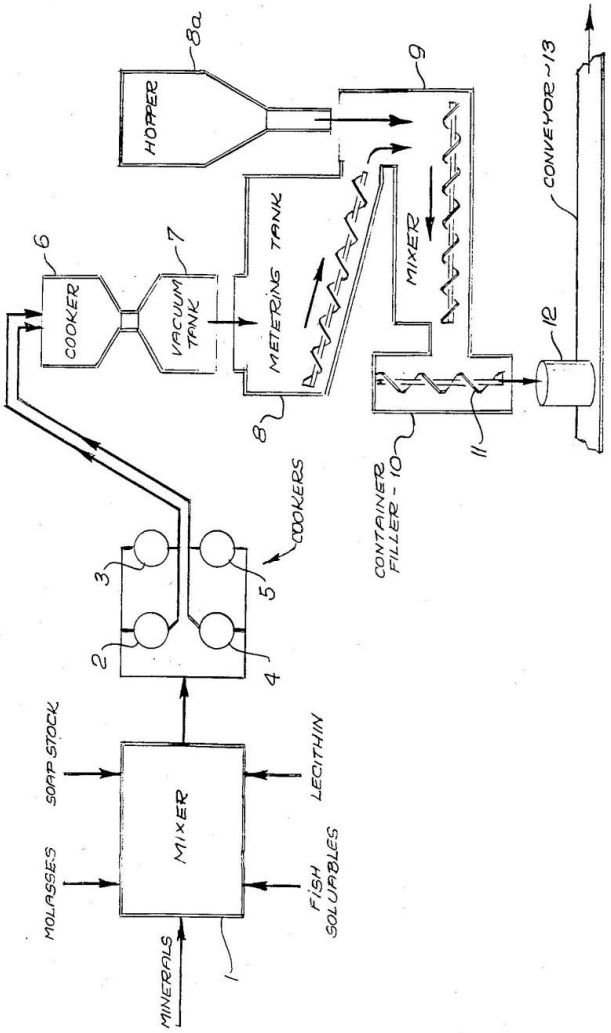
Vasconcelos, J. T. and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim. Sci. 85:2772-2781.

Wagner J. J., K. S. Lusby, and G. W. Horn. 1983. Condensed molasses soluble, corn steep liquor and fermented ammoniated condensed whey as protein sources for beef cattle grazing dormant native range. J. Anim. Sci. 57:542-552.

Westberg, J. A, inventor; Animal Feed Supplement, Inc. Belle Fourche, SD, assignee. 2002. Process for manufacturing animal feed supplement. U.S. Patent No. 7,045,165. July 26.

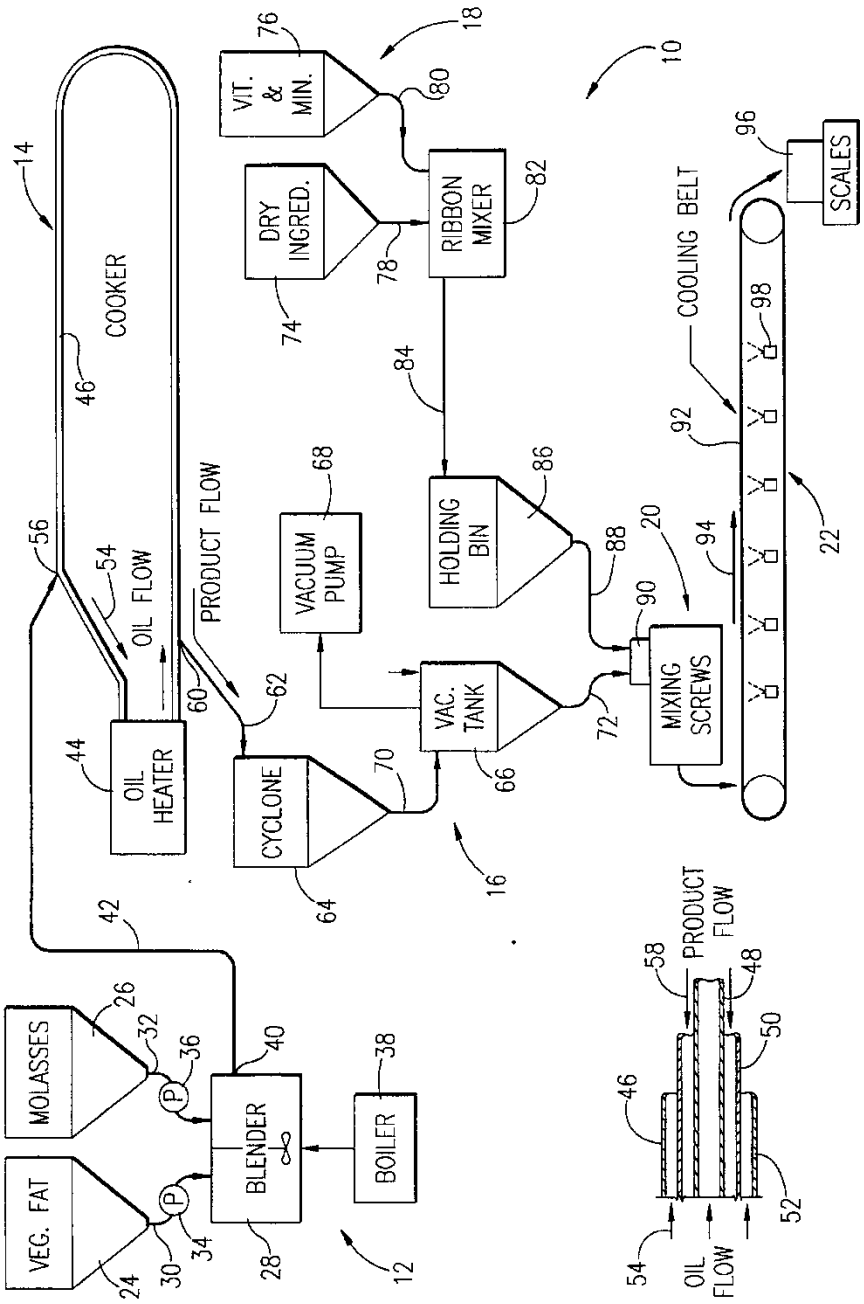
Yang, W. Z., K. A. Beauchemin, D. D. Vedres, G.R. Ghorbani, D. Colombatto, D. P. Morgavi. 2004. Effects of direct-fed microbial supplementation on ruminal acidosis, digestibility, and bacterial protein synthesis in continuous culture. Anim. Feed Sci. and Tech. 114:179-193.

Figure 1-1. Method for manufacturing low moisture blocks utilizing free fatty acids in combinations with a bivalent base to form a soap



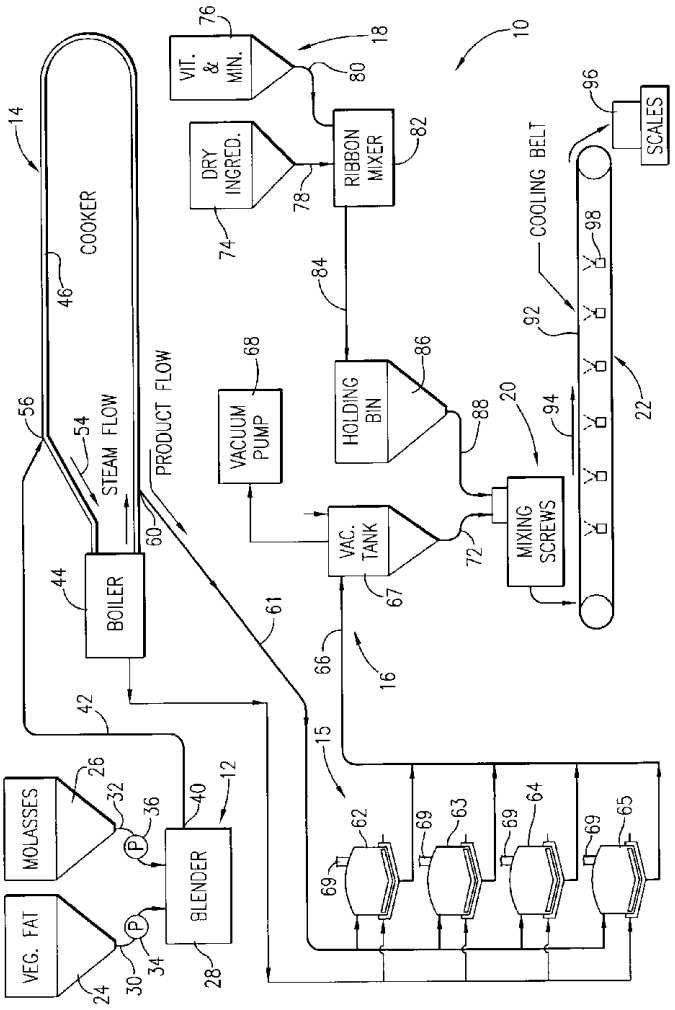
Benton and Patrick, 1985

Figure 1-2. A continuous flow process for manufacturing low moisture blocks



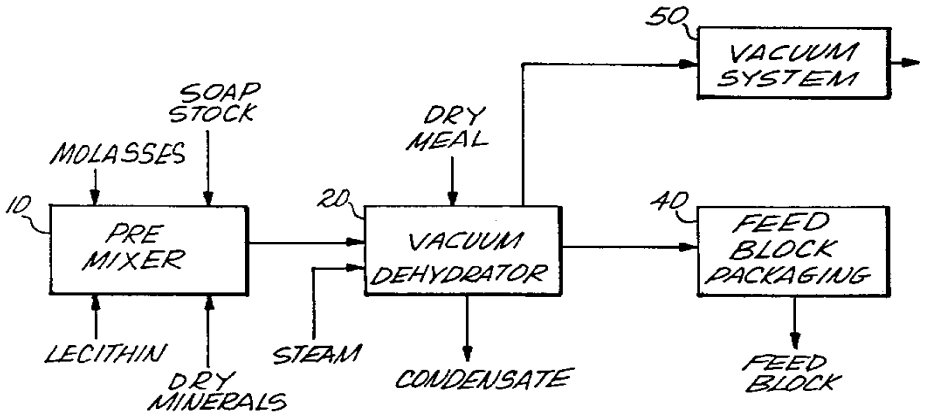
McKenzie et al., 1994

1-3. A continuous process for manufacturing low moisture blocks utilizing multiple batch systems within the process



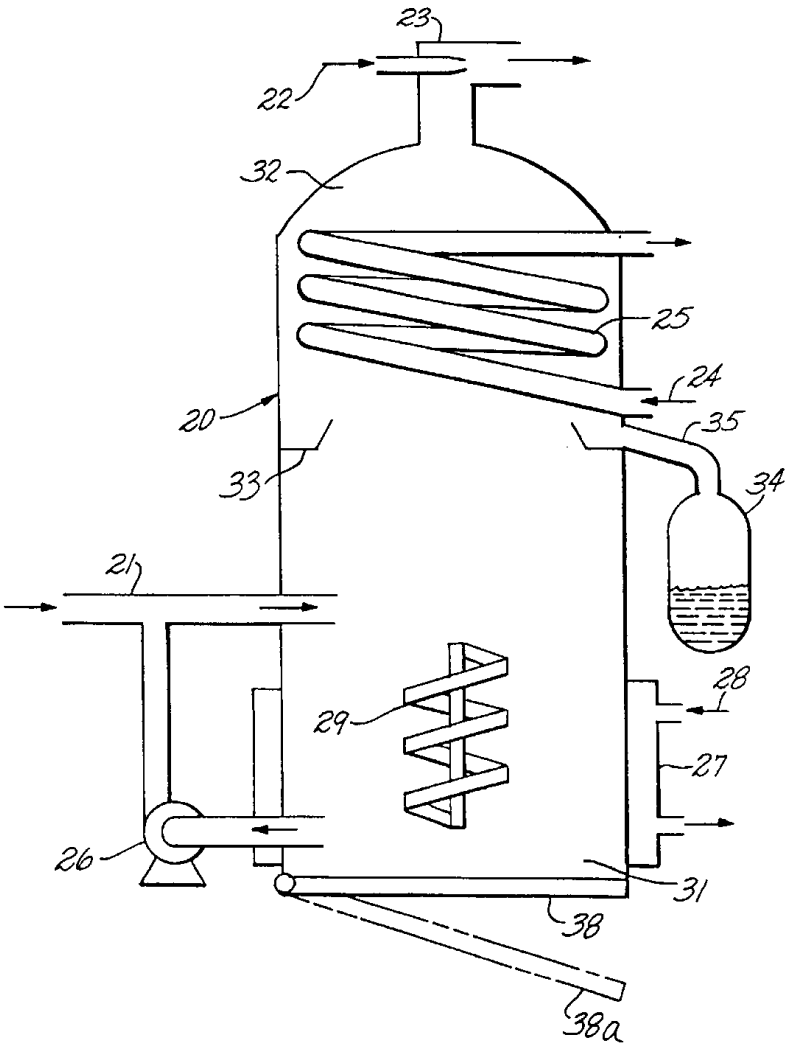
Westberg, 2002

Figure 1-4. Process for manufacturing low moisture blocks with a vacuum dehydration vessel



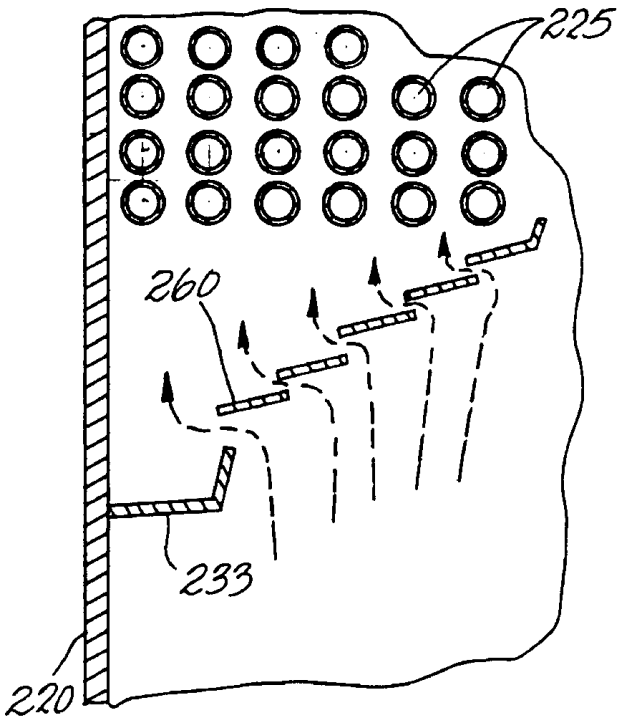
Benton and Beintema, 1996

Figure 1-5. Vacuum dehydration vessel



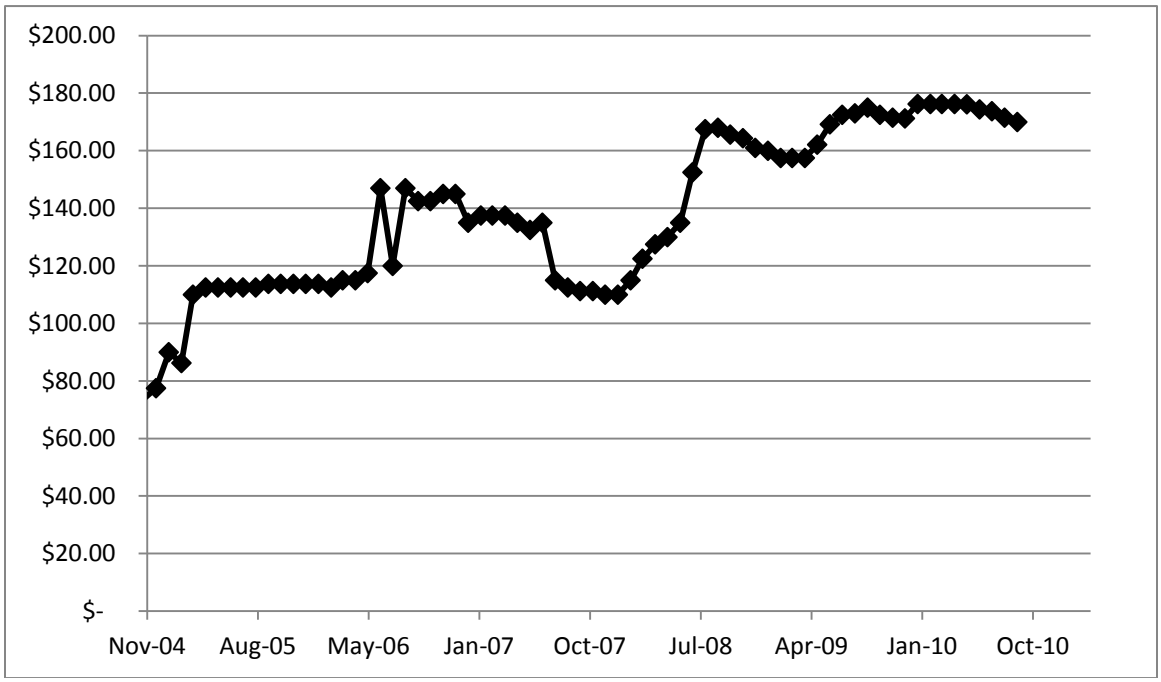
Benton and Beintema, 1996

Figure 1-6. Condensation collection system used in vacuum dehydration vessel



Benton and Beintema, 1996

Figure 1-7. Average Kansas City and Houston cane molasses price/ton, delivery included[a]



[a]Data points missing for Kansas City (Nov-04 to May-06 and July-06) and Houston (Dec-08 and Jan-09)
Feedstuff Magazine: Nov 2004 - Oct 2010

Chapter 2: **Effects of a Fructose-Based Block Supplement on Ruminal Concentrations of Lactate in Cattle Fed High-Forage Diets.**

K. A. Miller, G. L. Parsons, M. J. Quinn, and J. S. Drouillard

Kansas State University
Manhattan, KS 66506

[1]This is contribution no. from the Kansas Agriculture Experiment Station, Manhattan, Kansas
[2]Corresponding Author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

Abstract

A study was conducted to determine if ruminal lactate concentrations and populations of lactate utilizing bacteria could be increased in heifers consuming a high-forage diet by feeding a fructose-based block supplement. Blocks were manufactured by blending high fructose corn syrup with 4% vegetable oil, heating the mixture to 121°C in a steam-jacketed kettle to reduce moisture content, subjecting the dehydrated syrup to a vacuum, discharging the mass into a rigid container, and subsequently cooling to room temperature to form a solid, hardened, amorphous mass. Twelve ruminally-fistulated Angus heifers were blocked by weight and assigned to individual feeding pens. Heifers were allocated randomly within blocks to one of two treatments: CONTROL (no block) or BLOCK (fructose block intraruminally dosed at 0.9 kg daily). Heifers were adapted to a diet consisting of long-stemmed prairie hay and loose salt. For the BLOCK group, the supplement was placed directly into the rumen at approximately 0700 h for the final 3 d of the experiment. Ruminal digesta was sampled at 30-min intervals for 8 h after administration of the supplement to determine changes in ruminal pH, lactate, and volatile fatty acid concentrations on the first and last days of supplementation. At the final sampling point each day, ruminal fluid was obtained from each animal, strained through 4 layers of cheese cloth, and inoculated into anaerobic culture tubes containing lactic acid as an energy substrate. Changes in turbidity were monitored for 24 h as an indicator of differences in capacity for lactic acid metabolism. Ruminal lactate concentrations were greater ($P < 0.01$) for cattle supplemented with 0.9 kg of the high fructose BLOCK compared to controls (3.38 mM versus 0.66 mM). Ruminal butyrate concentrations also were greater ($P < 0.01$) for heifers fed the

BLOCK compared to those in the CONTROL treatment (6.6 versus 4.0 mM;), which likely was the result of lactate conversion to butyrate. Ruminal pH was lower ($P < 0.01$) for the first 3 h after administration of supplement. Incubation of ruminal contents with lactate medium revealed a trend for increased lactate utilization in heifers supplemented with fructose blocks. This study indicated that fructose-based blocks increased lactate production and subsequently stimulated growth of lactate-utilizing bacteria. Increasing the population of lactate-utilizing bacteria within the rumen prior to introduction of cereal grains may have application as a method to prevent acidosis in ruminants.

Keywords: acidosis, fructose, low-moisture blocks

Introduction

Acidosis is an important malady afflicting cattle fed significant amounts of grain and, therefore, has enormous economic impact for feedlots, dairies, and producers of seed stock. The highest incidence of acidosis occurs when animals are transitioned from high-roughage diets to diets containing high levels of concentrates. This transition normally occurs over a 2- to 4-wk period, allowing the ruminal flora and fauna to adapt from populations suited to fiber digestion to those that are suited to digestion of starches and simple sugars. When grain-based diets are consumed in excess, consumed too quickly, or fed without proper adaptation, digestive end-products (organic acids) can accumulate within the rumen, resulting in acidosis. Lactic acid is one of the key organic compounds that accumulate under these conditions, hence the common reference to “lactic acidosis”. Lactate accumulation occurs as a result of the disproportionate proliferation of lactate-producing bacteria

(primarily *Streptococcus bovis*) compared to lactate-utilizing bacteria such as *Megasphaera elsdenii* (Mackie and Gilchrist, 1979). These conditions, coupled with the animal's limited ability to metabolize lactate, lead to accumulation of lactic acid in the rumen. Lactate accumulation lowers ruminal pH, subsequently depressing feed intake until ruminal pH has returned to normal levels. Under extreme conditions, low ruminal pH can lead to reduced blood pH, which is life-threatening.

One means of preventing acidosis is to directly populate the rumen with lactate-utilizing bacteria (Kung and Hession, 1995; Galyean et al., 2000). Alternatively, exposure to low levels of lactate (i.e., levels insufficient to harm the animal) may stimulate the development of a population of lactate-utilizing bacteria (Owens et al., 1998). Previous studies have shown that supplementing fructose can increase lactate production in cattle fed high-roughage diets (Sutton, 1968; Heldt et al., 1999). This increase is observed for a brief period of time after feeding, after which it returns to low levels.

Providing fructose in the form of a low-moisture block could provide a convenient means of stimulating growth of lactate-utilizing bacteria in cattle fed fibrous feeds. This "prebiotic" feeding strategy could be effective for preventing acidosis when cattle subsequently are fed concentrate-based feeds.

The objective of our study was to determine if supplementation of forage-fed cattle with low-moisture blocks made of high-fructose corn syrup and vegetable oil could increase ruminal lactate concentrations, thus increasing the capacity for lactate utilization within the rumen.

Materials and Methods

Blocks were manufactured by blending 10.9 kg of high-fructose corn syrup (60% DM) with 0.45 kg of vegetable oil. The mixture was placed into a steam-jacketed, scraped-surface kettle that was operated at atmospheric pressure and heated to a final temperature of 121°C. The kettle then was subjected to a 0.75 bar vacuum for 60 s, after which the dehydrated mixture was discharged into high-density polyethylene containers. A sheet of clear plastic was placed directly onto the exposed surface, and blocks were allowed to cool to room temperature forming a solid, hardened, amorphous mass. Blocks were broken into small fragments, weighed into 0.9 kg aliquots, and sealed in plastic bags until used.

Twelve ruminally cannulated heifers (535 ± 54 kg) were fed a diet consisting of free-choice, long-stemmed prairie hay and loose salt. Heifers were blocked by initial body weight and assigned to individual feeding pens (1.5m × 3.7m) with slatted concrete floors. Each pen was equipped with a feed manger and an automatic water fountain. Heifers were randomly allocated to one of two treatments (6 heifers/treatment). Treatments consisted of CONTROL (no supplement) or BLOCK (0.9 kg per heifer daily of the fructose-based block supplement).

Following a 10-d diet adaptation period during which heifers were fed only hay and salt, the BLOCK treatment was administered as a 0.9-kg aliquot via the ruminal cannula for 3 consecutive days at approximately 0700 h each day. On first and third day of supplementation, immediately prior to supplement administration, samples of ruminal digesta were removed from each animal via the ruminal cannula to determine baseline pH, VFA, and lactate values. Additional samples of ruminal

digesta were collected at 30-min intervals post-supplementation for 8 h for determination of ruminal pH, VFA and, lactate values.

Ruminal digesta was strained through 4 layers of cheesecloth and pH was measured immediately using a 230A portable pH meter (Thermo Electron Corp., Beverly, MA). Aliquots (4 mL) of strained ruminal fluid were placed into labeled scintillation vials containing 1 mL of 25% metaphosphoric acid solution and samples were immediately frozen for subsequent analyses of lactic acid and other VFA concentrations.

On the final sampling period each day, sterile, anaerobic culture tubes containing 15 mL of a semi-defined lactate medium (lactate, peptone, and yeast extract) were inoculated with 1 mL of strained ruminal fluid from each animal using a sterile 18-guage needle. The contents of each tube were homogenized using a vortex mixer and absorbance (600 nm) was determined using a Spectronic-20 spectrophotometer (Thermo Fischer Scientific, Waltham, MA). Culture tubes were maintained at a temperature of 39°C for 24 h. Tubes were removed from the incubator at hourly intervals throughout the 24-h incubation period and vortexed to suspend cells prior to measuring absorbance. Changes in absorbance were used to determine increases in turbidity associated with proliferation of lactate-utilizing bacterial species.

Statistical Analysis

The MIXED procedure of SAS version 9.1 (SAS Inst., 2003, Cary, NC) was used to analyze VFA and pH. Animal was the experimental unit and block was included as the random effect. The model statement included fixed affects of

treatment, sampling day, hour post-feeding, and all possible interactions. Turbidity was analyzed using the MIXED procedure of SAS version 9.1(SAS Inst., 2003). Animal was the experimental unit and block was the random effect. The model statement included treatment, sampling day, incubation time, and all possible interactions.

Results and Discussions

Supplementation with fructose-based blocks increased ruminal lactate concentrations nearly 6-fold ($P < 0.05$; Figure 1). Peak differences in lactate concentration occurred 1 to 3 h after administration of the block, indicating a transient increase associated with supplementation and rapid metabolism of the lactic acid. Heldt et al. (1999) supplemented fructose (0.30% BW/d) and sodium caseinate (0.122% BW/d) to steers consuming prairie hay and observed increases in lactate concentrations in response to supplementation. The increases in lactate observed by Heldt et al. (1999) were transient, similar to the increases observed in our study. Similarly, ruminal infusion of fructose to cows on a forage diet resulted in increased lactate concentrations (Sutton, 1968). In our experiment, butyric acid concentrations were increased with supplementation of blocks ($P < 0.05$; Figure 2). Ruminal butyrate concentrations in supplemented heifers were greater than for cattle in the control group ($P < 0.05$) at 1, 2, 3, 4, 6, and 8 hours post-administration (differences of 1.57, 2.91, 4.42, 4.51, 2.67, and 1.84 mM for hours 1, 2, 3, 4, 6, and 8, respectively). Propionate concentrations were higher during the intermediate sampling points for cattle administered the fructose block (treatment x hour interaction, $P < 0.05$; Figure 3). Acetate concentrations were lower on day 3

compared to day 1 for both control and supplemented heifers ($P < 0.01$; Figure 4); however, there was no difference between treatments. An increase in butyrate accompanied with a decrease in acetate was seen by Heldt et al. (1999) when steers were supplemented fructose. Sutton (1969) observed an increase in the proportions of butyrate and propionate and a decrease in the proportion of acetate when fructose was infused into the rumen of cows on a roughage-based diet. In our study, increases in propionate and butyrate concentrations were not accompanied by a decrease in acetate concentrations. Increases in butyric acid and propionic acid levels within the rumen were likely the result of lactic acid metabolism by ruminal microbes. This is supported by the fact that increases in butyrate and propionate concentration seemed to lag behind the changes in lactate concentrations. Satter and Esdale (1967) found that adding lactate to ruminal fluid collected from a cow consuming a hay diet resulted in increased butyrate production and decreased production of acetate following 8 hours of incubation. They suggested that the increase in butyrate was not a direct conversion of lactate to butyrate but a result of lactate being converted to acetate. Subsequently driving the conversion of acetate to butyrate occurred in order to maintain an oxidation-reduction balance. Lactate can be converted to propionate via the succinate and acrylate pathways but the acrylate pathway appears to be the more predominate pathway of the two (Baldwin et al., 1962; Bruno and Moore, 1962). This may explain the increase in propionate concentrations observed in our study; however conversion of lactate to acetate is more common in forage-based diets (Satter and Esdale, 1968; Counotte et al., 1983). Concentrations of isobutyrate, valerate, and isovalerate were determined but no notable differences were observed

(Figures 5, 6, and 7). Acetate: propionate was reduced as a result of supplementation (Treatment x hour interaction, $P < 0.05$; Figure 8). Compared to acetate, the production of propionate is energetically more favorable, logically leading to improved energy status of cattle.

Supplementing with fructose-based blocks resulted in modest, transient reductions in ruminal pH (treatment x hour interaction, $P < 0.05$; Figure 9), reflecting increased fermentative activity in supplemented heifers. Ruminal pH of supplemented heifers was lower than controls between 1 and 3 hours ($P < 0.05$) post-supplementation of the block. At no point did pH decline to a level that would compromise digestion. The sharp decline in ruminal pH observed in this study was likely a function of introducing the entire aliquot of block supplement at a single point in time. More modest rates of intake, as would be anticipated with cattle that are offered blocks free-choice, would likely yield smaller changes in ruminal pH because the production of organic acids would occur over an extended period of time.

Absorbance readings from the inoculated culture tubes are summarized in Figure 10. There was a substantial effect of sampling day on growth of ruminal bacteria in semi-defined lactate medium ($P < 0.01$), as evidenced by faster rates of change on day 3 compared to day 1. Differences between the CONTROL and BLOCK treatments were modest but samples taken on day 3 reveal an advantage for cattle supplemented with the fructose-based blocks. It is possible that additional days of supplementation may be warranted in order to achieve maximum response in terms of stimulating the proliferation of lactic acid utilizing bacteria.

Implications

Supplementing with a fructose-based, low-moisture block resulted in a transient increase in ruminal lactate coupled with a transient decrease in ruminal pH. Lactate was readily metabolized in the rumen and supplementation increased the rate of change in absorbance from day 1 to 3. It may be possible to induce these changes without reaching levels that are detrimental to animals consuming roughage diets and, in so doing, establish populations of lactate-utilizing bacteria before significant amounts of concentrates are introduced into the diet.

Literature Cited

Baldwin, R. L., W. A. Wood, and R. S. Emery. 1962. Conversion of lactate-C^{14} to propionate by the rumen microflora. J. Bacteriol. 83:907-913.

Bruno, C. F. and W. E. C. Moore. 1962. Fate of lactic acid in rumen ingesta. J. Dairy Sci. 45:109-115.

Counotte, G. H. M., A. Lankhorst, and R. A. Prins. 1983. Role of DL-lactic acid as an intermediate in rumen metabolism of dairy cows. J. Anim. Sci. 56:1222-1235.

Cullen, A. J., D. L. Harmon, and T. G. Nagaraja. 1986. In vitro fermentation of sugars, grains, and by-product feeds in relation to initiation of ruminal lactate production. J. Dairy Sci. 69: 2616-2621.

Galyean, M. L., G. A. Nunnery, P. J. Defoor, G. B. Salyer, and C. H. Parsons. 2000. Effects of live cultures of *Lactobacillus acidophilus* (strains 45 and 51) and *aropionibacterium Freudenreichii* PF-24 on performance and carcass

characteristics of finishing beef steers. Burnett Center Internet Progress Report. No. 8

Heldt, J. S., R. C. Cochran, G. L. Stokka, C. G. Farmer, C. P. Mathis, E. C. Titgemeyer, and T. G. Nagaraja. 1999. Effects of different supplemental sugars and starch fed in combination with degradable intake protein on low-quality forage use by beef steers. J. Anim. Sci. 77:2793-2802.

Kung Jr, L. and A. O. Hession. 1995. Preventing in vitro lactate accumulation in ruminal fermentations by inoculation with *Megasphaera elsdenii*. J. Anim. Sci. 73:250-256.

Mackie, R. I. and Frances M. C. Gilchrist. 1979. Changes in lactate-producing and lactate-utilizing bacteria in relation to pH in the rumen of sheep during stepwise adaptation to a high-concentrate diet. Appl. Environ. Microbiol. p. 422-430.

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.

Satter, L. D. and W. J. Esdale. 1968. *In vitro* lactate metabolism by ruminal ingesta. Appl Microbiol. 16:680-688.

Sutton, J. D. 1968. The fermentation of soluble carbohydrates in rumen contents of cows fed diets containing a large proportion of hay. Br. J. Nutr. 22:689-712.

Figure 2-1.Ruminal lactate concentrations of heifers fed prairie hay and supplemented with fructose blocks (SEM = 1.47)

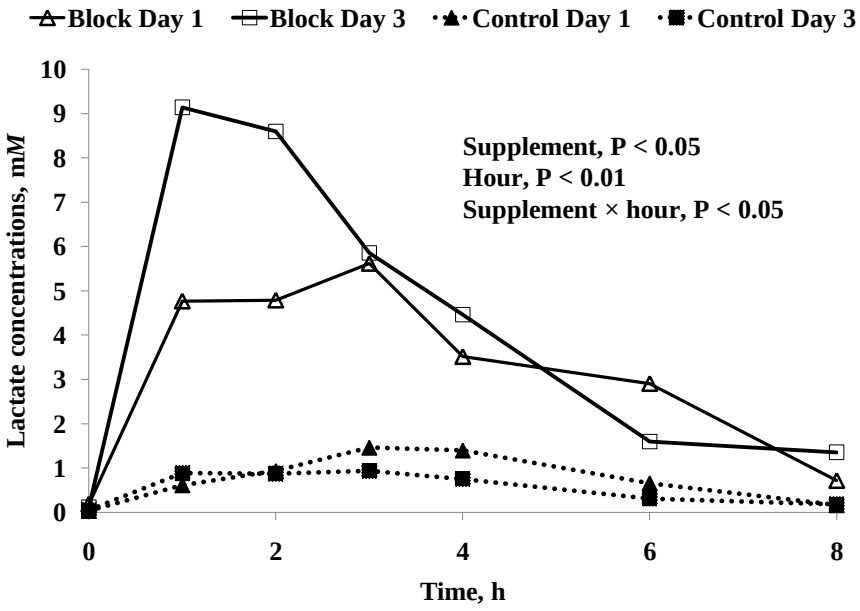
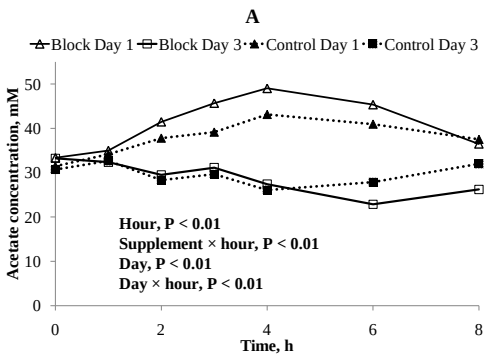
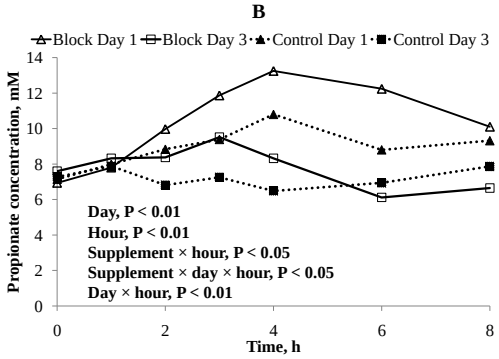
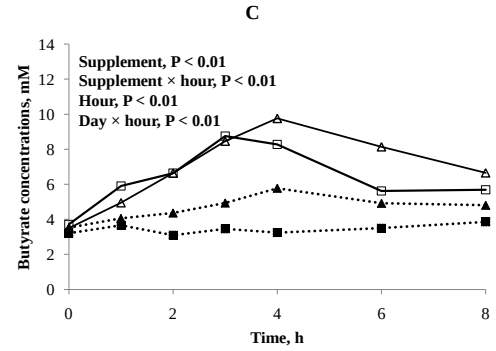
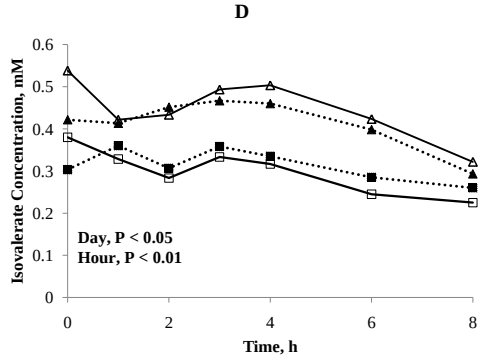

Block Day 1
Block Day 3
Control Day 1
Control Day 3
Lactate concentrations, mM
Time, h
Supplement, P < 0.05
Hour, P < 0.01
Supplement × hour, P < 0.05
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8

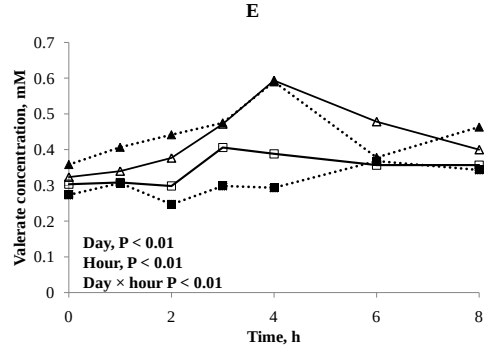
Figure 2-2. Ruminal VFA concentrations of heifers fed prairie hay and supplemented with fructose-based blocks: (A) ruminal acetate concentrations (SEM = 2.37); (B) ruminal propionate concentrations (SEM = 1.08); (C) ruminal butyrate concentrations (SEM = 0.95); (D) ruminal isovalerate concentrations (SEM = 0.06); (E) ruminal valerate concentrations (SEM = 0.05), (F) ruminal isobutyrate concentrations (SEM = 0.04); and (G) acetate:propionate ratio (SEM = 0.26).

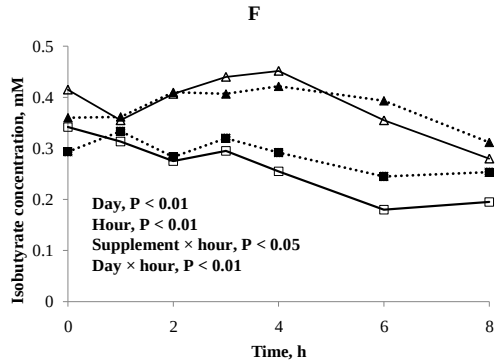

A
Block Day 1
Block Day 3
Control Day 1
Control Day 3
Acetate concentration, mM
Hour, P < 0.01
Supplement × hour, P < 0.01
Day, P < 0.01
Day × hour, P < 0.01
Time, h


B
Block Day 1
Block Day 3
Control Day 1
Control Day 3
Propionate concentration, mM
Day, P < 0.01
Hour, P < 0.01
Supplement × hour, P < 0.05
Supplement × day × hour, P < 0.05
Day × hour, P < 0.01
Time, h


C
Butyrate concentrations, mM
Supplement, P < 0.01
Supplement × hour, P < 0.01
Hour, P < 0.01
Day × hour, P < 0.01
Time, h


D
Isovalerate Concentration, mM
Day, P < 0.05
Hour, P < 0.01
Time, h


E
Valerate concentration, mM
Day, P < 0.01
Hour, P < 0.01
Day × hour P < 0.01
Time, h


F
Isobutyrate concentration, mM
Day, P < 0.01
Hour, P < 0.01
Supplement × hour, P < 0.05
Day × hour, P < 0.01
Time, h

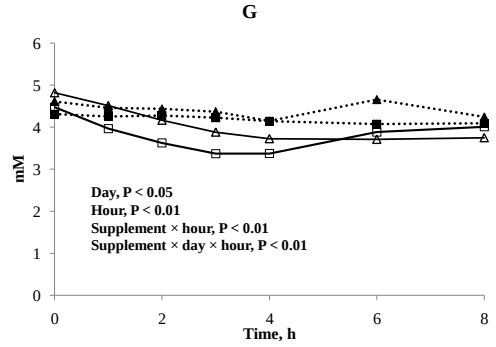

G
mM
Day, P < 0.05
Hour, P < 0.01
Supplement × hour, P < 0.01
Supplement × day × hour, P < 0.01
Time, h

Figure 2-3. Ruminal pH of heifers fed prairie hay and supplemented with fructose-based blocks (SEM = 0.14)

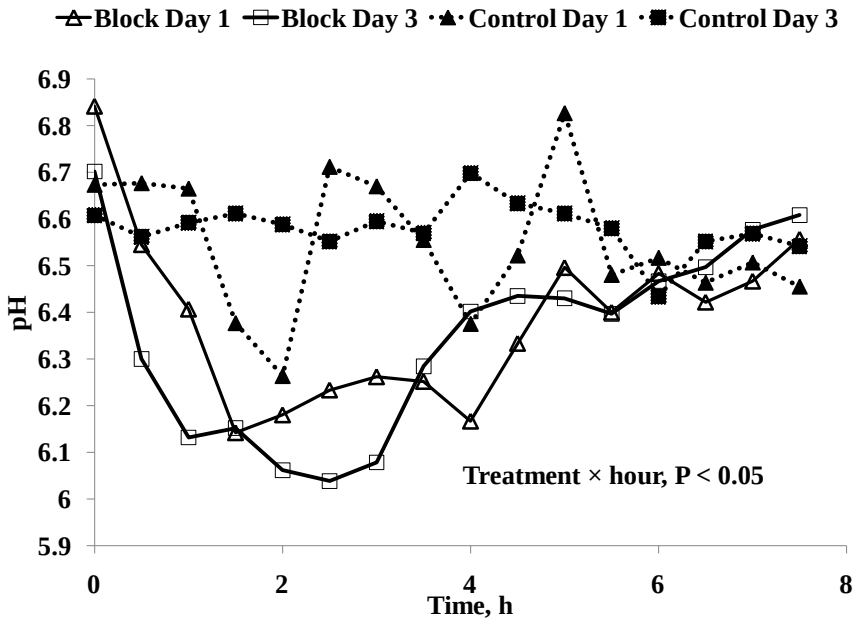
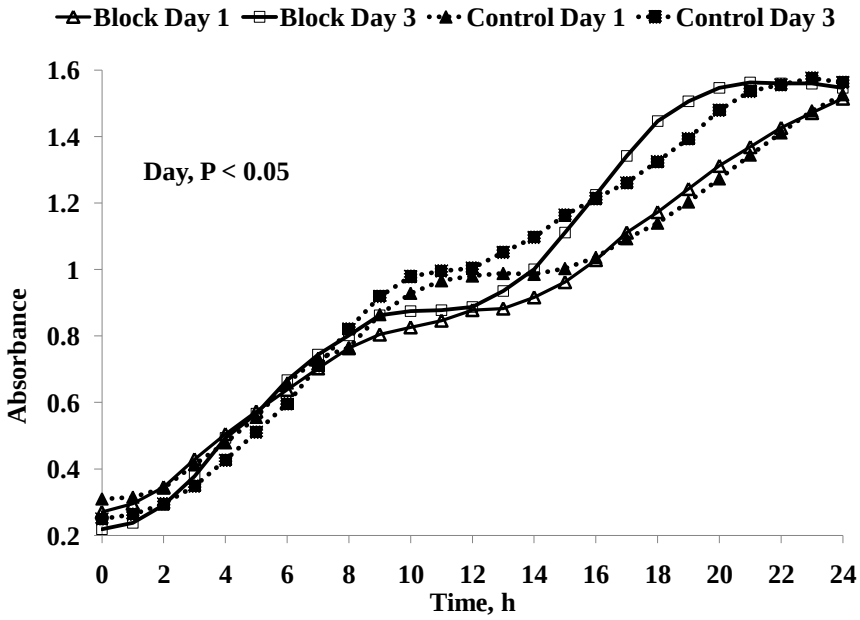

Block Day 1
Block Day 3
Control Day 1
Control Day 3
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
5.9
pH
0
2
4
6
8
Time, h
Treatment × hour, P < 0.05

Figure 2-4. Turbidity changes of ruminal fluid incubated in a semi-defined lactate medium (SEM = 0.11)


Block Day 1
Block Day 3
Control Day 1
Control Day 3
Day, P < 0.05
Absorbance
Time, h
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
18
20
22
24

Chapter 3: **Performance of heifers supplemented with low-moisture blocks manufactured by a novel process with a portion of the molasses replaced by corn steep liquor or condensed corn distiller's solubles.**

K. A. Miller, G. L. Parsons, and J. S. Drouillard[2]

Kansas State University
Manhattan, KS 66506

[1]This is contribution no. from the Kansas Agriculture Experiment Station, Manhattan, Kansas

[2]Corresponding Author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

Abstract

This study was conducted to compare the performance of heifers fed roughage-based diets and supplemented with a molasses–based, low-moisture blocks. Molasses-based blocks processed at high temperatures were compared to blocks in which portions of the molasses were replaced by corn steep liquor (CSL) or corn condensed distiller's solubles (CCDS) and subsequently processed at low temperatures using a vacuum. Heifers (n = 359; 293 ± 2.2 kg) were fed a diet containing 57% corn silage, 23% ground corn stalks, and 21% ground alfalfa hay(DM basis). Heifers had *ad libitum* access to salt blocks and 1 of 4 supplement blocks (Table 1). Supplement blocks were a 30% protein, molasses-based block manufactured at high temperature (Mol-30); a 30% protein block, with approximately 40% of the molasses replaced with CSL and manufactured at low temperatures (CSL-30); a 40% protein block with approximately 40% of the molasses replaced with CSL and manufactured at low temperatures (CSL-40); and a 40% protein block with all of the fat and approximately 40% of the molasses replaced by CCDS and manufactured at low temperature (CCDS-40). Heifers received the forage diet and respective supplements for 83 d, after which, all blocks were removed and heifers received a common mixed diet for 14 d to eliminate differences in gut fill. Due to an error in sorting, initial BW were different ($P < 0.01$) and averaged 315, 300, 286, and 272 kg for Mol-30, CCDS-40, CSL-40, and CSL-30, respectively. Daily block intake was less ($P < 0.01$) for heifers fed Mol-30 compared to heifers fed CSL-30, CSL-40 or CCDS-40. Dry matter intake (%BW) was greater for heifers fed CSL-30 and CSL-40 than those fed CCDS-40 ($P < 0.05$). Heifers supplemented with CSL-40 had greater

DMI (%BW) than heifers supplemented Mol-30 ($P < 0.01$). Average daily gain was similar ($P > 0.4$) for heifers fed Mol-30, CSL-40, or CCDS-40. Heifers fed CSL-30 tended ($P = 0.06$) to have greater ADG than heifers fed Mol-30 but were not different ($P > 0.2$) from heifers fed CSL-40 and CCDS-40. Heifers fed CSL-30 were the most efficient ($P < 0.05$) followed by heifers fed CCDS-40 which were more ($p < 0.01$) efficient than heifers fed Mol-30 and not different ($P > 0.1$) than heifers fed CSL-40. Gain efficiencies were similar ($P > 0.1$) for heifers fed CSL-40 and Mol-30. Supplementing heifers with blocks containing CSL or CCDS in place of a portion of the molasses resulted in similar or improved performance compared to heifers supplemented with a molasses-based supplement block.

Introduction

Low-moisture supplement blocks are a means of providing nutrients to cattle in all segments of the cattle industry but, most commonly, are fed to cattle grazing forages. Feeding molasses-based, low-moisture blocks free choice has been shown to increase DMI, digestibility, ADG and to improve efficiencies of cattle consuming forages (Greenwood, 2000; Titgemeyer, 2004). The primary ingredient in low-moisture blocks is molasses. Increased market price of molasses has resulted in efforts to find alternative ingredients to be used in low-moisture blocks. Two possible alternatives to molasses are corn steep liquor (CSL), a by-product of wet corn milling, and corn condensed distiller's solubles (CCDS), a by-product of ethanol production. Both products are readily available at low relative cost. In the existing processes used to manufacture low moisture blocks, a liquid mixture of molasses and oil is heated to temperatures ranging from 120 to 140° C to dehydrate the mixture.

This is followed by exposure of the mixture to vacuum, thus evaporating most of the moisture (McKenzie, 1974; McKenzie, 1994; Westberg, 2002).

These byproducts contain large quantities of proteins and reducing sugars, which are highly susceptible to the Maillard reaction at high temperatures. Trater et al. (2003) demonstrated that adding urea and sugar to molasses at the start of cooking resulted in reduced *in vitro* ammonia release compared to adding the urea and sugar after cooking the block. To maximize utilization of low-quality forages, adequate amounts of ruminally-degradable protein are required (Köster et al., 1996).

The objective of this study was to compare the performance of heifers fed a forage-based diet and supplemented with molasses blocks manufactured using a high temperature process to heifers fed a forage-based diet and supplemented with blocks containing CSL or CCDS manufactured using a novel, low-temperature process.

Materials and Methods

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee. Crossbred heifers (n = 359, BW = 293 ± 2.2 kg) were used in a 97-d growing study. Heifers were housed in 24 dirt-surfaced pens (432 m^2) with automatic water fountains and 9.4 m of bunk space. Upon arrival at the feedlot, heifers had *ad libitum* access to water and alfalfa hay. All heifers were processed 24 h after arrival. They were weighed, vaccinated with Bovishield-4 and Fortress-7 (Pfizer Animal Health, Exton, PA), drenched with Safe-Guard (Intervet Inc., Millsboro, DE), and received uniquely-numbered ear tags in both ears. Treatments consisted of a commercially available 30% CP molasses-based product with 15% non-protein nitrogen (NPN), using feather

meal as the primary source of natural protein and urea as the NPN source (Mol-30); a 30% CP product with no NPN or animal protein and approximately 40% of the molasses replaced by CSL (CSL-30); a 40% CP product with 15% NPN and no animal proteins, and approximately 40% of the molasses was replaced by CSL (CSL-40); and a 40% CP product with 20% NPN, no animal proteins, and all of the fat and a portion of molasses replaced with 40% CCDS (CCDS-40; Table 3-2). Following a 4-wk acclimation period heifers were weighed, blocked by weight, and randomly assigned to treatment within block. Due to an error in sorting, animals were not placed in the correct pens resulting in a significant difference in starting body weight between treatments. The study was comprised of a forage feeding phase (83 d) and a common diet phase (14 d) where blocks were removed and all heifers received a common mixed diet to minimize differences in gastrointestinal tract fill. During the forage feeding phase, all heifers received a roughage diet containing 57% corn silage, 23% ground corn stalks, and 21% ground alfalfa hay (DM basis) and free-choice salt blocks (Table 3-1). Supplement blocks were offered *ad libitum* and were replaced as needed so pens always had supplement available. Blocks were weighed before being placed in their respective pens and when they were removed from the pen. In addition, blocks were weighed on a weekly basis to estimate daily block consumption.

After 83 days, all blocks were removed from the pens and animals were weighed. All heifers were fed a steam flaked corn-based diet containing approximately 60% concentrate and 40% roughage for an additional 14 days (Table 3-3). All animals were weighed at the end of the 14-d period. This final common diet

was used to adjust for any differences in gut fill due to differences in intake and digestion of the forage diet.

Block Manufacturing Process

CSL-30, CSL-40, and CCDS-40 were manufactured using a low-temperature vacuum cooking process. Blocks were manufactured in a 150 L double planetary mixer (model HDP-11-40-5-01, Hockmeyer Equipment, Elizabeth City, NC) equipped with a jacketed mixing tank. The mixing tank was heated using oil as its medium (model H44124, Mokon, Buffalo, NY). A Vmax Lt vacuum pump (model vmx0089MA1-00, Dekker Vacuum Technology inc., Michigan City, IN) equipped with an inline shell and tube heat exchanger cooled by water, was used to facilitate cooking under vacuum and removal and collection of moisture. A separate vessel connected to a port on the mixer allowed for addition of dry ingredients upon completion of the cooking process. This was completed by opening a valve at the bottom of the vessel allowing the vacuum to draw the ingredients into the mixer. After completion, the final product was removed from the tank into containers using a hydraulic press (model HP40-5-01, Hockmeyer Equipment, Elizabeth City, NC). Cooking parameters for the 3 blocks cooked under vacuum are summarized in Table 3-1. Following addition of the liquid ingredients into the mixer, it was sealed, subjected to vacuum, the mixer was started, and heating began. Once the majority of moisture had been removed heating was stopped and dry ingredients were added and mixed for 5 min, after which the final product was pressed out of the tank into containers.

Statistical Analysis

Performance data were analyzed as a completely randomized block design using PROC GLM of SAS 9.1 (SAS Inst., 2003, Cary NC). Initial BW could not be used as a covariate because mean BW were different across treatments. Pen was the experimental unit. The model statement included an effect for treatment only. Treatment means were reported as least-squares means.

Results and Discussions

Forage feeding Phase

An error in sorting resulted in differences in initial BW ($P < 0.01$) with heifers fed Mol-30 having the greatest BW followed by CCDS-40, CSL-40, and CSL-30 (Table 3-4). Titgemeyer et al. (2004) reported an increase in ADG when heifers were fed prairie hay and supplemented with cooked molasses blocks. In this study heifers supplemented with CSL-30, CSL-40, and CCDS-40 had similar ADG to heifers supplemented with Mol-30 blocks ($P > 0.7$). The manufacturer of the Mol-30 block recommended an intake of 0.23-0.45 kg/hd/d. Intake of the Mol-30 block (0.38 kg/hd/d) fell within the manufactures recommendation. Intake of the CSL-30, CSL-40, and CCDS-40 blocks (0.48 kg/hd/d) were greater ($P < 0.01$) than the Mol-30 block but were not different from each other ($P > 0.7$). Differences in block intake may have occurred because of differences in deliquescent properties of the base ingredients. Supplementing with molasses blocks increases DMI of low quality forages (Badurdeen et al., 1994; Greenwood et al., 1998; Greenwood et al., 2000). In our study, DMI was expressed as a %BW using the initial BW. Heifers fed the CSL-40 block had a greater forage intake than heifers supplemented with Mol-30 and CCDS-40 ($P < 0.01$) and tended to consume more forage than heifers fed the CSL-30

(P = 0.07). Total DMI (block intake + forage intake) was greater (P < 0.05) for heifers fed CSL-30 and CSL-40 than for heifers fed CCDS-40 and greater (P < 0.01) for heifers fed CSL-40 than heifers fed Mol-30. Supplementing with CSL-30 resulted in improved efficiency compared to heifers supplemented with Mol-30 and CSL-40. Feed efficiency of heifers supplemented with CCDS-40 was intermediate and not different from other treatments (P > 0.09).

Forage feeding phase and common diet phase

Dry matter intake for the forage-feeding phase and common-diet phase combined followed a similar pattern to total intake in the forage feeding phase; CSL-30 and CSL-40 had greater intakes than CCDS-40 (P < 0.03) and CSL-40 had greater intakes than Mol-30 (P < 0.01). Average daily gain tended (P = 0.06) to be greater for heifers fed CSL-30 compared to heifers fed Mol-30. Averaged daily gain for heifers fed CSL-40 and CCDS-40 blocks were intermediate and were not different from other treatments (P > 0.2). Heifers fed CSL-30 blocks were more efficient than other treatments (P < 0.05). Heifers supplemented with CCDS-40 were more efficient (P < 0.01) than heifers supplemented with Mol-30 and not different (P > 0.1) from heifers supplemented with CSL-40. Supplementing with Mol-30 resulted in similar efficiencies compared to supplementing with CSL-40 (P > 0.1).

Implications

Supplementing heifers consuming a roughage-based diet with low-moisture blocks cooked under vacuum and containing corn steep liquor or corn condensed distiller's solubles in place of a portion of the molasses resulted in similar or

improved performance compared to heifers supplemented with a commercially-available molasses–based low-moisture block.

Literature Cited

Badurdeen, A. L., M. N. M. Ibrahim, and S. S. E. Ranawana. 1994. Methods to improve utilization of rice straw III. Effect of urea ammonia treatment and urea molasses blocks supplementation on intake, digestibility, rumen and blood parameters. Asian-Australas. J. Anim. Sci. 7:363-372.

Greenwood, R. H., E. C. Titgemeyer, C. A. Löest, and J. S. Drouillard. 1998. Effects of supplement strategy on intake and digestion of prairie hay by beef steers and plasma amino acid concentrations. Prof. Anim. Sci. 14:56-61.

Greenwood, R. H., E. C. Titgemeyer, and J. S. Drouillard. 2000. Effects of base ingredient in cooked molasses blocks on intake and digestion of prairie hay by beef steers. J. Anim. Sci. 78:167-172.

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgardir, and G. St-Jean. 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473-2481.

McKenzie, G. R., R. P. Hunt, C. H. Jones, inventors. 1994 Continuous process for manufacturing animal feed blocks. US Patent No. 5,482,729. June 16.

McKenzie, C. O, inventor. 1974. Molasses feed block for animals and method of making same. U. S. patent 3,961,081. Mar. 12.

Titgemeyer E. C., J. S. Drouillard, R. H. Greenwood, J. W. Ringler, D. J. Bindel, R. D. Hunter, and T. Nutsch. 2004. Effect of forage quality on digestion and performance responses of cattle to supplementation with cooked molasses blocks. J. Anim. Sci. 82:487-494.

Trater, A. M., E. C. Titgemeyer, J. S. Drouillard, J. N. Pike. 2003. Effects of processing factors on in vitro ammonia release from cooked molasses blocks containing urea. Anim. Feed Sci. Tech. 107:173-190.

Westberg, J. A, inventor; Animal Feed Supplement, Inc. Belle Fourche, SD., assignee. 2002. Process for manufacturing animal feed supplement. US Patent No. 7,045,165. July 26.

Table 3-1. Cooking parameters of low-moisture blocks containing CSL and CCDS manufactured at reduced temperature and pressure

	Blocks		
Item	CSL-30	CSL-40	CCDS-40
Vacuum, bar	0.86	0.92	0.89
Input heating oil temperature, °C	142	141	144
Output heating oil temperature, °C	124	124	126
Final cooking temperature, °C[1]	80	73	86
Cooking time, min	170	153	265

[1]Product temperature just prior to discharge.

Table 3-1. Forage diet composition on a DM basis

Item	Diet composition[1]
Corn silage	56.6
Corn stovers	22.6
Alfalfa hay	20.7
Nutrient composition	
Crude protein	8.97
Calcium	0.56
Phosphorous	0.22
Potassium	0.48
NDF	51.3

[1]Loose salt provided *ad libitum*

Table 3-2. Composition of supplement blocks containing CSL or CCDS in place of a portion of the molasses and cooked under vacuum on a DM basis

	Block composition (%DM)		
Item	CSL-30	CSL-40	CCDS-40
Liquid ingredients[a]			
Corn steep liquor	35.8	39.2	--
Molasses	23.9	28.5	24.6
Condensed corn distiller's soluble	--	--	45.7
Soybean oil	5.8	4.8	--
Base mix			
Soybean meal	26.7	10.2	8.5
Corn gluten meal	1.8		
Dried corn distiller's grains	--	--	2.7
Limestone	3.5	3.8	3.2
Calcium phosphate	6.0	6.1	6.3
Urea	--	5.5	6.9
Vitamin premix[b]	0.6	0.6	1.0
Mineral premix[c]	1.2	1.3	1.1
Nutrients			
Crude protein	24.57	36.41	39.7
Crude protein equivalent as NPN	0	13.19	14.47
Ether extract	4.93	4.84	8.24
Calcium	2.94	3.11	2.83
Phosphorus	1.69	1.74	1.89

[a]Liquid ingredients were combined into a homogeneous mixture and the heated under reduced pressure (CSL-30, CSL-40, and CCDS-40). Following evaporation of liquid mixture, the base mix ingredient mixture was added and thoroughly blended, and the resulting mixture was poured into plastic containers and allowed to cool. Cooled products had a brittle, glassine form.
[b]Formulated to provide 40,000 IU vitamin A and 40 IU vitamin E per kg of block DM
[c]Formulated to provide 300 mg Cu, 15 mg I, 1720 mg Mn, 3 mg Co, 1720 mg Zn, and 4 mg Se per kg of block DM.

Table 3-3. DM composition of common mixed diet

Ingredient	Diet Composition
Steam flaked corn	19.4
Dry distiller's grains	23.2
Corn silage	30.4
Corn stalks	12.2
Alfalfa hay	11.2
Supplement[a]	1.7
Feed additive premix[b]	2.0
Nutrient composition	
Crude protein	13.6
Calcium	0.72
Phosphorous	0.38
Potassium	0.96
Crude fat	2.5
NDF	34.4

[a]Formulated to provide 10 mg Cu, 0.25 mg Se, 0.13 mg Co, 60 mg Mn, 60 mg Zn, 0.63 mg I, 1,200 IU vitamin A, and 10 IU vitamin E per kg of diet DM

[b]Feed additive provided 300 mg monensin, 90 mg tylosin, and 0.5 mg melengesterol-acetate per animal daily

Table 3-4. Performance of heifers supplemented with molasses based low-moisture blocks or blocks cooked under vacuum where a portion of the molasses was replaced with CSL or CCDS

	Treatment				
Item	Mol-30	CSL-30	CSL-40	CCDS-40	SEM
Number	90	89	90	90	---
Forage phase					
Forage DMI, %BW[1]	2.29[aef]	2.32[abe]	2.44[bf]	2.21[af]	0.12
Block intake, g/d	379.7[a]	476.7[b]	474.0[b]	481.3[b]	0.02
Total DMI, %BW	2.41[abc]	2.50[ab]	2.61[b]	2.37[ac]	0.12
ADG, kg/d	0.81	0.82	0.81	0.82	0.02
G:F[2]	0.106[a]	0.119[b]	0.108[a]	0.114[ab]	0.0136
97-d trial					
DMI, %BW	2.72[abc]	2.83[ab]	2.92[b]	2.67[ac]	0.13
ADG, kg/d	0.76[e]	0.79[f]	0.78[ef]	0.78[ef]	0.01
G:F	0.089[c]	0.104[a]	0.093[bc]	0.097[b]	0.0009

[abcd]Means in rows with different superscripts differ ($P < 0.05$)

[ef]Means in rows with different superscripts tend to differ ($P < 0.09$)

[1]Intake as a %BW was calculated using initial BW

[2]Calculated as ADG divided by total DMI

Chapter 4: **Effects of Low-Moisture Blocks Containing Corn Steep Liquor Cooked Atmospherically or Under Vacuum on Growth Performance of Heifers Fed a Forage Diet**

K. A. Miller, G. L. Parsons, L. K. Thompson, and J. S. Drouillard[2]

Kansas State University
Manhattan, KS 66506

[1]This is contribution no. from the Kansas Agriculture Experiment Station, Manhattan, Kansas
[2]Corresponding Author: jdrouill@ksu.edu; Phone: (785) 532-1204; Fax: (785) 532-5681

Abstract

A study was conducted at Kansas State University to evaluate a novel process for manufacturing low-moisture supplement blocks with a portion of the molasses replaced with corn steep liquor (CSL). Crossbred heifers (n = 359; BW 236 ± 8.9 kg) were used in a randomized complete block design. Heifers were fed a forage-based diet containing 44% corn silage, 29% corn stalks, and 27% alfalfa hay on a DM basis. Heifers received no supplement (control), blocks containing 15% CSL and processed at atmospheric pressure and high temperatures (HT-15), blocks containing 15% CSL processed under vacuum at low temperatures (LT-15), or blocks containing 40% CSL and processed under vacuum at a low temperature (LT-40). Final body weights were 302, 302, 310, and 312 kg for control, HT-15, LT-15, and LT-40, respectively, and were not different among treatments ($P > 0.2$). Supplementing LT-15 or LT-40 blocks increased heifer ADG over the non-supplemented control and HT-15 supplemented heifers ($P < 0.05$). Average daily gains were similar between the control and HT-15 groups ($P > 0.8$). There was no difference in ADG ($P > 0.6$) when comparing LT-15 and LT-40 blocks. Forage DMI was not different between treatments ($P > 0.1$). Heifers fed LT-15 and LT-40 blocks consumed more ($P < 0.01$) block per day than the heifers receiving the HT-15 block, but daily intakes of the LT-15 and LT-40 blocks were not different ($P > 0.2$). Total intake (block intake + forage intake) was greater for heifers supplemented with the LT-15 and LT-40 blocks than control heifers ($P < 0.05$). Total intakes of heifers fed HT-15 were intermediate and not different ($P > 0.2$) from control or other block treatments. Gain efficiency was not different ($P > 0.1$) when comparing the control heifers to the supplemented

heifers. Heifers fed LT-40 tended to have improved (P = 0.07) gain efficiencies compared to heifers fed the HT-15 and the LT-15 fed heifers were intermediate (P > 0.1) Supplementing heifers with blocks containing CSL processed at low temperatures improved ADG but final BW and gain efficiency were not affected by supplementation. Supplements containing CSL processed at high temperatures yielded no discernible benefit to cattle.

Introduction

Low-moisture block manufacturing processes have been described by McKenzie (1974), McKenzie (1994), and Westberg (2002), whereby molasses or a molasses-oil blend is heated to temperatures in excess of 140°C at atmospheric pressure. Once the majority of the moisture has been removed, the product is subjected to a vacuum to flash off remaining moisture. Dry ingredients consisting of protein, minerals, and vitamins can be incorporated into the dehydrated blend. The mixture is placed into containers, covered, and allowed to cool, forming a hardened, amorphous block with a glassine consistency.

Historically, molasses has been readily available and relatively inexpensive as a base ingredient for production of low-moisture block supplements. Changes in the sugar refining process have resulted in decreased molasses supplies. One possible alternative to molasses for production of low-moisture supplement blocks is corn steep liquor (CSL), a liquid byproduct of wet corn milling. Corn steep liquor contains substantial amounts of reducing sugars and protein and these components in combination with heat can result in Maillard products that decrease ruminal availability of the protein. Heating of soybean meal results in the formation of

Maillard products, increasing the percentage of protein that is ruminally unavailable (Cleale et al., 1987; Faldet et al., 1991). In both cattle and sheep, supplementation with ruminally available protein increased forage intake and digestion (Bandyk et al., 2001; Salisbury et al., 2004). Current manufacturing processes are not well suited for the use of CSL as a replacement for molasses due to high cooking temperatures. These may have deleterious effects on the quality of the final product. The objective of our study was to replace a portion of the molasses in a low-moisture block with CSL and to evaluate the effects of cooking temperature of the block on heifer performance.

Materials and Methods

The study was conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee. We used 359 crossbred heifers (236 ± 8.91 kg) in a 98-d randomized complete block feeding study. Upon arrival, heifers were given *ad libitum* access to ground alfalfa hay and water. Twenty four h after arrival, calves were weighed, vaccinated with Bovi-Shield 4 (Pfizer Animal Health; Exton, PA), Fortress-7(Pfizer Animal Health; Exton, PA), and drenched with Safe-Guard (Intervet/Schering-Plough; Millsboro, DE). Calves also received a subcutaneous injection of tilmicosin at 3.3 ml/kg BW (Micotil; Elanco, Greensburg, IN) and a uniquely numbered ear tag. Four wk after initial processing heifers were revaccinated with Bovi-shield 4 (Pfizer Animal Health, Exton, PA). Following a 60-d adaptation period, heifers were weighed, stratified by BW, and assigned randomly to treatments within strata (6 stratas). Animals were housed in 24 soil-surfaced pens (278 m^2) with 14 to 15 animals/pen. Pens were equipped with

concrete fence-line bunks (10.4 m long) and automatic waters were shared by adjacent pens.

The study consisted of two phases: a forage feeding phase (84 days) and a common diet feeding phase where all heifers were on a common mixed diet (14 days) to minimize differences in gut fill associated with differences in intake and digestion.

During the forage feeding phase, heifers were fed once daily *ad libitum* a diet containing 44% corn silage, 29% ground corn stalks, and 27% ground alfalfa hay on a dry matter basis (Table 4-1), along with *ad libitum* access to lose salt. Treatments consisted of no supplement block (control); a block containing 15% CSL and manufactured using a high temperature at atmospheric pressure (HT-15); a block containing 15% CSL and manufactured using a low temperature vacuum process (LT-15); and a block containing 40% CSL manufactured using a low temperature vacuum cooking process (LT-40). All blocks were offered *ad libitum* and replenished as needed. In order to estimate daily block intakes, all blocks were weighed weekly and as needed when new blocks were placed into pens.

Block supplementation was discontinued and all heifers were weighed at the conclusion of the 84 day forage feeding phase. They were placed on a common mixed diet (Table 4-3), and fed *ad libitum* once daily for 14 days. Heifers were weighed again at the end of the 14 days.

Block Manufacturing

The low-temperature vacuum manufacturing process was comprised of a 150 liter double planetary mixer and jacketed kettle (model HDP-11-40-5-01, Hockmeyer Equipment, Elizabeth City, NC) mounted on load cells, an oil heating system (model

H44124, Mokon, Buffalo, NY), a vacuum system (model vmx0089MA1-00, Dekker Vacuum Technology inc., Michigan City, IN), a condensing system, a dry-ingredient feeding system, and a discharge press (model HP40-5-01, Hockmeyer Equipment, Elizabeth City, NC). Hot oil was pumped through the kettle bring it to temperature. Once the kettle temperature had been established, the liquid ingredients were added (molasses, CSL, and vegetable oil). The mixer was sealed, agitation was initiated, and the process was subjected to a vacuum The vapors produced by the heating of the liquid ingredients were drawn through the vacuum line to the cooling zone comprised of a shell and tube heat exchanger with cool water circulating through it. The cooling zone condensed the vapors and the resulting fluids were collected in a condensate tank. Once the liquid portion had been dehydrated, the heating cycle was terminated and no further heat was applied. At this point, the liquid blend had a viscous and taffy-like consistency. Dry ingredients were added through a port in the mixer while maintaining a vacuum. The dry ingredients were mixed under vacuum until homogeneously distributed throughout the product. Once mixing was complete the vacuum was released and the mixing apparatus was lifted out of the kettle. The kettle was mounted on wheels allowing for its transport to the discharge press where the final product was pressed out of the kettle into rigid containers through a 7.6 cm ball valve located at the bottom of the kettle (approximately 27 kg per container). The containers were covered and the product was allowed to cool, resulting in a hard block. Cooking parameters are summarized in Table 4-1.

Statistical Analysis

Growth Performance was analyzed using the PROC MIXED procedure of SAS version 9.1 (SAS Inst., 2003, Cary NC). Pen was the experimental unit. The model statement included an effect for treatment. Treatment means were reported as least-squares means.

Results and Discussion

Forage feeding phase

Supplementing heifers with the LT-40 and LT-15 blocks improved ADG ($P<0.05$) 13.5% and 15.2% respectively over the non-supplemented heifers and 9.8% and 11.4% respectively compared to heifers supplemented with HT-15. Cattle supplemented with cooked-molasses blocks had greater ADG then their non-supplemented counterparts when grazing low-quality forages (Titgemeyer et al., 2004). In contrast, supplementing with a HT-15 block didn't improve ADG ($P > 0.3$) compared to non-supplemented heifers. Average daily gains were similar ($P > 0.6$) when heifers were supplemented with LT-15 or LT-40 blocks. It is possible that, in the HT-15 block, Maillard products were produced reducing the amount of protein available to the ruminal microbes. Despite differences in ADG, there were no differences in final body weight as a result of block supplementation. Daily block intakes was not different between LT-15 and LT-40 ($P > 0.2$) but daily consumption of the HT-15 block was 43% less than that of the LT-15 and LT-40 blocks ($P < 0.01$). The lower intakes of the HT-15 may have been related to palatability. This block was visually darker than the other two blocks suggesting scorching due to the high cooking temperatures. An alternative explanation for the lower intake of the LT-15 block was a possible decrease in hygroscopicity. Block intakes in this study were

substantially greater than those reported by Paisley et al. (2001) when blocks were offered free-choice to newly-received stocker calves. Daily block intakes observed by Titgemeyer et al. (2004) were 0.37 and 0.42 kg for 14.4 or 27.5% CP molasses blocks, respectively. There were no differences in forage DMI for any of the treatments ($P > 0.1$). Löest et al. (2000) reported also that prairie hay intake was not different when steers received no supplement or cooked molasses blocks fed at .125% of BW. Greenwood et al. (2000) fed prairie hay to steers supplemented with cooked beet molasses, cane molasses, or corn separator byproduct blocks and observed an increase in prairie hay intake over their unsupplemented counterparts. Total intake (forage DMI + daily block intake) was greater ($P < 0.05$) for heifers supplemented with the LT- 45 and LT-40 blocks compared with non-supplemented heifers. Total intake was not different ($P > 0.2$) between unsupplemented heifers and heifers supplemented with the HT-15 block. There was no difference ($P > 0.2$) in total intake for any of the supplemented heifers. Feed efficiency was not affected ($P > 0.2$) by supplementation.

Forage phase and common diet phase

When comparing treatments over the entire feeding trial (forage phase + common diet phase), final BW was not affected ($P > 0.4$) by block supplementation. Over the entire feeding period ADG was greatest ($P < 0.01$) for heifers supplemented with the LT-15 and LT-40 blocks compared with the control and HT-15. Heifers supplemented with the HT-15 blocks had similar ADG ($P > 0.8$) to that of the control heifers. Supplementing with LT-15 and LT-40 blocks increased DMI 8.3 ($P = 0.05$) and 8.5% ($P < 0.05$), respectively, compared to the control. DMI for heifers

supplemented with HT-15 was intermediate and not different (P > 0.1) from other treatments Heifers fed the HT-15 block had DMI similar (P > 0.4) to the non-supplemented heifers. Gain efficiency of control heifers was not different (P > 0.1) from that of heifers fed blocks. When comparing gain efficiency of supplemented heifers there was a tendency for improved (P = 0.07) gain efficiency in heifers fed LT-40 compared to heifers fed the HT-15 block. Heifers fed the LT-15 block were intermediate and not different (P > 0.1) from other supplemented heifers.

Implications

Performance of heifers consuming roughage diets can be improved by supplementing with low moisture blocks contain molasses and CSL when the block is manufactured using a low temperature vacuum cooking process. The benefits of supplementation with low-moisture blocks containing CSL are not realized when the product is manufactured using a high-temperature process.

Literature Cited

Bandyk C. A., R. C. Cochran, T. A. Wickersham, E. C. Titgemeyer, C. G. Farmer, and J. J. Higgins. 2001. Effect of ruminal vs postruminal administration of degradable protein on utilization of low-quality forage by beef steers. J. Anim. Sci. 79:225-231.

Cleale R. M., IV, T. J. Klopfenstein, R. A. Britton, L. D. Satterlee, and S. R. Lowry. 1987. Induced non-enzymatic browning of soybean meal. I. Effects of factors controlling non-enzymatic browning on in vitro ammonia release. J. Anim. Sci. 65:1312-1318.

Greenwood, R. H., E. C. Titgemeyer, and J. S. Drouillard. 2000. Effects of base ingredient in cooked molasses blocks on intake and digestion of prairie hay by beef steers. J. Anim. Sci. 78:167-172.

Faldet, M. A., L. D. Satter, and G. A. Broderick. 1992. Determining optimal heat treatment of soybeans by measuring available lysine chemically and biologically with rats to maximize protein utilization by ruminants. J. Nutr. 122:151-160.

Löest, C. A., E. C. Titgemeyer, J. S. Drouillard, B. D. Lambert, and A. M. Trater. 2001. Urea and biuret as non-protein nitrogen source in cooked molasses blocks for steers fed prairie hay. Anim. Feed Sci. Technol. 94:115-126.

McKenzie, G. R., R. P. Hunt, C. H. Jones, inventors. 1994. Continuous process for manufacturing animal feed blocks. U.S. Patent No. 5,482,729. June 16.

McKenzie, C. O, inventor. 1974. Molasses feed block for animals and method of making same. U. S. patent 3,961,081. Mar. 12.

Paisley, S. I., G. L. Stokka, F. K. Brazle. 2001. Effect of cooked molasses tubs on performance and health of newly received stocker calves. KSU Progress Report. 873:91-94. Kansas State Agric. Exp. Sta.

Salisbury, M. W., C. R. Krehbiel, T. T. Ross, C. L. Schultz, and L. L. Melton. 2004. Effects of supplemental protein type on intake, nitrogen balance, and site and

extent of digestion in whiteface wethers consuming low-quality grass hay. J. Anim. Sci. 82:3567-3576.

Titgemeyer, E. C., J. S. Drouillard, R. H. Greenwood, J. W. Ringler, D. J. Bindel, R. D. Hunter, and T. Nutsch. 2004. Effect of forage quality on digestion and performance responses of cattle to supplementation with cooked molasses blocks. J. Anim. Sci. 82:487-494.

Westberg, J. A, inventor; Animal Feed Supplement, Inc. Belle Fourche, SD., assignee. 2002. Process for manufacturing animal feed supplement. U.S. Patent No. 7,045,165. July 26.

***Table 4-1*. Cooking parameters of blocks containing CSL manufactured at reduced pressure and temperature.**

	Blocks	
Item	LT-15	LT-40
Vacuum, bar	0.87	0.88
Input heating oil temperature, °C	152	153
Output heating oil temperature, °C	121	128
Final product temperature, °C[1]	82	76
Cooking time, min	98	134

[1]Product temperature just prior to discharge.

Table 4-1. Basal diet during the forage feeding-phase[1]

Ingredient	Diet Composition, % DM
Corn silage	44
Corn stover, ground	29
Alfalfa, ground	27
Nutrients	
Crude protein	9.95
Calcium	0.64
Phosphorus	0.22
Potassium	0.58
NDF	54.94

[1]loose salt was offered *ad libitum*

Table 4-2. Ingredient and nutrient composition of supplement blocks

	Block Composition, % DM		
Item	HT-15	LT-15	LT-40
Liquid Ingredients[a]			
Molasses	46.40	46.40	24.18
Corn steep liquor	16.15	16.15	41.68
Vegetable oil	2.75	2.75	1.06
Base mix ingredients			
Distillers corn grains	2.88	2.88	15.63
Soybean meal, dehulled	14.62	14.62	2.50
Urea, 46% N	10.26	10.26	9.49
monocalcium phosphate	2.94	2.94	0.31
Limestone	2.44	2.44	3.64
Trace mineral mix[b]	1.08	1.08	1.06
Vitamin premix[c]	0.48	0.48	0.47
Nutrients			
Crude protein	43.33	43.33	48.22
Crude protein equivalent as non-protein nitrogen	23.24	23.24	22.15
Ether extract	3.15	3.15	2.76
Calcium	2.72	2.72	1.98
Phosphorus	1.30	1.30	0.73

[a]Liquid ingredients were combined into a homogeneous mixture and the heated under atmospheric (HT-15) or reduced (LT-15 and LT-40) pressure. Following evaporation of liquid mixture, the basemix ingredient mixture was added and thoroughly blended, and the resulting mixture was poured into plastic containers and allowed to cool. Cooled products had a brittle, glassine form.

[b] Formulated to provide 217 mg Cu, 10 mg I, 823 mg Mn, 2.2 mg Co, 800 mg Zn, and 5.5 mg Se per kg of block DM.

[c]Formulated to provide 50,000 IU vitamin A, 5,000 IU vitamin D, and 45,000 IU vitamin E per kg of block DM

Table 4-3. Ingredient and nutrient composition of common mixed diets.

	% DM	
Ingredient, % of DM	Step 1	Step 2
Dry-rolled corn	38.03	55.15
Corn silage	25.12	7.01
Corn stover	12.41	13.35
Alfalfa hay	11.79	12.70
Corn steep liquor	7.09	6.26
Supplement[a]	3.21	3.20
Feed additive premix[b]	2.35	2.34
Nutrient, % of DM		
Crude protein	15.36	15.56
Calcium	0.75	0.75
Phosphorus	0.28	0.29
Potassium	1.04	0.94
NDF	30.40	26.50

[a]Formulated to provide 1 KIU of Vitamin A, 10 mg of Cu, 0.25 mg of Se, 0.1 mg of Co, 60 mg of Mn, .63 mg of I, and 60 mg of Zn per kg of DM.
[b]Feed additive premix provided 300 mg monensin, 90 mg tylosin, and 0.5 mg melengestrol acetate per animal daily.

Table 4-4. Performance of heifers fed a forage-based diet and supplemented with low-moisture blocks

	Treatment				
Item	Control	HT-15	LT-15	LT-40	SEM
Number	90	90	89	90	---
Forage feeding phase (84 d)					
Initial BW, kg	236	236	236	236	8.9
Final BW, kg	285	287	293	292	9.0
Forage DMI, kg/d	5.52	5.55	5.80	5.72	0.15
Block intake, kg/d	0.00[a]	0.22[b]	0.31[c]	0.33[c]	0.01
Total DMI, kg/d	5.52[a]	5.77[ab]	6.10[b]	6.05[b]	0.15
ADG, kg/d	0.59[a]	0.61[a]	0.68[b]	0.67[b]	0.02
G:F[1]	0.106	0.106	0.112	0.111	0.009
98-d feeding trial					
Final BW, kg	302	301	310	311	9.4
DMI, kg/d	6.01[a]	6.18[ab]	6.51[ab]	6.52[b]	0.17
ADG, kg/d	0.67[a]	0.67[a]	0.75[b]	0.77[b]	0.02
G:F	0.112[de]	0.109[d]	0.116[de]	0.117[e]	0.003

[abc]Means in rows with different superscripts are significantly different ($P < 0.05$)

[de]Means in rows with different superscripts tend to be different ($P = 0.07$)

[1]Calculated by dividing ADG by total DMI