2013

Effects of Varying Levels of Caclium Lignosulfonate, Mixer-Added Fat and Feed Form on Feed Manufacture and Broiler Performance

Alina M. Corey

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Effects of Varying Levels of Calcium Lignosulfonate,
Mixer-Added Fat and Feed Form
on Feed Manufacture and Broiler Performance

Alina M. Corey

Thesis submitted to the
Davis College of Agriculture, Natural Resources and Design
at
West Virginia University
in partial fulfillment of the requirements
for the degree of

Master of Science
in
Nutrition and Food Science

Joseph S. Moritz, Ph.D., Chairperson
Janet Tou Ph.D.
Harry Boone, Ph.D.

Division of Animal and Nutritional Sciences

Morgantown, West Virginia
2013

Keywords: Calcium lignosulfonate, mixer- added fat, feed production, pellet quality, broiler
performance

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Abstract

EFFECTS OF VARYING LEVELS OF CALCIUM LIGNOSULFONATE, MIXER-ADDED FAT AND FEED FORM ON FEED MANUFACTURE AND BROILER PERFORMANCE

by Alina M. Corey

Feed manufacture accounts for approximately 60-70% of the costs required for commercial broiler chicken production. Increased costs resulting from manufacturing high quality pellets can be problematic for commercial poultry production. However, these costs can be justified by improved broiler performance attributed to high quality pellets. In Experiment 1 pellets were manufactured by utilizing varying levels of a commercial Calcium lignosulfonate (CaLS) pellet binder inclusion (0, 0.5, or 1%), mixer-added fat (MAF) (1 or 3%), and feed form (pellet or ground pellet) in order to create 12 dietary treatments. In Experiment 2 diets were fed and broiler performance and digesta viscosity were assessed. In Experiment 3, effects of the aforementioned diets on true amino acid digestibility (TAAD) were examined. The use of CaLS and 3% MAF independently decreased measures of electrical energy use of the pellet mill and hot pellet temperature post pellet die extrusion, and increased pellet durability. The use of CaLS increased broiler feed intake (FI) and live weight gain (LWG). An interaction was demonstrated between 0.5% CaLS and 3% MAF that increased digesta viscosity compared to other treatments. A 3-way interaction of main effects demonstrated that pelleted diets had a negative effect on digestibility of several tested amino acids in diets manufactured with 1% MAF + 1% CaLS and 3% MAF + 1% CaLS. These experiments collectively demonstrated that varying levels of CaLS and MAF, in addition to feed form, can affect feed manufacture and broiler performance.

ACKNOWLEDGEMENTS

I would first like to thank my advisor, Dr. Joe Moritz for encouraging me to continue my education and always providing me with guidance and support along the way. He has been the most helpful faculty member throughout my entire collegiate career. I would also like to thank my committee members; Dr. Janet Tou and Dr. Harry Boone. Dr. Tou has also served as a major support system throughout my graduate career, and always encouraged me to challenge myself. Dr. Boone inspired me to broaden my horizons and get involved with Extension Education in order to share my knowledge with others. Also, I would like to thank Rick Wood for his technical support throughout my research. Rick was instrumental in replacing water lines in the research building and assisting with our total clean-out. Due to the fact that any research involving feed manufacture can be labor intensive, I would like to express my great appreciation for past and present members of Dr. Moritz's lab who have helped me throughout my graduate career: Kelley Wamsley, Angela Lamp, Ashley Evans, Kevin Shipe, Amanda Brink, John Boney, and Mark Lemons. Finally, I would like to thank my family: Sita, Lindsey, and Aunt Marion. Without their constant love and support, none of this would have been possible.

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KEY

CHAPTER 1

1. Calcium Lignosulfonate – CaLS
2. Mixer-Added Fat – MAF
3. Live Weight Gain – LWG
4. Feed Conversion Ratio – FCR
5. Pellet Quality – PQ
6. Pellet Durability Index – PDI
7. Modified Pellet Durability Index – MPDI

CHAPTER 2

1. Feed Intake – FI
2. True Amino Acid Digestibility – TAAD
3. Calcium Lignosulfonate – CaLS
4. Mixer-Added Fat – MAF
5. Live Weight Gain – LWG
6. Feed Conversion Ratio – FCR
7. Pellet Quality – PQ
8. Pellet Durability Index – PDI
9. Modified Pellet Durability Index – MPDI

CHAPTER 1: LITERATURE REVIEW

COMMERCIAL BROILER PRODUCTION IN WEST VIRGINIA

Broiler production is the number one agricultural commodity in West Virginia. From December 1, 2011, through November 30, 2012, approximately 94 million broilers were produced in the state, ranking West Virginia 19th in total U.S. broiler production [1].

FEED MANUFACTURE AND FEED FORM

The majority of feed in the commercial poultry industry is pelleted. Behnke [2] estimates that 60 - 70% of the total costs incurred in a commercial broiler production system are associated with feeding costs which include raw ingredient and manufacturing costs. These costs may be justified through improved broiler performance variables such as an increase in live weight gain (LWG) and a decrease in feed conversion ratio (FCR) [3]. However, the extent of improved broiler performance is dependent upon pellet quality (PQ) and use of manufacture techniques that do not decrease nutrient availability. The majority of production costs are acquired during the three - six week phase which is also known as the grower/finisher phase. Feed consumption and LWG are at their peak during this time. Therefore, the majority of production costs are incurred during this phase of production [4,5].

Pellet Quality

Pellet quality can be defined as the pellet's ability to maintain its structural integrity from the time it is manufactured at the feed mill until it is placed in feed pans for broilers to ingest. There are several ways to define PQ including the pellet durability index (PDI) and modified pellet durability index (MPDI) via the Pfast tumbling can method [6], calculating the pellet: fine ratio, and pellet length. Pellet quality can be affected by diet formulation, feed conditioning temperature, the rate of feed production in the pellet mill, diet formulation, feed particle size, cooling and drying techniques, and the thickness of the pellet die in which the feed is extruded [7].

Production Rate

In order to meet the needs of an ever-growing industry, many commercial feed mills operate beyond their capacity. The demand for feed mills to operate beyond their capacity is continuous due to the increasing number of contract poultry growers and the lack of contribution to ensure the feed mills can maintain an adequate rate of production to compensate for this growth. If feed is manufactured at a slower rate of production, retention time of the feed within the pellet die can be increased. Several studies show that this will increase nutrient binding and PQ, ultimately leading to improved broiler performance if nutrient availability is not compromised [6,8].

Conditioning Temperature

In addition to low mixer-added fat (MAF) and the inclusion of pellet binders, conditioning temperature can also affect PQ. Conditioning allows feed to become more pliable to aid in pellet formation. Conditioning subjects feed to temperatures that typically range between 70 and 93°C. Increasing conditioning temperature will increase moisture and heat within feed and cause interactions such as starch gelatinization and protein denaturation [9], subsequently improving PQ. During conditioning, feed is heated with saturated steam and conveyed toward a pelleting chamber. In the pelleting chamber feed is pressed into and extruded through a pellet die. Extrusion occurs due to conditioned feed being pressed between rolls and the pellet die. This occurs with each rotation of the die or roll system depending on the type of pellet press utilized. As conditioned feed is extruded through the pellet die it is subjected to high frictional force and pressure. Frictional force and pressure increase as conditioning temperature decreases [10]. In pelleted diets, conditioning at 90°C has been shown to improve PQ. Abdollahi et al. [11] found that diets conditioned at 90°C, regardless of pellet binder addition, had higher pellet durability and pellet hardness than diets conditioned at 60°C. Therefore, it may be concluded that conditioning temperature may affect PQ.

PELLET QUALITY AND BROILER PERFORMANCE

In an attempt to minimize production cost while maximizing broiler performance, research has investigated the effect of feed form (mash vs. pellet) on broiler performance [12]. According to Reimer, [13] PQ can be attributed to the following factors: diet formulation (40%), conditioning (20%), particle size (20%), die specification (15%), and drying/cooling (5%). In modern feed manufacture, PQ has been suggested to be affected more by equipment than by diet formulation [14]. Pelleting feed has been shown to provide broiler performance improvements due to decreased feed wastage, reduced selective feeding, decreased ingredient segregation, decreased energy expenditure for feed apprehension, improved palatability, and increased digestibility [4]. Runnels [15] found that at four weeks of age, broilers fed pelleted or crumbled diets had increased body weights and improved feed efficiencies. However, the magnitude of benefit has been shown to be dependent upon pellet quality [16].

PELLETED FEED AND NUTRIENT AVAILABILITY

Research has shown that pelleting feed may have significant influence on nutritional value. Heywang and Morgan [17] noted that the efficiency of utilization of a chick ration was improved by pelleting. Lanson and Smith [18] found that the increased density of pelleted feed allowed birds to fulfill their nutritional requirements more efficiently. Additionally, Hinds and Scott [19] found that pelleting improved the nutritional value of the diet. Equivalent weights and feed efficiencies were observed when feeding high energy mash diets supplemented with fat and low energy pelleted diets with no fat. Therefore, it can be concluded that pelleting feed provides a sparing effect on the energy requirements of chicks [20].

Although feeding high quality pellets provides performance advantages in modern meat bird genotypes, performance benefits are dependent upon manufacturing techniques having minimal impact on decreasing nutrient availability. Research has indicated that manufacturing

technique can decrease amino acid digestibility [21,22], enzyme efficacy [23,24] and the protein to energy ratio [25,26,27]. High quality pellets have potential to provide performance and flock uniformity benefits by decreasing ingredient and nutrient segregation [7].

CALCIUM LIGNOSULFONATE AND BROILER PERFORMANCE

The increased use of pelleted feeds and expansion of birds fed without upgrades to feed mills that necessitate high pellet throughput to meet feed volume requirements has prompted feed manufacturers to become interested in efficiency of pelleting and pellet durability. In attempts to improve pellet durability, manufacturers have used various types of pellet binders, methods of conditioning, and different sizes of dies [28]. Acar et al. [29] found that the addition of Calcium lignosulfonate (CaLS) in broiler diets significantly improved the amount of intact pellets by 56%. Waldroup et al. [30] observed that the addition of CaLS improved the amount of intact pellets. Waldroup noted 72.5% of intact pellets when 1% CaLS was used in the diet and a reduction to 55.9% when 1.5% CaLS was used in the diet. More recently, lignin pellet binders have been used to increase pellet durability [31,32]. Lignosulfonates are by-products of the paper industry and may be used as pellet binders [14]. Lignin has a three-dimensional structure consisting of a six- carbon benzene ring attached to a straight side chain of three carbon atoms. Because lignin can consist of carbon, hydrogen, and oxygen in different proportions, it is a very dynamic molecule. Lignosulfonates can be used as a binder in animal feed [33]. Lignosulfonate pellet binders are available as sodium, calcium, or ammonium salts and contain high percentages of various wood sugars and hemicellulose [34]. Kivimae [35] found that lignosulfonates did not significantly affect the feed efficiency of broilers and laying hens, the quality of broiler carcasses, or the taste and appearance of eggs when CaLS was added as high as 6% of the diet. However, Acar et al. [29] found that feed consumption and feed conversion of broilers were both

increased by approximately 3.4 and 2.9%, respectively, when CaLS was included in the diet. It can be concluded that the inclusion of CaLS in the diet may affect PQ and broiler performance, but further research is needed to determine the level of inclusion of CaLS needed for optimal PQ and broiler performance.

MIXER-ADDED FAT AND BROILER PERFORMANCE

High growth rate of broilers is assisted by genotypes having a high rate of feed intake and metabolism [36]. Without adequate nutrient utilization, it would be difficult for broilers to maintain a high rate of growth. Broiler nutrient utilization and growth rate may be affected if the chemical structure of ingredients is altered during feed production. In addition to various conditioning temperatures, feed production variables such as production rate, pellet die specification, and level of MAF influence feed exposure to pellet die frictional heat and pressure, and may alter conformational structure of ingredients. Protein is especially heat sensitive and can change its physical structure in the presence of moist heat. Unpublished data from our laboratory suggests that this physical alteration may result in a considerable change in reactivity, functionality, and nutritional quality [10]. Pelleting, which combines shear forces, heat, pressure and water may result in partial protein denaturation [37] and may result in changes in protein availability to a non-ruminant animal [38]. The addition of MAF may improve nutrient quality and utilization by reducing frictional heat and pressure within the pellet die [32]. MAF lubricating properties have been shown to reduce the electrical energy required to pellet broiler feed [39]. However, many feed mills utilize low MAF and add the remainder of the fat post-pelleting in order to improve ingredient binding and PQ [40].

Currently, industry practices are focused around reducing the amount of added fat in broiler diets to reduce diet cost and improve PQ [16,41]. Recent research has demonstrated that

a thick pellet die (4.76 x 44.96 mm) and decreased MAF can be detrimental to production rate and nutrient digestibility; particularly amino acids [40].

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CHAPTER 2: Effects of Varying Levels of Calcium Lignosulfonate, Mixer-Added Fat, and Feed Form on Feed Manufacture and Broiler Performance

SUMMARY

Pelleting technique can affect feed form and nutrient availability. Increasing mixer-added fat (MAF) decreases frictional heat and pressure within the pellet die, but reduces pellet quality (PQ). The use of Calcium lignosulfonate (CaLS) may enable use of moderate inclusions of MAF while maintaining PQ. A series of experiments with treatments consisting of CaLS (0, 0.5, or 1%), MAF (1 or 3%), and feed form (pellet or ground pellet) were performed to explore feed mill efficiency, PQ, broiler performance, digesta viscosity, and true amino acid digestibility (TAAD). Increased MAF and CaLS independently reduced energy use of the pellet mill, pellet temperature post extrusion, and decreased and increased PQ respectively. A three-way interaction of main effects for feed conversion ratio (FCR) demonstrated that the 0.5% CaLS + 3% MAF treatment lowered pelleted treatment FCR. The 0.5% CaLS + 3% MAF treatment combination also increased digesta viscosity demonstrated by a CaLS x MAF interaction effect. Additionally, a three-way interaction of main effects demonstrated that the 0.5% CaLS + 3% MAF treatment maintained a high level of TAAD in pelleted treatments. The ratio of CaLS:MAF was found to be important to PQ, as well as broiler performance, digesta viscosity, and TAAD. Adding 0.5% CaLS to treatments containing 3% MAF improved PQ, and feeding these pellets decreased FCR, and increased TAAD.

Key words: Pelleting technique, pellet quality, broiler performance, Calcium lignosulfonate, mixer-added fat

DESCRIPTION OF THE PROBLEM

Feed and feed manufacture account for a substantial amount of production costs within an integrated poultry company. Research has consistently demonstrated production benefits associated with feeding pelleted diets to broiler chickens [1,2]. Pelleting broiler feed benefits both the integrator and grower because pelleting broiler feed improves handling characteristics, increases feed intake (FI) and live weight gain (LWG), and decreases FCR [1,2]. In order to maximize these benefits, feed must not only be pelleted, but produced using techniques that result in high quality pellets without decreasing nutrient availability. One technique used to resolve poor PQ is the application of low MAF, adding any remaining fat post- pelleting. Another technique includes the utilization of pellet binders; both inherent in ingredients and commercially available additives.

Briggs et al. found that increasing the fat inclusion in feed incrementally reduces PQ [3]. However, the use of increased MAF has been shown to decrease detrimental pelleting effects on nutrient digestibility, specifically amino acids [4]. Increasing MAF inclusion to three percent or more has been suggested to prevent reduced nutrient availability and maintain activity of mixer added enzymes [5]. Fat added in the mixer may contribute to improved nutrient utilization and enzyme efficacy by coating feed particles [6,7]. Cutlip et al. [8] observed performance benefits without detriment to nutrient availability with improved feed form from high conditioning temperatures (i.e. 93°C) that may have been possible due to the 3% MAF inclusion.

Calcium lignosulfonate has been used by industry in a wide variety of applications. The usefulness of lignosulfonate products comes from their dispersing, binding, complexing, and emulsifying properties [9]. Emulsifying and stabilizing properties make CaLS a valuable food additive because it prevents aggregation of small particles and droplets [10]. One of CaLS' most

pronounced properties is the ability to disperse particles in aqueous solutions; therefore, it is commonly used to disperse the cement and fine particles in solution to improve the workability of dense suspensions such as mortar or concrete [11]. Due to the binding properties demonstrated by CaLS, it is used as a pellet binder in animal feed to improve PQ [12]. In addition to improving PQ, CaLS inclusion has also been linked to improved amino acid digestibility [4]. Acar et al. found that broiler feed intake increased with the use of CaLS binder, but FCR also increased [12].

The use of an appropriate level of CaLS may enable use of moderate inclusions of MAF, maintain PQ, and improve nutrient digestibility. The objective of the current study was to determine the effects of varying levels of CaLS, MAF, and feed form on feed manufacture, broiler performance, and TAAD.

MATERIALS AND METHODS

Experiment 1: Feed Manufacture

Finisher diets were formulated to 90% of Cobb Vantress digestible amino acid recommendations (Table 1) [13]. Treatments were batched and pelleted at West Virginia University's pilot feed mill. Finisher phase treatments were pelleted as a randomized complete block design using a 3 x 2 factorial arrangement of treatments with four replications. Main effects consisted of the inclusion of a commercial CaLS pellet binder [14] (0, 0.5, or 1%) and MAF (1 or 3%). Treatments containing 1% MAF had the remaining 2% fat added post pelleting. Batching was accomplished over a 2 d period and blocked by time of manufacture. Each batch contained 1% MAF and various inclusions of CaLS (0, 0.5, or 1%). On d1 of batching, six 544.5 kg (1,200 lb) batches were equally allotted to each respective treatment to be pelleted for the first two replications of feed manufacture, creating an experimental unit of 272.23 kg (600 lb) to be steam conditioned and pelleted. On d2 of batching, six 544.5 kg (1,200 lb) batches were equally allotted to each respective treatment to be pelleted for replications three and four of feed manufacture, creating an experimental unit of 272.23 kg (600 lb) to be steam conditioned and pelleted.

Mash feed was conditioned in a 1.3 m length x 0.31 m diameter, short term (10 s) conditioner [15] to a temperature of 82°C (180°F), with a gauge steam pressure just prior to the conditioner of 262 kPa (38 psi). Conditioned mash temperature was monitored with an 80 PK-24 temperature probe [16]. The temperature probe was inserted at the interface between the end of the conditioning barrel and beginning of the chute that connects to the pellet die chamber. Rate of feed entering the conditioner and conditioner shaft rpm was held constant for all treatments. Pellets were made using a 38.1 (effective thickness) x 4.76 mm pellet die without relief, and a 40 HP California Pellet Mill [17] and were cooled on a horizontal belt cooler [18] using forced

ambient air. An infrared temperature gun was used to take an initial die temperature one minute prior to each run. A hot die temperature was also taken with the infrared temperature gun immediately after each run was complete. Electrical energy usage of the conditioner and pellet mill were measured throughout each run with a Square D amperage meter [19]. Pellet mill motor amperage was additionally measured by a HOBO U12 Data Logger [20] at 1 s intervals throughout each run. Other measured variables included: Pellet mill production rate, pellet durability, average hot pellet temperature, and percentage of pellets (Table 2). Hot pellet temperature was obtained by placing an insulated container under the pellet mill, catching hot pellets as they were extruded from the pellet mill, and immediately closing the lid on the container. The temperature of the hot pellets was measured using a thermocouple thermometer [21]. This procedure was performed five times during each run, and the average hot pellet temperature was reported. Post- pellet fat application was accomplished by adding cooled pellets and the remaining fat at the mixer [22] for 10 minutes. One representative bag from each replicate treatment was reserved to assess PQ one day after manufacture [23,24].

In order to determine feed form effects of the aforementioned treatments, each treatment replicate were evenly split so that half of the intact pellets could be ground using a rollermill. Average particle size of the ground pellets ranged from 875 to 907 microns. Based on this manufacture scheme, a 3 x 2 x 2 factorial arrangement of treatments was created with three levels of CaLS (0, 0.5, or 1%), two levels of MAF (1 or 3%), and two feed forms (pellets or ground pellets), for a total of 12 dietary treatments to be fed in Experiment 2.

Experiment 2: Broiler Performance

A total of 2,220 one-day-old, straight run, Cobb x Cobb 500 broilers [25] were obtained from a commercial hatchery [26], then randomly placed in equal allotments to one of 96 floor

pens [0.69 x 2.44m (2.26 x 8.00 ft.)] located within three rooms of equal size. Rooms were located in a cross-ventilated negative-pressure house with forced-air brooders. Common starter (d1-10) and grower (d10-23) diets were formulated to 90% of Cobb Vantress digestible amino acid recommendations [13] and fed to each of the 96 pens. Birds were provided feed and water for ad libitum consumption. Ziggity nipple drinkers [27] were utilized for water delivery and chicks were provided feed using a feed pan for the first seven days, and then transitioned to Kuhl feed hoppers [28] on d7. Initial temperature of the rooms was kept at 32.2°C (90.0°F) and incrementally decreased to 21.1°C (70.0°F) during the experiment. Broilers were provided 24 h of light from 0 to 7d, 22 h of light from 8 to 9d, 20 h from 10 to 26d, 23 h from 27 to 34d, and 20 h from 35 to 42d in attempt to mimic a commercial lighting program.

On d23, each pen was weighed and birds that were either excessively large or small were removed. Pens were manipulated to contain 23 birds and be of similar weight. Next, the 12 finisher dietary treatments manufactured in Experiment 1 were provided to pens and arranged as a randomized complete block spanning all three rooms, creating eight replications per treatment. On d42, each pen was weighed and 2 birds $\pm$ 100g of the average bird weight/pen were selected and marked from each pen for viscosity (Table 3) and processing metrics on d43. Measured performance variables from d23-42 were beginning pen weight, average ending bird weight, average LWG, pen FI, and FCR (adjusted with mortality weight).

On d43, birds that were selected the previous day were killed via cervical dislocation. Next, individual bird weights and respective hot, boneless, skinless breast and fat pad weights were obtained to determine average weights and yields per pen. In addition, these birds were used to obtain ileal digesta for viscosity measurements (Table 3). Ileal digesta was gently squeezed in a common container, flash frozen using liquid nitrogen, and stored at -80°C.

Previously frozen samples were suspended in 1000 mL of water at 25°C for 30 minutes. Thawed samples were then stirred and placed in BD Falcon centrifuge tubes and centrifuged at 12,700 RPM at four degrees Celsius for five minutes [29]; 0.5 ml of supernatant was measured in a Brookfield digital viscometer [30] at 25°C. Viscosity readings were taken at 30 s and 60 s intervals at 20 RPM.

Experiment 3: True Amino Acid Digestibility

Forty-eight, 38 week old cecectomized Single Comb White Leghorn roosters were utilized to determine true amino acid digestibility of 12 treatments that were previously fed to broilers in the 23-42d finisher phase. A factorial arrangement of treatments included (0, 0.5, or 1%) CaLS, (1 or 3%) MAF, and pellets or ground pellets. Each treatment was precision fed to four roosters following modified methodologies of Sibbald [31]. Collected excreta were dried at 50°C for 24h before amino acid analysis to determine true digestibility of methionine, valine, alanine, glutamic acid, aspartic acid, and threonine. (Table 4).

Statistical Analysis

Experiment 1. Feed manufacture data were analyzed as a randomized complete block using one-way ANOVA. Blocking criterion was time of manufacture. Main effects and interactions were considered, and significance was determined at $P \leq 0.05$. Multiple comparisons of all treatment means were made using Fisher's LSD. The statistical analyses were conducted using the GLM procedure of SAS (2013) [32].

Experiment 2. Viscosity and broiler performance data were analyzed as a randomized complete block design using one-way ANOVA while considering main effects and interactions. Blocking criterion consisted of pen location in the barn. The experimental unit was a pen of 23

straight-run broilers. Significance was determined at $P \leq 0.05$. The statistical analyses were conducted using the GLM procedure of SAS (2013) [32].

Experiment 3. True digestibility of the tested amino acids was analyzed as a completely randomized block design using one-way ANOVA while considering main effects and interactions. Significance was determined by $P \leq 0.05$. The statistical analyses were conducted using the GLM procedure of SAS (2013) [32].

Interactions of main effects for each experiment were graphed in order to render interpretations.

RESULTS AND DISCUSSION

Experiment 1: Feed Manufacture

CaLS Effects. Inclusion of CaLS increased pellet durability index (PDI) ($P=0.0001$) and modified pellet durability index (MPDI) ($P=0.0001$). The increase in PDI and MPDI was likely due to CaLS becoming liquid with steam conditioning, filling interstitial space of feed particles, and hardening upon drying; thus improving pellet quality [33]. The use of CaLS also decreased pellet mill motor amperage and pellet temperature post die extrusion ($P<0.05$). Perhaps CaLS demonstrated dispersing agent qualities that allowed rheology of particles to be maintained during pellet extrusion, decreasing friction throughout the period of manufacture [34] (Table 2).

Mixer-added fat Effects. The inclusion of 3% MAF decreased PDI and MPDI ($P<0.05$) similar to past observations [5]; however, percent pellets fed were increased ($P<0.05$, Table 2). The effect on percent pellets was due to 1% MAF cooled pellets being mixed with the remaining 2% fat. The difference in percent pellets was five percentage points. The addition of 3% MAF also decreased measures of electrical energy usage of the pellet mill and hot pellet temperature post die extrusion ($P<0.05$), likely associated with improved lubrication of the pellet die. Pellet mill motor amperage measured with the HOBO U12 data logger showed that CaLS combined with treatments containing 3% MAF decreased pellet mill motor amperage beyond decreases achieved with CaLS and 1% MAF.

Experiment 2: Broiler Performance

Broilers fed treatments manufactured with CaLS increased FI and LWG ($P<0.05$, Table 3). A three way interaction between CaLS, MAF, and feed form was demonstrated for FCR ($P<0.05$, Table 3, Figure 1). Pelleted treatments manufactured with 1% MAF had a lower FCR when compared to ground pelleted treatments manufactured with 1% MAF. As CaLS inclusion

increased in treatments manufactured with 1% MAF, FCR decreased. However, feed form and CaLS benefits were not consistently demonstrated in treatments manufactured with 3% MAF. The 0.5% CaLS + 3% MAF treatment lowered pelleted treatment FCR, but 0% CaLS + 1% MAF and 1% CaLS + 3% MAF pelleted treatments increased FCR. The converse relationship was observed with ground pelleted treatments.

Treatments manufactured with 1% MAF may have had the greatest potential for thermally induced changes that could have negatively affected nutrient digestibility, and perhaps this lower plane of nutrition allowed for feed form and CaLS benefits to be best demonstrated. Gehring et al. demonstrated that there is potential for nutrient and exogenous enzyme destruction with low inclusions of fat (0.5 to 1%) due to frictional heat and shear forces produced in the pellet die [5]. It is probable that increased MAF of the current study partially negated thermally induced nutrient detriment and performance effects were more associated with digesta viscosity and gastrointestinal tract transit time effects on nutrient digestibility.

An interaction between CaLS and MAF regarding digesta viscosity ($P < 0.05$) was demonstrated by the combination of 0.5% CaLS + 3% MAF increasing viscosity compared to other treatments. It is important to note that this level of viscosity was lower than viscosity levels associated with decreased performance of wheat and barley based diets measured using the same viscometer in past research [35]. Perhaps the moderate increase in viscosity of the current study allowed for a slower gastrointestinal tract transit time and improved nutrient digestibility. A similar finding relating viscosity and performance was found by Lamp, et al., where broilers were shown to have increased digesta viscosity that corresponded to increased FI and LWG [35].

These data corroborate past benefits demonstrated with CaLS in pelleted diets; however, the ratio of CaLS and MAF may determine the extent of the benefit. Perhaps fat emulsions are formed by mechanical shear when feed is extruded during pelleting [36]. A 0.5: 3 ratio of CaLS to MAF may stabilize the emulsion, effectively increasing the number of oil droplets in feed, increasing digesta viscosity. Levels of CaLS and MAF that exceeded this ratio may have fluidized the digesta and decreased viscosity to a degree detrimental to nutrient digestibility.

Experiment 3: True Amino Acid Digestibility

A three way interaction between CaLS, MAF, and feed form was demonstrated for TAAD ($P < 0.05$, Table 4, Figure 2). The interaction demonstrated that pelleted treatments had a negative effect on digestibility of several tested amino acids for treatments containing 1% CaLS + 1% MAF as well as treatments containing 1% CaLS + 3% MAF. Pelleted diets manufactured with 3% MAF followed a trend similar to that of the FCR benefit. More specifically, TAAD was improved in pelleted treatments manufactured with 0.5% CaLS and 3% MAF suggesting that the 0.5: 3 ratio of CaLS to MAF may optimize TAAD.

The ratio of CaLS: MAF was found to be important to PQ, as well as broiler performance, digesta viscosity, and TAAD. Adding 0.5% CaLS to treatments containing 3% MAF improved PQ, and feeding these pellets decreased FCR, and increased TAAD.

CONCLUSIONS AND APPLICATIONS

1. Increased MAF and CaLS independently reduced energy use of the pellet mill, pellet temperature post extrusion and decreased and increased PQ respectively.
2. A three-way interaction of main effects for feed conversion ratio (FCR) demonstrated that the 0.5% CaLS + 3% MAF treatment lowered pelleted treatment FCR.
3. The 0.5% CaLS + 3% MAF treatment combination increased digesta viscosity demonstrated by a CaLS x MAF interaction effect.
4. A three-way interaction of main effects demonstrated that the 0.5% CaLS + 3% MAF treatment maintained a high level of TAAD in pelleted treatments.

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24. Pellet quality was assessed one day following production using the New Holmen NHP Portable Pellet Durability Tester, Lignotech USA, Inc., Rothschild, WI. 100 g of pellets were placed in the chamber, blown about from 30 to 60 seconds by a jet of air, and then weighed, giving a direct read of pellet durability. Fines are removed during the blowing process.
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Table 1. 23-42d Broiler Finisher Diet Formulation

Ingredient	Inclusion (%)
Corn	68.36
Soybean Meal	11.94
DDGS, corn	8.00
Porcine Meat & Bone Meal	4.80
Animal and Vegetable Blend Fat	3.00
Binder or Sand	0.00, 0.50, or 1.00
Limestone	0.78
Dicalcium Phosphorus	0.57
Lysine	0.34
Sodium Bicarbonate	0.31
Vitamin Premix ¹	0.25
DL-Methionine	0.22
Threonine	0.19
Salt	0.10
BMD 60 ²	0.08
Coban 90	0.05
Calculated Values	
ME (kcal/kg)	3183
Crude Protein (%)	16.20
Digestible Lysine (%)	0.86
Digestible TSAA ³ (%)	0.67
Calcium	0.90
Available Phosphorus	0.45
Sodium	0.19
Analyzed Values	
Crude Protein (%)	15.87
Total Methionine (%)	0.47
Total Threonine (%)	0.63
Total Lysine (%)	1.08

¹Vitmin Premix Composition

²Bacitracin methylene disalicylate

³Total sulfur amino acids

Table 2. Effect of Calcium Lignosulfonate and Mixer-Added Fat on Finisher Diet Feed Manufacture and Pellet Quality

CaLS ¹ (%)	MAF ² (%)	PDI ³ (%)	MPDI ⁴ (%)	Percent Pellets (%)	Conditioner EEU ⁵ (kwh/MT)	Pellet Mill EEU ⁶ (kwh/MT)	Pellet Temperature Post Extrusion (°C)	Pellet Mill Motor Amperage ⁷
Marginal Means								
0.0	--	86.4 ^b	78.4 ^b	81.0	0.86	8.0	81.0 ^a	17.6 ^a
0.5	--	89.9 ^a	83.9 ^a	82.7	0.87	8.5	79.5 ^b	17.4 ^b
1.0	--	91.0 ^a	85.8 ^a	83.8	0.87	8.1	79.6 ^b	16.8 ^c
----	1	95.1 ^a	90.7 ^a	80.0 ^b	0.85	8.9 ^a	80.5 ^a	17.3
----	3	83.1 ^b	74.7 ^b	85.0 ^a	0.87	7.5 ^b	79.5 ^b	17.2
CaLS		0.0042	0.0010	0.2759	0.9279	0.0731	0.0068	0.0001
MAF		0.0001	0.0001	0.0028	0.4291	0.0001	0.0173	0.1632
CaLS X MAF		0.1316	0.1467	0.6384	0.6326	0.5527	0.0744	0.0118

¹Calcium lignosulfonate pellet binder

²Mixer-added fat

³Pellet durability index using the Pfost tumbling method

⁴Modified pellet durability index using Pfost tumbling method with 5 13mm hex nuts

⁵Electrical energy usage of the conditioner measured throughout each run with a Square D amperage meter

⁶Electrical energy usage of the pellet mill measured throughout each run with a Square D amperage meter

⁷Pellet mill motor amperage was measured with a HOBO U12 data logger at one second intervals throughout each run

Table 3. Effect of Calcium Lignosulfonate, Mixer-Added Fat, and Feed Form on 23-42 d Broiler Performance and Viscosity

CaLS ¹ (%)	MAF ² (%)	Feed Form	Feed Intake per bird 23-42d (kg)	Ending weight per bird 23-42d (kg)	Live weight gain per bird 23-42d (kg)	Feed Conversion Ratio ³ 23-42d	Viscosity 20 RPM for 60s
Marginal Means							
0.0	--	--	2.45 ^b	1.87	1.23	1.98	3.25
0.5	--	--	2.64 ^a	1.95	1.31	2.00	3.71
1.0	--	--	2.60 ^a	1.94	1.30	1.98	3.18
--	1	--	2.59	1.93	1.29	1.99	3.08
--	3	--	2.53	1.90	1.26	1.98	3.67
--	--	Ground Pellet	2.55	1.90	1.26	2.00	3.44
--	--	Pellet	2.57	1.93	1.29	1.97	3.29
Main Effects and Interactions							
CaLS			0.0046	0.0077	0.0093	0.6822	0.0552
MAF			0.1895	0.1654	0.1972	0.6972	0.0027
Feed Form			0.6202	0.1701	0.1439	0.1292	0.5497
CaLS X MAF			0.7921	0.5492	0.5348	0.3517	0.0238
CaLS X Feed Form			0.2920	0.0719	0.0632	0.5247	0.7392
MAF X Feed Form			0.7196	0.0997	0.0921	0.0690	0.6157
CaLS X MAF X Feed Form			0.5243	0.8002	0.8370	0.0458	0.7337

¹Calcium lignosulfonate pellet binder

²Mixer-added fat

³Feed Conversion Ratio is total pen feed intake divided by the sum of total weight gain and mortality weight

Table 4. True Amino Acid Digestibility Using Diets That Vary in Calcium Lignosulfonate, Mixer-Added Fat, and Feed Form

CaLS ¹ (%)	MAF ² (%)	Feed Form	Aspartic Acid (%)	Threonine (%)	Glutamic Acid (%)	Alanine (%)	Valine (%)	Methionine (%)
Marginal Means								
0.0	----	-----	81.3	81.8	78.2	79.5	80.7	90.2
0.5	----	-----	80.8	83.9	76.3	78.0	80.2	89.4
1.0	----	-----	80.8	83.2	77.1	78.1	79.5	89.5
-----	1	-----	80.7	82.8	77.4	77.2	80.0	88.9
-----	3	-----	81.3	83.1	77.0	79.8	80.3	90.6
-----	---	Ground Pellet	82.6	84.1	78.4	79.7	81.3	89.8
-----	---	Pellet	79.5	81.9	75.9	77.4	80.0	89.6
Main Effects and Interactions								
CaLS			0.9741	0.7093	0.5170	0.7753	0.8991	0.7825
MAF			0.7320	0.9351	0.7241	0.1883	0.9064	0.0973
Feed Form			0.0445	0.3353	0.0634	0.2636	0.3125	0.8792
CaLS X MAF			0.1875	0.7370	0.2567	0.2351	0.2053	0.6961
CaLS X Feed Form			0.8114	0.9432	0.9253	0.7700	0.5770	0.8296
MAF X Feed Form			0.2722	0.6846	0.3464	0.3815	0.6268	0.5763
CaLS X MAF X Feed Form			0.0129	0.1988	0.0050	0.0278	0.0260	0.0640

¹Calcium lignosulfonate pellet binder

²Mixer-added fat

Figure 1. Interactive Effects of CaLS X MAF X Feed Form on FCR

*P ≤ 0.05

Figure 2. Interactive Effects of CaLS X MAF X Feed Form on TAAD

Lysine

* $P \leq 0.05$

Alina M. Corey

•960 Chestnut Ridge Road Apt. 403 • Morgantown, WV 26505 • Acorey1@mix.wvu.edu • (304) 281 4427•

Enthusiastic and works well within a team, but also proficient working as an individual. Not foreign to hard-work and thrives under pressure.

Goal: To educate and inspire others in the area of Poultry Production.

EDUCATIONAL RECORD:

Master of Science - 2013; West Virginia University

Major: Nutrition and Food Science

Thesis: Effects of Varying Levels of Calcium Lignosulfonate, Mixer-Added Fat and Feed Form on Feed Manufacture and Broiler Performance

Bachelor of Science - 2012; West Virginia University

Major: Animal and Nutritional Sciences

EDUCATION HONORS/AWARDS:

Publications:

Abstracts

A. M. Corey, K. G. S. Wamsley, T. S. Winowiski, J. S. Moritz. 2012. The effect of Calcium lignosulfonate and mixer-added fat on feed manufacture and 23-42d broiler performance. 2013 International Southern Poultry Science Forum. Atlanta, GA. (Accepted Abstract).

A. M. Corey, K. G. S. Wamsley, T. S. Winowiski, J. S. Moritz. 2013. The effect of Calcium lignosulfonate, mixer-added fat, and feed form on true amino acid digestibility and digesta viscosity. 2013 Poult. Sci. San Diego, CA. (Accepted Abstract).

Popular Press Manuscript:

Moritz J. S., **Corey A.** 2013. The Effect of Calcium Lignosulfonate, Mixer-Added Fat, and Feed Form on Feed Manufacture and 23-42d Broiler Performance. Available from URL <http://www.feedinfo.com>.

Awards and Honors:

- Graduate Student Research Paper Certificate of Achievement, "*The effect of Calcium lignosulfonate and mixer-added fat on feed manufacture and 23-42d broiler performance.*" Presented at the annual International Poultry Scientific Forum. Atlanta, GA. (Jan. 29, 2013).
 - Graduate Student Research Paper Certificate of Excellence, "*The effect of Calcium lignosulfonate, mixer-added fat, and feed form on true amino acid digestibility and digesta viscosity.*" (Received top score for student presentations) Presented at the 2013 annual Poultry Science Association Meeting. San Diego, CA. (July 23, 2013).
-

TEACHING EXPERIENCE:

Graduate Teaching Assistant

Fall 2012 –Present

- Teaching Assistant for Poultry Production Class and Corresponding lab (Role includes lecturing occasionally in class and organizing and lecturing for lab at the WVU Animal Science Farm)
- Guest Lecturer for Intro to Animal Science Course
- Presented Poultry Production lecture for Boy Scout's Animal Science Merit Badge (February, 2013)
- Presented backyard layer production talk at Organic Field Day (August, 2012) and (August, 2013)
- Presented Animal Welfare, Animal Husbandry, and Animal Nutrition lectures for A-STEM Summer Camp at West Virginia University's Animal Science Farm (August, 2013)
- Presented Gilmer County Extension talk on backyard poultry production, WV (October, 2012)
- Directed Poultry Career Development Events (September, 2012) and (July, 2013)

RESEARCH EXPERIENCE:

Graduate Research Assistant

Fall 2012 –Present

- Assisted with Contract Studies with Verenum, Poet Nutrition, Virginia Poultry's Grower's Cooperative, Alltech, BioResource International, Inc. and Lignotech

SERVICE EXPERIENCE:

- Assisted with WV poultry week activities (7/26-7/27/2012)
- Assisted with activities and displays (birds and poster) for Monongalia County (August 2012, 2013)
- Poultry Judge for County Fairs
Berkeley County Youth Fair, WV (July, 2012)

- Supervised the Poultry Building at the WV State Fair (August 2012, 2013)
- Assisted with Preston County Kid's Safety Day, WV (June 2012, 2013)
- Assisted with poultry displays at Family Day at the WVU Animal Science Farm (October, 2012)
- Developed a detailed program evaluation plan for a local Cub Scout group (May, 2012)
- Assisted with Doddridge and Preston County Poultry Processing Workshop, WV (August, 2013)

National Meeting Paper Presentations

- 2013 International Southern Poultry Science Forum (Atlanta, GA).
"The effect of Calcium lignosulfonate and mixer-added fat on feed manufacture and 23-42d broiler performance."
- 2013 Poultry Science Association (San Diego, CA)
"The effect of Calcium lignosulfonate, mixer-added fat, and feed form on true amino acid digestibility and digesta viscosity."

Undergraduate Research Assistant

Fall 2011-June 2012

- Conducted study "Evaluating the effects of Calcium lignosulfonate, varied mixer-added fat and feed form in practically formulated and manufactured diets on pellet quality, feed mill production, rooster TMEn and TAAD, broiler performance, and gut viscosity."
- Assisted with Contract Studies with Verenium, Poet Nutrition, and Virginia Poultry Growers Cooperative.

EXPERIENCE:

Case Farms Intern

Summer 2011

- Completed 10 week Live Production internship

Children's Consignment Shop Worker

2009-2011

- Scheduled appointments
- Handled financial transactions
- Organized clothing

Pizza Shop Worker

2007-2010

- Customer Service

Horse Stable Worker

2006-2009

- Handled horses
- Daily feedings

Small Animal Veterinary Clinic Assistant/Kennel Cleaner

2004-2006

- Assisted in surgery
- Handled animals

SKILLS:

- Internet Literate
- Savvy in Window's Microsoft Programs
- Poultry Handling, Judging and Husbandry
- Feed Manufacture and Diet Formulation
- Precision-feeding
- Cecectomy Surgery
- Tibia Extraction
- Experience with SAS
- Experience with SPSS

Agricultural/Animal specific courses taken:

- Poultry Production (3 credits)
- Poultry Judging (3 credits)
- Applied and Animal Nutrition (6 credits)
- Animal Physiology (3 credits)
- Principles of Animal Science (3 credits)

Graduate Courses:

- Agricultural and Natural Resource Communications (3 credits)
- Methods in Extension Education (3 credits)
- Program Evaluation in Community Education (3 credits)
- Data/Analysis Interpretation (3 credits)
- Nutrition Disease Prevention (3 credits)
- Statistics (6 credits)