

IMPACT OF FEED FORM AND NUTRIENT DISTRIBUTION IN AN AUTOMATED
COMMERCIAL BROILER FEEDING SYSTEM

by

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Abstract

The modern poultry industry uses auger feed lines to transport feed for broilers to pans to make feed available for them while greatly reducing labor costs. The feed given to broilers is manufactured at significant cost into a pelleted form. Pellets reduce broiler production costs by increasing feed intake and growth rate while reducing feed. Pellet quality is expressed using a method called the Pellet Durability Index (PDI). A series of studies was conducted to determine the effects of these destructive forces on both pellet quality and nutritive value. In Experiment 1, it was found that pellets of 78 and 86 PDI had 30% more fines in the final pan compared to the initial pan, but there was no significant difference between the two diets. In Experiment 2, a significant difference existed between a 23 PDI diet and an 82 PDI diet in the percentage of fines found at 12 selected pans. This indicates destruction occurring along the length of the feed line. In Experiment 3, soybean oil was applied to the exterior of the pellets and they were transported through the feed line. A significant difference in the amount of fat at each collection site was found, as the fat was removed from the exterior of the pellets in earlier pans, indicating destructive forces having an effect on the pellets. In Experiment 4, whole sorghum was used to create four diets with similar PDI. The feed was then placed in the feed line, collected at twelve locations, and analyzed for crude fat, CP, DM, ash and Ca. The results indicated the presence of whole sorghum in the pellets had no effect on percent fines or nutrient values. In Experiment 5, three diets with different PDI were transported through the feed line. Five collection sites were selected. Results indicate that high quality pellets withstand handling while pellets below 68 PDI show increased fine percentage. These experiments indicate pellets are damaged during transport in the feed line, but nutrients remain the same unless they are on the exterior of the pellet.

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Chapter 1 - Literature Review

Introduction

Pelleted feed is commonly used in the broiler industry. This feed is commonly delivered using auger feed lines, which may cause some level of pellet destruction, compromising the benefits of pelleting. Many factors may contribute to pellet quality, with pellet mill retention time, mix time, diet composition and steam temperature among them. Each of these factors may have an impact at a variety of levels, but are generally done quickly so as to spare input costs to the feed mill. The effort to which the proper methods are used to create the pellets can be negated by the destructive forces of the feed line.

Broiler House Feed Lines

The development of automated feed lines was, and is, an essential part of the commercial poultry industry. Prior to the development of automated feed lines, birds were fed by hand, requiring hours of expensive labor. Feed was placed in hanging tube feeders. As house size increased, a need for automated feed lines arose.

Flocks increased from 500 birds to 250,000 or greater in the modern industry. Without automated handling, a single poultry grower would need to spend many hours transporting feed. One of the first devices designed to feed broilers was manufactured by Cyclone Manufacturing (Urbana, Ind.). This device would take a canvas bag of seed, the common feedstuff of the era, and would scatter the feed on the ground via a hand crank. This was ineffective as feed would mix with the litter, therefore greatly reducing consumption and feed availability, inevitably effecting overall bird performance.

Many auger feed lines found in modern poultry facilities are controlled by a computer. This computer will start and stop the movement of feed along the line, and automatically adjust feeder height, depending on the age of the birds and the correlating height of the flock. This is essential to ensure the birds are eating the maximum amount of feed possible and bring it to a visual level where it will remain in their sight range. Feeder height is critical for both visual selectivity of feed as well as the physiological consumption of feed. By having feed at the appropriate height, this can limit the energy used to consume the feed while increasing the amount of feed consumed.

A gentleman named Howard S. Brembeck founded CTB International Corporation (Milford, IN.). This company operates under the names Chore-Time and Brock currently, which are two of the most commonly used feed dispersion products in the poultry industry. Chore-time was originally founded in 1952, Brock founded five years later. The business of Chore-time was to create a better and more efficient system for feeding poultry.

By the latter part of the decade, Mr. Brembeck had created a new device which utilized a motorized auger to feed from its source. This auger also had a unique flexibility, allowing it to curve in many directions. The next question that was posed was in regards to the feed source or storage system. Brock manufactured the hoppers that stored the feed to be distributed along the line. Auger feed lines operate by transporting feed through a steel tube with a helix-shaped metal line that operates in a screw-like fashion. As it rotates, feed is transported down the line and dropped in holes along the pipe into feeders that are attached.

These were not the first automated feed lines, however. In 1938, an American company named Big Dutchman was founded by Netherlands immigrants Richard and Jack DeWitt. The automated feed line created by the DeWitts utilized a mechanically driven chain. The feeders

manufactured by Big Dutchman eventually expanded to a global market. These have come to be known as drag-chain feeders. While their use is limited in broiler production today, it is a common method in the layer industry, where the feed is not pelleted.

Drag chain feeding creates many problems in the broiler industry, as does using a mash feed. When mash feed travels along a feed line, or more specifically a drag-chain feed line, feed particles will segregate. As poultry feed segregates, the birds will then become increasingly selective regarding what they eat, based primarily on size and color. Pellets will also become damaged and segregate along a drag chain feeding system. This will then cause uniformity issues as well as growth and nutrition issues.

Another reason drag chain feeding systems are not used in broiler growth is their setup. A drag chain feeding system runs along the bottom of the cages in layer operations. Most broilers are floor-raised, making the possibility for litter and excreta entering the feed a potential issue. The feed may also become covered, and therefore not available on a consistent basis. If feed is limited in any capacity in a broiler operation weight gain may be lost, causing decreased bird growth and potential profits.

Auger feed lines do still have some deficiencies. Uniform distribution of nutrients is one of the foremost concerns with this type of feeding system. Once the feed line has filled completely, both the line and the feeders, the automatic shut-off located after the terminal pan will prevent the auger from running. This will only re-activate when the equipment detects a lack of feed in the final pan. If another pan is to run low on feed, it may not be replenished until the final pan is at a similar level. There is a device manufactured by Chore-Time to aid with this dilemma, but placement is crucial as it may not be cost effective. The same style of termination switch that is found on the terminal pan may be placed on other pans as well. This will aid in

indication that the pan is without feed and reactivate the feed line. This may cause undue stress on the motor, however, as it must activate while the area directly next to the motor is still full, causing excess friction, which can cause an increase in fines. These are particularly useful in poultry houses where dividers are utilized to limit flock migration from one end of the house to the other.

The lifting component of the feed lines allows for a greater ease in cleaning as well as proper height adjustment for consumption. Due to the ability to lift the feed line to the ceiling, a skid steer or other litter removal device can easily fit in the house to remove the litter, as well as keep from contaminating the feed during sanitation. Feed may be spilled onto the litter if the feeder is not at the appropriate height. Birds may kick feed out of the feeder if it is too low, or be more selective in what they eat. While nutritionists formulate precise diets, their effort may become futile if the feed is in the litter or certain portions of the feed are being selected by the birds. Auger lines were originally developed to alleviate some of these concerns.

The computer that operates the feeders also can be programmed to control the heater, fans and curtains in a poultry house. This can help control temperature-related movement within a house. Nipple drinkers, the standard water supply for broiler houses, are also controlled via the computer. The nipple drinkers provide water constantly while the feeders are intended to provide feed on an ad libitum basis as well. The system will control water line height in the same fashion as it controls the feed line height. This is crucial as water consumption will directly affect feed consumption and growth rates. As a bird is warm and does not have access to sufficient water to aid in cooling, they will likely consume less feed as well. Proper water consumption also increases bird consumption and digestibility, thus causing a desire to consume more feed and increasing the need for the feed to be appropriately available.

As the poultry industry has evolved over the years, the equipment has remained similar in design. The primary change has been in the size of the equipment. As the size of poultry houses has increased, so have the size and number of both the feed bins and feed lines, as well as the length of the auger and drag-chain lines. The increased length of the lines also causes more opportunities for pellets to succumb to increased amount of destructive forces, thus causing a potential decrease in pellet quality further along the line. This has also caused an increase in the motor size to move this feed, which has consequently increased energy costs. This will cause a decrease in the profit margin directly.

Most modern poultry facilities use two large feed bins per house, or three bins per two houses. These modern facilities also typically have two lines of pan feeders in a 40 foot wide house. The feed lines are suspended from cables that allow the feeders to be raised for cleaning the house and gathering and loading the birds. These feed lines generally run 200-250 feet in length along either direction inside a house, but may be as long as 400-500 feet. With a device of this size, there is potential for numerous problems.

Chiba *et al* (1984) reported a trend for linear decrease of dietary protein along a distribution system, however also reported that this may have been due to the high values of crude protein. It was also reported that other nutritional factors were not found to vary over the course of an automated feeding system, indicating that nutrients remained uniform in each pan as the feed was transported the length of the feeding system

Feed Formulation and Pelleting

Analyzing the cost benefits of pelleting can be difficult in an integrated operation, a model under which most North American poultry companies operate. Most integrated poultry operations own the feed mills that supply the feed to the contract growers. In many other animal

industries, feed is often purchased from a feed mill and the cost and quality can be directly assessed. Generally, the cost of a feed mill to produce pellets is \$3.50/ ton. However, integration can lead to reduced feed quality when integrators are cost cutting compared to feed made by independent producers.

As companies continue to find ways to decrease costs and increase profitability, many methods of feed manufacturing are considered, some of which can lead to reduced feed quality. One such method to maximize profitability is utilization of a least cost formulation when formulating diets. This takes several factors into account, such as feed availability, feed costs, and nutrient availability. The feedstuffs used to create a diet have a major impact on the pellets created as well as bird performance, as measured by growth rate and feed conversion. Unfortunately, feed formulation programs do not consider losses in pellet quality when changing nutrient sources, so although the ingredient costs are reduced, feed and pellet quality may also be reduced. This reduction in quality can result in great increases in fines when the feed is augered, thus exacerbating the problem.

Most diets formulated in the United States primarily consist of corn and soybean meal. These are generally readily availability in the US at the lowest cost. A diet may not contain solely these two ingredients, however, and some of the lesser utilized ingredients present feed quality challenges. One commonly used source of energy is oil, such as soybean or poultry oil, which is high in fat and energy. Added oil will greatly reduce feed quality making this feed more difficult to handle. Even with this addition, a diet is far from complete. Other micro- and macro-minerals are added, such as limestone and salt, to compensate for the birds physical demands for these nutrients. The availability of nutrients can be a key issue in diet formulation, as some grains are more digestible than others. Recently, enzymes have been incorporated to

increase feed conversion rates. All of these inputs have a great impact on the formulation of the feed and the feed type utilized for the flock, as well as an effect on overall pellet quality, but the added cost may not be worth the value of the returns.

As feed inputs may have an impact on pellet quality, the availability of nutrients to the birds may become lessened. As a pellet becomes reduced in quality, it is prone to disintegrate when passed through handling systems. Birds are selective of their feed by visual means, and generally select their preferred particle size. This will then reduce feed consumption. While pellet binders may aid in the creation of pellets, integrated producers typically will not use them due to increased costs. Pellet binders are popular in other parts of the world, even though they are used sparingly in the U.S. Pellet binders will aid in keeping the pellet together, therefore helping with particle size and nutrient availability.

As feed costs have increased, the need for greater feed efficiency has intensified. Feeding systems and methods, such as auger feed lines and trough feeders, can have a profound effect on feed quality and bird performance. As feed becomes more available to the birds with these feed systems, an increase in growth rate and feed intake may occur due to the constant availability of feed as compared to feeding inconsistencies that may occur with hand feeding. Feeding systems have increased the rate at which feed travels to the birds and decreased the amount of labor input necessary to feed them. It is likely that feeding and handling systems continue to be engineered differently will also affect how feed maintains its form during the feeding process, thus increasing the risk of pellets and crumbles disintegrating.

There are many different methods of feeding management utilized around the world. For example, feed formulations may include whole grain in the diet. While some may add whole grain prior to pelleting, others will add whole grains to the pelleted diet. Adding whole grains

after pelleting may reduce costs but allows birds to segregate feed and consume the whole grain first. Adding whole grains to pellets will lead to reduced pellet quality since the pellets may fracture easily in the handling system. Other methods found both in United States and internationally may include choice feeding, on-site blending and sequential feeding. These methods all tend to incorporate pellets as a primary feedstuff.

Feed formulation is just one of several key factors influencing pellet quality. The nutritional composition of corn is a key factor in both feed production and pellet quality as it is typically the primary ingredient in poultry diets. Many facets and byproducts of corn are utilized for the feedstuff, such as corn starch and corn oil. Cavalcanti and Behnke (2005) reported the effects of corn oil and corn starch on pellet quality. It was discovered that the highest quality pellet, as measured in PDI, was accomplished with intermediate levels of corn starch in the corn and low levels of corn oil. Conversely, the poorest PDI levels were observed when fats were at their highest inclusion rate and starch was at its lowest inclusion rate. A negative affect was observed when starch levels exceeded 65% inclusion rates. Clark *et al* (2009) reported that while corn and its byproducts may negatively affect pellet quality, corn is necessary in a diet and may potentially negatively impact pellet quality. It has been shown that producing pellets using protein base with micro and macro minerals creates a higher quality pellet when corn is removed and fed as a mash aside it. This may limit nutrient availability and starch gelatinization. Starch gelatinizes in corn in the steaming portion of the pelleting process, and without this nutrients from the corn may be less available. The different particle sizes also may impact the feed selectivity of the birds. This demonstrates that the processing of some ingredients differently will affect quality and can affect how feed moves through a feed line.

Clark *et al* (2009) also stated that feedstuffs used to create these pellets have other effects on pellet traits. One such feedstuff that may be utilized is cracked corn. Using cracked corn as a supplement for ground corn may be added to the diet at a rate of up to 25% without having a negative impact on bird growth. This also increases pellet mill output 19% while decreasing overhead costs. A linear negative impact is observed when adding cracked corn at greater rates, however. With a decrease in the amount of corn going into the mill, there is less time in the steamer required as well as less friction-causing product traveling through the die. As mill output increases, typically production costs will decrease even though electrical input increases, as output offsets the increased costs decreasing the cost/ton of feed. Increased mix time, steam holding time and slower output through the die will also create an increase in costs as well. While there is no ideal cost effective diet, reduction in feed mill costs will always be a factor when attempting to manufacture the ideal diet.

As stated by Beyer and Behnke (2002) and Clark (2006), pelleting is one way to enhance the utilization of feeds in a diet. The benefits of pelleting have been well documented. Moritz *et al* (2002) and Beyer and Behnke (2002), some of the benefits include a decrease in feed wastage, a reduction in selective feeding, decreased ingredient segregation, less time and energy spent on prehension, thermal modification of starch and protein, reduced energy expended during prehension and improved palatability. Pellets and their benefits are not isolated solely to the broiler industry. Pellets have been used in the swine industry as well as pet and fish industries.

Feeding devices also have an impact on swine. Feed availability is crucial to the feed selection of the animal. Amornthewaphat *et al* (2005) found that swine were found to be more likely to consume higher rates of feed on a raised wet/dry feeder than in a deep dish. This impact

is also seen in the poultry industries as feed selection is as critical as feed availability. Feed must be easily accessed to increase growth rate as well as feed being the appropriate size to consume.

In the swine industry, Wondra *et al* (1995) found that pellets increased average daily gain (ADG) by 5% as well as increasing feed/gain ratio by 7%. It is believed these benefits derive from increase nutrient digestibility as well as decreased feed waste. It has been found that swine have a decreased average daily feed intake (ADFI) when fed a pellet diet. As the cost of feed, particularly corn, has risen, swine companies are further evaluating the benefits of pelleting to get the maximum amount of energy and nutrient availability from the feed. This may cause an increase in the amount of pelleted feed that is fed in swine production.

In the poultry industry, feed efficiency is not always impacted by pellet quality, but the ADFI and total feed consumed is affected. As the birds consume more feed at the same F:G, they will become heavier and inevitably yield a higher amount of meat, which may then validate the cost of the feed processing, such as pelleting. Pellets have a very significant impact on protein intake and retention. Pellet quality also has an effect on these traits. Lemme *et al* (2006) stated that high quality pellets were found to increase growth by 25% over lower quality pellets and mash in a protein-supplemented diet. Average feed intake also increased with the high quality pellets. The mash diet indicated a higher feed intake with a similar weight gain to the low quality pellets, thus indicating that low quality pellets increase digestibility over mash diets. This is very important when analyzing feeds to determine whether the flock is consuming the optimal diet, which has been shown to be high quality pellets. This also indicates a need to analyze potential causes of pellet degradation, causing a decrease in growth due to a lower quality feed.

Pelleting can also aid in amino acid digestibility, such as lysine. Greenwood *et al* (2004) found birds had a lower lysine conversion ratio when fed pelleted diets in comparison to a mash while achieving similar body weights. This indicates that pellets are better utilized for energy and digestibility and therefore lysine utilization. A higher quality pellet would have an even greater positive effect on amino acid utilization, indicating a need for a more durable pellet.

Pellets have also been shown to increase bone density and mobility in broilers. This is vital as birds must not only be able to move freely to build muscle mass and get to the feeder, but also need appropriate bone density to support larger amounts of much on their frame. Brickett *et al.* (2007) found that gait scores increased for all ages examined when fed pellets instead of mash. Bone ash was found to increase when broilers were fed pellets instead of mash. Feed intake is suspected to be the cause for the increase in bone ash in broilers fed the mash diet as they would go to the feeder with higher frequency. There are many benefits of pelleting, and more specifically producing a high quality pellet, as this is another example of these numerous benefits. Higher gait scores and bone densities also allow the birds to move with greater ease to the feeders.

A mash diet is generally defined as the ground form of a feedstuff. Clark (2006) stated that the need for grinding feed became prominent in the 1920's as studies were conducted showing the benefits of grinding the feed. The primary benefit of grinding feed is a decrease in selection of larger particles by the birds. The amount of segregation that is limited is dependent upon the feed being properly mixed for a reasonable amount of time, as well as being properly ground for a reasonable amount of time. A shorter time of grinding will cause a variation in particle sizes, thus eliminating the purpose of the grinding.

Modern mash diets are first ground and placed in a mixer to enhance uniformity. Feed is then transported in a feed mill to different phases of the process via drag lines, auger lines, elevators, hydraulic, pneumatic and drop systems. When a mash diet is to be pelleted, the feed is then placed into a machine called a conditioner after mixing. The conditioner contains a screw auger or paddle mixing and is fed steam at a previously specified rate. The amount of time feed spends in the conditioner is generally referred to retention time. Increased retention time tends to lead to increased pellet quality.

Some feed mills, specifically overseas, have a device called an annular gap expander. This device is used to increase pressure and temperature prior to pelleting. The annular gap expander hinders feed from leaving the conditioner at a rapid rate, thus forcing it to condition longer and invariably increase pellet quality. This is accomplished by forcing feed into a cone-like structure, increasing both pressure and temperature. The friction also causes an increase in gelatinization of starch, which has a positive impact on pellet quality as well as nutrient availability. Cramer *et al.* (2003) found that expanding also reduced microbial contamination and allow for higher levels of energy-dense fats and oils. While these devices are capable of producing higher quality pellets, they also will slow the pelleting process, therefore decrease profitability.

Expansion also allows for an increased amount of fats and oils to be placed in the pellet, thus increasing growth rate in the flock. A balance may be found between the lowered production of feed using an expander and the increase in bird production with the addition of these feedstuffs. Cramer *et al* (2003) also found expansion to have a 43% increase in gelatinization of starch as well as a 17% increase in pellet quality in comparison to pellets

produced without use of an expander. This will increase the quality of the feedstuff that moves into the pellet mill.

The pellet mill then pushes the feed through a pellet die. The die is a circular metal device with a series of holes at specified widths. The speed at which the blade rotates dictates the length of the pellets. The pellet size generally used in the boiler industry is 5/32 in. width by 1.25 in. length. The pellets are then transferred to a pellet cooler, where they will harden and be prepared for transport.

Studies have shown steam to have an effect on pelleting. Briggs *et al* (1999) found that increased amounts of steam will allow more moisture into the conditioner while increasing water penetration into the ingredients, thus making the feed more apt to binding and inevitably creating a higher quality pellet. The addition of steam increased production rates by up to 64%. Steam not only adds moisture to the feed, thus lubricating it, but also aids in starch gelatinization and increases particle binding. Moritz *et al.* (2002) found that steam also increased pellet durability by 26%. Feed temperature was decreased across the die by 5% with the addition of steam. While the addition of steam has proven effective in aiding the pelleting process, steam pressure has shown no significant difference in the outcome of pellet quality. One potential way to decrease costs is to increase moisture of the feed prior to pelleting. This has been shown to greatly increase production rates while not compromising PDI in corn-soy based diets. This may increase live weight gain in broiler production, and cause a positive impact on PDI in some cases.

Briggs *et al.* (1999) found feed particle size was not found to have an impact on pellet quality in a corn (72.4%) and soybean meal (20.0%) diet. It was found that rations containing raw protein, as compared to denatured protein, produce dramatically stronger pellets. Starch

gelatinization had also been reviewed, but there is conflicting research regarding its effect on pellet quality. Increased oil content has been shown to negatively effect pellet quality. These results merely reflect the many facets of the pelleting process and what may impact the quality of the pellet. A larger particle will mean that there may be more interstitial space and less surface area binding to other particles.

Feed form entering the pellet mill may have an impact on pellet quality. A rolled corn additive was found to increase pellet production rate greatly. Rolled corn did not affect growth rate at 18-29d but when added at or below 25% but did when added at 35%. No noticeable difference was observed at that addition rate, however, from 30-41d. Using whole wheat as an alternative to this was found to have an adverse affect on growth rate but not total body weight. These procedures could potentially offset some of the costs of the feed mill, but may still create the desired pellet quality. Whole wheat is generally used internationally in pellets, which is primarily due to increased availability of the feedstuff. While using a rolled corn additive decreases production costs, it may still create a weaker pellet, causing breakage during the handling process and increasing the potential for selectivity when feeding, causing birds not to obtain the desired formulated diet in full.

Crumbles

Crumbles are a feed form fed to young broiler chicks, typically ranging from 0-14 d, sometimes as long as 21-d. They are created by coarsely breaking apart pellets into a smaller particle size. This allows younger birds easier prehension while still receiving the benefits of pelleting. This allows for the advantages of pelleting, such as starch gelatinization and higher fat contents, to be received by birds in the starter phase as well. Cramer *et al* (2003) found birds between the ages of 8-16d consume primarily particles ranging from 1.18 to 2.26mm, which is a

size found commonly in crumbled diets. The efficiency of crumbling may come into question, as it creates an increased feed mill cost. The benefits of crumbling are generally believed to be higher than the cost of creating them. This also may allow for a smoother transition into a pelleted diet as the bird matures and grows.

Feed Handling

When creating either crumbles or pellets, quality has a significant impact on bird performance. While pellets must be examined for a variety of qualities, durability is a key factor in pellet quality. To quantify this, pelleted feed is tested to determine the effects of common feed mill transfer systems on particular pellet quality measurements. The overall propensity for pellet degradation in a feed mill is likely due to the methods of feed transfer found in that situation. In one particular test conducted by Mina-Boac *et al.* (2006), the feed transferred bins six times, was left for a week and transferred once more. In the first four transfers, there was a 1.9mm difference in the pellets, but the ensuing transfers showed no impact. The amount of broken pellets increased from 17.5% to 50.2% after the eight transfers. This demonstrates the impact common destructive factors may have on pellet quality. Destruction of the pellets may occur in other settings as well, such as feed lines, bagging or transport of the feed.

Pellet quality is often expressed using the term Pellet Durability Index (PDI). While there are many methods of determining PDI, the most common method is the tumbling box, also referred to as a tumbling can. The tumbling box method of PDI testing involves obtaining five hundred grams of sifted sample that is then placed into a dust tight enclosure deemed a “tumble box” and is then rotated for 10 minutes at 50 RPM . An alternative version to simulate heavy destruction utilizes the tumbling box and places up to 5, 13mm hex nuts in the box to aid in the degradation of pellets. This will result in a lower PDI but is utilized when heavy pellet

degradation is likely, such as on-site auger feed lines and multiple passes through feed mill equipment and is typically referred to as adjusted PDI.

In order to appropriately review pellet degradation, we must first review methods for simulating pellet destruction. Most methods are compared to the tumble box for validation, while a validation of the tumble box for broiler feeds has not yet been described. Thomas and Van Der Poel (1996) discussed that one of the first methods was an indirect method utilizing Stoke's Tablet Hardness Tester (Bristol, PA). This was also referred to as a Kahl device. It was originally developed for medication tablets, but was discovered to be effective in measuring animal feed pellets as well. This device is operated manually and places pressure on the pellet to determine the amount of force necessary for it to crack. Most modern versions of this device are automated. This test will generally be run on ten pellets and the average force necessary to break the pellet will be utilized as the hardness figure.

Thomas and Van Der Poel (1996) discussed another such hardness testing device called the Kramer shear press. Usage of this device consists of a hydraulic ram with which a measuring body of shearing blades is attached. This will simulate both compression and shearing damage to the pellet. A graph will be created charting the maximum force. The speed of the ram may also be adjusted to compensate for lower quality pellets.

In a study conducted by McEllhiney (1988), the tumbling box method, which was developed at Kansas State University, was compared to a more modern system called a Holmen tester. The modern Holmen tester is composed of a pneumatic pump pushing pellets through a piped square circuit with pellets enduring destructive forces via simulation by the collisions against the 90 degree angles. Pellets will, on average, run through the circuit 120 times in 1 min. Mean variance on this device was found to be 1.6%. The Holmen tester would derive results in

30 seconds to 2 minutes, in comparison with the ten minute cycle time of the tumbling box. In this study, different feedstuffs were utilized and tested at different time intervals. The Holmen method is most commonly used in Europe due to the pneumatic conveyor devices used in European feed mills, as the Holmen test is a form of pneumatic testing. Pellets will, on average, run through the circuit 120 times in 1 min. Mean variance on this device was found to be 1.6%. The time of the cycle has a very significant impact on the pellet reading, however. In pellets found to have a 89.4 PDI using the Tumble Box method, a 91 PDI feed was shown with a 30s run time, an 82 PDI was shown at one minute while a 64 PDI feed was shown at the company recommended 2 min run time.

Kaliyan and Morey (2006) discussed a more recently developed testing method, named the LignoTester, has been developed. It is manufactured by Boregaard Ligno Tech USA (Omaha, NE). This test utilizes a 100g sample in a perforated chamber and uses air to move the pellets around the chamber for 30 seconds. After the feedstuff is tested, only pellets may be removed from the chamber. The box contains an inverse pyramid design. Forced air is used as the pressure, recommended to be set at 60 millibar. The Ligno-tester did show more sensitivity to pellet binders as well as more destructive force than the alternate method of the tumbling can using two hex nuts. The fines are discarded automatically by the equipment after sifting through the floor of the machine. A PDI will result from the remaining pellets.

Pellet quality is important due to the mechanical handling of the feed. As pellets break apart while traveling along the feed lines, among other transport methods, uniformity becomes an issue. Different birds in different parts of a house may receive different levels of pellets and fines. This will effect growth rates and flock uniformity. This is a greater issue in houses that use barricades to prevent bird migration, as pellets at the end of a feed line may have been

exposed to further destructive forces than those closer to the beginning of the line, thus causing a fluctuation in the quality of feed consumer between sections of the house.

Feeding devices are one of many forms of pellet degradation. Pellets having been placed in such equipment have shown a decreased diameter as well as a larger mass of broken pellets with increased transferring of feed. Mina-Boac *et al.* (2006) used a high PDI (92.9) diet to test handling concerns in a storage bin transfer system, and was found to have an increase of 4% fines after every transfer. The three defined forces of pellet destruction are impact, compression and shear. These are all potential hazards in an auger system. Many of the afore mentioned tests evaluate pellet quality in regards to handling in the feed mill. These tests, however, may also be directly applied to the pellet degradation occurring in an auger feed line. The auger feed line is a potential source of significant destructive factors to pellets.

There are many concerns regarding the auger feed line that need to be examined. One of these issues is in regards to what level of destruction occurs along the feed line. Another problem is with regards to which methods should be using to determine segregation of feed. After that can be determined, it will then be necessary to examine the effect of pellet durability on the destructive ability of the feed line, which would likely be represented in percent fines versus percent pellets. This was determined using a scientific grade number seven sifting screen.

Feed Quality and Feed Handling Systems

Birds tend to flock to different parts of a poultry house dependant on a variety of conditions. Feed, temperature and ammonia content are considered the most likely contributors to house movement. Mobility is another factor that may be influenced by temperature and ammonia content. Over-stocking can lead to a variety of issues related to feed consumption and growth rates, as well as movement within the house and health concerns. This can create a

situation where poor leg health may become prevalent, causing a potential inability to move, which then creates an inability to get to the feed source to consume the necessary amounts of nutrients required for proper bone and muscle health. While the feed lines allow for feed to be available throughout the house, there may be pans or areas where less is available, thus limiting some of the availability options. There have been a number of studies done to evaluate the appropriate flocking densities in poultry houses.

Poultry houses that utilize walls or fences to segregate sections of the house may be more prone to the pitfalls of pellet degradation due to the feed line than a completely open house. Birds with feed available only at the terminal end of the line will receive a much poorer quality of feed than those fed at the initial end of the feed line.

Although birds may have an entire house available, they may still be prone to flocking into one area, thus limiting the feed they consume to one portion of the feed line. This is one area where uniform delivery of feed along a feed line is crucial. The density of modern houses causes the birds to still eat from different parts of the feed line even when dividers are not present. Temperature variations may also cause movement in the house and alter the birds feeding habits. In warm temperatures, birds will flock to the coolest part of the house and limit their movement. In cooler temperatures, they will flock close together around heating units to increase body temperature. If the feed line and the corresponding feed availability is not adjusted or properly analyzed to compensate for such behavior, a decrease in growth rates is likely. Pelleting aids in reducing feed selection. Birds will naturally pick larger pieces of feed from a feeder, making pellets and pellet durability equally important. A lower quality feed will break and thus cause the birds to only select the larger particles, therefore potentially depriving themselves of certain necessary nutrients.

Many aspects of poultry management can be affected by stocking density, such as final BW, ADFI, mortality, overall flock health and F:G. Estevez (2007) discussed the first significant findings related to stocking density were in 1960, when it was shown that final BW decreased as stocking density increased even when the amount of feeders available was adjusted for the amount of birds. Studies have shown a decrease in bird performance when densities reached 14-16 birds per square meter. Feed lines do compensate for some stocking issues as they spread the birds along the house instead of having a single feeding area.

The primary feed selection tool birds will use is vision, especially as the bird ages. Bird feed preferences have been studied using many different methods, one of which is a device called an SRABox. This device has been shown to effectively measure feed selection by placing a bird in a cage with the box in front of them giving multiple locations of two feed options. Birds showed a significant preference for pellets in this scenario, thus increasing the importance of providing a reasonable pellet along an entire feed line. This also indicates that pellet quality is of importance as a higher quality pellet is more likely to maintain its form under modern feed management programs, such as auger feed lines.

Pellet quality will not only impact feed selectivity, but also activity levels, in particular times spent eating and time spent resting. Birds have been found to select pellets over fines when given the option. McKinney and Teeter (2004) found that when birds were offered 80% pellets and 20% fines, the birds opted to consume 87% pellets and 13% fines, showing a significant preference. As pellet amounts reduced below 40% pellets, it became increasingly difficult for birds to choose pellets, and the consumption ratio was equal to that of the feed portion. This became a significant difference after 60% pellets, however, displaying the need to produce a high quality pellet and the impact selectivity has on it. This indicates the selectivity

swayed towards the larger particle size of pellets, thus producing another reason a sturdier pellet should be produced to avoid the destructive forces present within the feed line.

Bird weight uniformity is another issue, as it may impact a farmer's ability to receive a bonus. Integrators sometimes give financial benefits to growers for a large percentage their flock being within a certain weight range. This benefits the integrator due to the increased use of automated equipment. In the harvesting facilities, the birds are stunned and exsanguinated via an automated hanging rack. If birds are different sizes, the blade would need to be adjusted to compensate for the different sizes of the birds, thus slowing the process and increasing labor costs. Pellet uniformity aids in gaining flock uniformity, but may become compromised as pellets may degrade long the length of a feed line. Finding ways to compensate for such variation, such as producing a high quality pellet, may increase the profits of the contract grower when properly utilized.

Mixing

Mix uniformity plays a significant role in pellet production, as one of the benefits of pelleting is uniformity of diet and a complete mix will ensure that uniformity of nutrients. Proper mixing can spread out nutrients such as fat that may have a negative impact on pellet quality. Poor mixing may sacrifice pellet quality as well as nutrient distribution and particle size, as some larger particles may distribute with each other. It also ensures that each pellet is a representative of the formulated diet.

Most diets are mixed to create a complete, uniform diet. Uniformity is important as each pellet should have an equal amount of nutrients. Improper mixing may cause nutrient variability from pellet to pellet. As feed enters the pellet mill, it must be uniform in order to ensure the pellets have the appropriate amount of nutrients. If improper mixing occurs, micronutrients, and

possibly even macro nutrients, will not be properly received by the flock. These variation can effect ADG, ADFI, and F:G. Many studies have been conducted to show these discrepancies.

Clark (2006) found a quadratic linear response was observed through 5 different mix times. ADG was significantly lower in 10-s mix time (56.85g) that 120-s mix times (57.88g). A significantly lower ADFI was observed in the 10-s mix time(105.79) as well when compared to the 120-s mix time(106.35). F:G was affected by two points (1.86 vs. 1.84) between the two diets. While not statistically significant, this may be considered economically significant in an integrated broiler facility.

The effects of mix uniformity are most notable in the grower phase. There are still differences throughout the entire lifespan of broilers, but they aren't as noticeable as the differences found in the grower phase. Feed intake is the most significant trait affected by mix uniformity, as a lower mix time will cause a decrease in ADFI and inevitably a decrease in total bird weight. The issue with an increase in mix time is an increase in feed manufacturing costs.

As mix time increases, the potential to evenly spread nutrients throughout the pellets increases. This is critical to F:G ratios as well as ADFI. A bird will naturally consume more if their dietary needs are not adequately met, reducing growth rates and increasing feed consumption and inevitably total feed costs. Mix uniformity is often represented as coefficient of variation (CV). Clark *et al.* (2007) used a double-ribbon mixer to test the effect of mix time on uniformity. A dry mix time of 120-s, followed by a wet mix time of 180-s was used the standard time used at the facility. A 2.5 min mix time was used to represent 50% of that time, as well as a .5 min mix time. All markers showed a significantly reduced CV in correspondence with decreased mix time. The markers showed inconsistent variations rates in the different times, however. As nutrients are unevenly distributed, they may be received in one section of the line

but not in another. Proper CV and mix time can ensure these issues are not present as well as potentially enhance pellet quality, which in turn indicates less likelihood of pellet degradation in a feed line.

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Chapter 2 - Effect of Automated Feed Systems on Broiler Pellet Quality

Abstract

Automated feed lines are commonly used in commercial broiler houses to provide broilers with feed. Although automatic feeders greatly reduce labor, mechanical handling systems provide the potential for pellet disintegration. A commercial feeding system was used to move experimental broiler feed manufactured to different specifications and samples were collected from feed pans to determine the extent of pellet destruction. In Experiment 1, broiler grower rations manufactured to obtain 78 and 86 Pellet Durability Index (PDI). Broiler grower rations were then placed in the feed line and collected at 12 pans to determine the effect of physical handling on feed form. In Experiment 2, two broiler grower diets (23 and 82 PDI) were transported through the feed line and percent pellets was collected again. The results of Experiment 1 indicated a significant difference in percent pellets between the initial and terminal pans, but no difference in percent pellets between the two diets. Experiment 2 indicated a significant difference in percent pellets between the two diets at all 12 collection sites. A greater amount of fines existed at every pan in the diet with a 23 PDI. Results indicate that feed quality is important when feed is handled by automated equipment.

Introduction

Pelleting feed has been a common practice in the broiler industry for many years.

Pelleting is utilized to increase nutrient digestibility and ease transport, decrease feed segregation and decrease particle selectivity by the birds (Moritz *et al* 2001). Because modern commercial broiler grower operations house and care for as many as hundreds of thousands of birds, it is necessary to use automated equipment such as feed augers to reduce the labor required to run the operation. Friction from rough handling could cause pellets to disintegrate, reducing feed quality and broiler performance. Lemme *et al* (2006) stated that high quality pellets were found to increase growth by 25% over lower quality pellets and mash in a protein-supplemented diet. Average broiler feed intake also increased with the high quality pellets when compared to a lower quality feed. The mash diet resulted in a higher feed intake with a similar weight gain to the low quality pellets, thus indicating that low quality pellets increase digestibility over mash diets and that pelleting reduces the energy needed for digestion. Thus, to maximize growth and reduce feed consumption, manufactured feed must retain its form during handling from the feed mill to the broiler feed pans.

McKinney and Teeter (2004) found that when birds were offered feed with 80% pellets and 20% fines, the birds chose to consume 87% pellets and 13% fines. The difference between pellet consumption and fines consumption became significant after the feed contained 60% pellets. As the amounts of pelleted feed available fell below 40% pellets, it became increasingly difficult for birds to choose pellets, and the consumption ratio was equal to that of the feed portion. This study indicated that broilers selected larger pellets, thus providing evidence for improving pellet quality to avoid the destructive forces present within the feed line.

In transporting the feed via auger feed line, pellets have the potential to become damaged and possibly destroyed as the mechanical action creates friction and shearing that may break pellets and increase fines. These forces are also found in other feed transport methods, such as those found in feed mills. In one particular test conducted by Mina-Boac *et al.* (2006), feed was transferred between bins six times, stored for a week and then transferred once more. In the first four transfers, there was a 1.9 mm difference in the pellets, but the ensuing transfers showed no impact. The amount of broken pellets increased from 17.5% to 50.2% after the 8 transfers. This demonstrates the impact common destructive factors may have on pellet quality. Destruction of the pellets may occur in other settings as well, such as broiler and turkey feeding systems.

When pelleting, steam temperature and retention time are crucial to producing a quality pellet. As pellets are retained in the conditioner for longer amounts of time, the ground feed particles have greater opportunity to bind to each other as well via enhancing the gelatinization of starch. The speed with which the feed is sent through the die also impacts the pellet quality. As speed of the pelleting process increases, the pellet quality will decrease. However, altering the conditions required to manufacture a better pellet increases feed mill costs. Loss of pellet integrity via handling reduces the financial benefits of pelleting. Cutlip *et al* (2008) stated feed manufacturing costs are 60-65% of the total cost of a broiler operation, therefore creating a greater need to maintain feed form as it was manufactured.

Peak *et al* (2000) stated that the modern poultry industry has an interest in increased speed of the automated carcass processing line, which requires a high degree of flock uniformity. Flock uniformity may become an issue as pellet quality decreases along a feed line because birds eating higher amounts of fines will grow slower than the birds consuming pellets. Fattori *et al* (1992) stated that improper feed allocation will become evident in varied body weight goals.

Some companies offer a financial bonus for uniform flocks, as it makes the carcass processing easier. This increases the need to limit variables affecting uniformity, including loss of pellet form as feed is handled in the field. These studies were conducted to determine the effects of automated feeding systems on pellet quality, which may impact flock uniformity and overall broiler performance.

Materials and Methods

Feed was manufactured at the Kansas State University Grain Science Feed Mill (Manhattan, KS) and pelleted using a 1000 series “Master D” 30 horsepower CPM pellet mill. A 5/32 in. width die was used in manufacturing the pellets, which were cut to 1.25 in (4mm x 31.75mm). Feed was bagged in 50 lb. (22.73kg) paper sacks and transported via truck to the Tom Avery Poultry Unit (Manhattan, KS). Feed was stored in dry conditions until use. Feed was then placed in a Chore-Time C2 plus Auger Feed Line with Brock Surge Bin (CTB Manufacturing, Milford, IN). All feed was placed directly in the surge bin, then transported through the 240 foot auger line with 93 pans, spanning 4 pans per 10 ft. segment.

Experiment 1

In Experiment 1, two pelleted broiler diets were formulated and manufactured at the Kansas State University Grain Science Feed Mill (Manhattan, KS) to meet or exceed the National Research Council recommendations for the broiler grower phase (Table 1). Diet 1 was found to have a PDI of 78 as determined via tumble box method (ASAE S269.4), while Diet 2 was found to have a PDI of 86. These diets were then placed in an automated feeding system and the feed was allowed to be distributed to all the pans until the system automatically stopped. Pans 1 (initial pan), 2, 3, 14, 25, 36, 47, 58, 69, 80, 91 and 93 (terminal pan) were selected as collection sites, and pans at those locations were emptied into plastic tubs and were evaluated

when all samples were collected. The total weight, pellet weight and fine weight were determined after sifting the feed by hand with a #7 sifting screen, as determined by the ASTM, placed in a 2 ft. by 2 ft. wooden box with handles. Pellet weight was defined as the weight of all feedstuff left on the sifting screen and fine weight was defined as all feedstuff that passed through the screen. The screen was gently brushed to remove any excess feed particles from the holes so as to avoid improper sifting. These feedstuffs were considered to have stayed with the screens and been added to the pellet weight. This process was repeated through 4 replications.

Pellet durability for all diets was obtained using the tumble box method (ASAE S269.4). This method incorporates a metal box rotating at 50 rpm for 10 minutes with 500g of sample in each of the 4 compartments. Two of the compartments also contained five 13mm hex nuts to simulate aggressive handling.

Experiment 2

Two diets (Table 1) were created with a PDI of 23 (diet 1) and 82 (diet 2), respectively, as determined via tumble box method (ASAE S269.4). The diet with a PDI of 23 was made in the CPM at a rate of 1429.1 kg/hr at ambient T with a 30 sec. blade rotation, operating at 80% motor load. The diet with an 86 PDI was manufactured at 185°C as measure at the expander with a rate of 1272.7Kg/hr, operating at 30% motor load. The same collection pans were utilized to collect feed samples as were described in Experiment 1. Feed was collected as previously described, then sifted using a #7 sifting screen, and total weight, pellet weight and fine weight were determined. Four replications were conducted, collected in plastic tubs and evaluated when all samples were collected, with feed left in the feed line in between replications. The feed was completely removed between the different diets.

Statistics and Analysis

Data was analyzed using a mixed procedure of SAS (release 9.1 for windows, SAS institute, Cary, NC). Experiments were analyzed with feed line replication as the experimental unit. A Dunnett adjustment as used to determine stronger significance. For all tests, $\alpha=.05$.

Results

Experiment 1

A significant ($P>.05$) difference was observed percent fines between pans 1 and 93 on the feed line, but no significant differences were observed among the other data collection points. Feed fines increased from 8.7% fines in the first pan to 33.7% in the last pan in the 78 PDI diet (Table 2). A difference of 8.2% to 27.7% fines was observed in the 86 PDI diet from the initial pan to the final pan. Results did not indicate a significant difference between the percent fines between the two diets. This shows that a difference in PDI of 8% is not relevant to the amount of damage to the pellets that is caused by the feed line, but does indicate that damage occurs along the feed line.

The increase in percent fines indicated pellet degradation along the line of 30%. This indicates that 30% of the total pelleted feed is destroyed to a degree that it becomes classified as fines when measured using the #7 sifting screen box.

Experiment 2

A significant difference ($P>.05$) in percent fines was observed between the initial and terminal pans (Table 3). A significant difference ($p>.05$) was also determined in percent fines between the two diets at each pan, although they degraded at a similar rate. Diet 1 (lower PDI) averaged 80.7% fines among all pans observed as compared to diet 2, which averaged 12.7% fines observed among all pans. A difference in total weight of feed in each pan was observed

between the 23 PDI diet (789 g/pan) and the 88 PDI diet (737g/pan), likely due to greater amount of fines found in 23 PDI diet filling the interstitial space.

Discussion

Regardless of pellet quality as measured by PDI, the auger feed system increased fines during handling and transport. There is a correlation between pellet quality and the percent fines found in the terminal pan, indicating a benefit to producing a higher quality pellet. Producing a higher quality pellet will decrease the amount of fines found at the terminal pan.

The destructive forces of auger feeding systems on pellets will create an increased amount of fines, which will have a negative effect on flock uniformity, potentially costing the contract grower money and creating issues in the processing plant. Flock uniformity becomes compromised as ADFI and growth rate decrease when an increased amount of fines is consumed.

Broilers have instincts to move within a house, whether to huddle to the warmest part of the house during cold weather or to cooler parts of the house during extreme heat. These flocking instincts and the visual selectivity of the broilers also may determine which locations along the feed line they choose to eat from. When a greater amount of fines is present, certain heavier nutrients from the degraded pellet may sift to the bottom of the pan and birds may not be consuming the correct proportions of the rationed diet.

Use of partitions in a poultry house may cause the effects of feed lines on pellet degradation to become more noticeable. Partitions may be used to control bird movement in a larger poultry house or when birds attempt to migrate to more comfortable areas. If one section of the house is receiving a considerably larger percentage of fines in their diet, it is likely that growth rates of the birds in that area, and also their final body weights, will be negatively impacted. This will lead to variation in flock uniformity.

Pelleting is commonly used as a method of enhancing nutrient availability and consistency, but it is possible some of the benefits of pelleting may be offset by the damage a feed line causes to them. Pellets are commonly fed to broilers instead of a mash diet for several reasons, but many of these benefits may be lost when the pellets are returned to a fine form. As Lemme *et al* (2006) discovered, fines have actually been shown to be inferior to feeding a mash diet.

Automated feed lines are very efficient feeding systems, but they may cause considerable damage to pellets, particularly pellets of lower quality. Feed quality may suffer when producers attempt to reduce feed mill production costs or increase feed output. In an integrated operation, a feed mill will be responsible for supplying many farms with feed and therefore need to have the appropriate output to achieve the amount of feed required, which may only be accomplished by moving feed quickly through the pellet mill. Parsons *et al* (2006) stated that nearly 80% of all broiler feed is pelleted, but the benefits may only be realized if pellet integrity is maintained to consumption.

While automated feeding systems have a negative impact on pellet quality, and inevitably ADFI and growth rate, their use is widespread and necessary. Feed mills could compensate by manufacturing higher quality pellets, but further studies need to be conducted to determine if the benefits of producing higher quality pellets is worth the increase in feed mill costs and decrease in feed mill output.

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Table 1. Ingredients and Nutritional Composition of Broiler Grower Rations (Experiment 1 and Experiment 2).

Ingredient	Diet 1	Diet 2
Ground Corn	59.6%	62.7%
Soybean Meal (48.5%)	31.8%	27.2%
Soybean Oil	4.78%	4.00%
Porcine Meat and Bone Meal	2.00%	4.00%
Limestone	1.10%	1.10%
Defluorinated Phosphate	0.47%	0.47%
Salt	0.29%	0.29%
Poultry Vitamin/TM Premix (NB 3000) ^{1,2}	0.25%	0.25%
DL-Methionine	0.10%	0.10%
Feed Additives ^{3,4}	0.23%	0.10%
Calculated Composition		
Metabolizable Energy (kcal/kg)	1472	1456
Crude Protein (%)	20.9	20.0
Lysine (%)	1.14	1.16
Methionine (%)	.43	.41
Methionine and Cysteine (%)	.77	.73
Calcium (%)	.9	.9
Available Phosphorus (%)	.44	.44
Sodium	.17	.17

¹NB3000 supplied by Nutrablend, Neosho, MO

²NB 3000 Supplied at per kg of diet .02% manganese, .02% zinc, .01% iron, .0025% copper, .0003% iodine, .00003% selenium, .69 mg folic acid, 386 mg choline, 6.61 mg riboflavin, .03mg biotin, 1.38 mg vitamin B₆, 27.56mg niacin, 6.61 mg pantothenic acid, 2.20 mg thiamine, .83 mg menadione, .01 mg vitamin B₁₂, 16.53 IU vitamin E, 2133 IU vitamin D₃, 7716 IU vitamin A.

³Diet 1 supplied at per kg of diet .006% Monensin, .05% BMD 50, .005% Thiamin, .003% Vitamin D.

⁴Diet 2 Supplied at .006% Monensin, .05% BMD 50, .005% Thiamin, .003% Vitamin D.

Table 2. Average Percent Fines Per Pan in Two Diets Differing in Pellet Quality (Experiment 1).

Diet 1 (78 PDI)		Diet 2 (86 PDI)	
Pan	Percent Pellets	Pan	Percent Pellets
1	91.3 ^a ±1.7	1	91.8 ^a ±11.0 ^a
2	90.4 ^a ±2.3	2	92.7 ^a ±8.3 ^a
3	93.9 ^a ±1.7	3	95.6 ^a ±7.7 ^a
14	85.0 ^b ±4.1	14	86.0 ^b ±4.3 ^b
25	85.6 ^b ±6.6	25	87.1 ^b ±5.2 ^b
36	83.8 ^b ±7.3	36	85.6 ^b ±6.3 ^b
47	83.1 ^b ±3.1	47	87.2 ^b ±2.5 ^b
58	80.4 ^c ±3.3	58	87.2 ^b ±3.8 ^b
69	73.3 ^c ±5.2	69	81.9 ^c ±3.9 ^c
80	80.9 ^{bd} ±2.0	80	90.9 ^a ±2.6 ^a
91	68.5 ^c ±5.8	91	76.3 ^c ±6.9 ^c
93	66.3 ^c ±7.4	93	72.3 ^d ±7.6 ^d

^{a-d} Numbers without similar superscript in same column are significantly different (p<.05)

Table 3. Average Percent Fines Per Pan in Two Diets Differing in Pellet Quality (Experiment 2).

Diet 1(23 PDI)		Diet 2 (86 PDI)	
Pan	Percent Pellets	Pan	Percent Pellets
1	23.2 ^a ±5.5	1	89.9 ^d ±3.3
2	22.0 ^a ±4.8	2	91.5 ^d ±4.6
3	22.4 ^a ±5.2	3	89.7 ^d ±5.4
14	18.3 ^a ±2.9	14	88.3 ^d ±3.0
25	18.7 ^a ±3.3	25	89.4 ^d ±2.4
36	18.9 ^a ±4.1	36	87.9 ^d ±1.8
47	17.8 ^a ±1.6	47	88.9 ^d ±4.6
58	13.4 ^b ±1.1	58	87.2 ^d ±3.1
69	20.1 ^b ±1.4	69	83.4 ^e ±2.0
80	19.9 ^a ±1.3	80	88.5 ^d ±3.5
91	15.9 ^c ±1.9	91	80.6 ^d ±3.2
93	15.2 ^a ±2.2	93	81.6 ^d ±2.9

^{a-c} Numbers without similar superscript are significantly different (p<.05)

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**Chapter 3 - The Interaction of Feed Quality and Composition on
Nutrient Distribution and Pellet Quality in an Automated
Commercial Broiler Feeding System**

Abstract

Automated feed lines are used in commercial broiler operations to provide broilers with feed. These systems also reduce labor costs. Broiler operations may have hundreds of thousands of birds and efficient distribution of feed via automation is essential for the farm to operate. A 240 foot auger feed line was utilized to distribute feed to a set of broiler pans. Samples were collected from selected pans to determine the extent of pellet degradation. In Experiment 1, a pellet ration was coated with a spray-on liquid fat, placed in the feed line and then samples were collected, sifted, weighed and analyzed for crude fat. The fat content was higher in fines as compared to pellets. An increased amount of fat was observed in the terminal pan compared to the initial pan. Experiment 2 was conducted by creating 4 diets with varying degrees of whole sorghum added at 0%, 10% 20% and 30% whole sorghum. These diets were transported via automated broiler feeding system and collected at specific pans for analysis of CF, crude fat, CP, ash and Ca. There were no significant differences between the nutrient levels between collection pans. In Experiment 3, three diets were manufactured with varying quality (PDI levels 23, 66, and 86) as determined using the tumble box method and a Lignotester for comparison. Each diet was then placed in the automated feeding system, transported, and collected from 5 different pans. While tumble box PDI levels were within 8.5% of the percent pellets remaining at the end of the feed line, the Lignotester tester indicated greater inconsistencies. Pellet quality testing remains important as it affects feed selection and broiler performance, even though a complete nutrient profile may be available in each pan.

Introduction

Pelleting feed has been a common practice in the broiler industry for many years. Moritz *et al* (2001) stated that pellets are beneficial to broiler chickens and farmers due to ease of handling and improved gains in bird performance. McKinney and Teeter (2004) discovered that pelleted feeds reduce energy required by broilers due to less energy spent on acquiring feed. Average broiler feed intake also increased when fed high quality pellets, while lower quality feed caused a lower feed intake. This is important since increased feed consumption will lead to faster growth rates and less time on the farm. The mash diet indicated a higher feed intake when compared to the low quality pellets, with a similar weight gain to the low quality pellets, thus indicating that low quality pellets increase digestibility over mash diets. Lemme *et al* (2006) found that high quality pellets were found to increase growth by 25% over lower quality pellets and mash in a protein-supplemented diet.

Parsons *et al* (2006) stated that nearly 80% of all broiler feed is pelleted, but the benefits may only be realized if pellet integrity is maintained from the feed mill to the fed pans. The destructive forces of a feed line may compromise that feed form. In transporting the feed via automated broiler feeding system, pellets have the potential to become damaged and possibly destroyed as the mechanical action creates a destructive force. These forces are also found in other feed transport methods, such as those found in feed mills. In a test conducted by Mina-Boac *et al.* (2006), pelleted feed was transferred between bins 6 times, left for a week, then transferred once more. In the first four transfers, there was a 1.9mm difference in the pellets, but the ensuing transfers showed no impact. The amount of broken pellets increased from 17.5% to 50.2% after the 8 transfers. This demonstrates the impact common destructive factors may have

on pellet quality. Destruction of the pellets may occur in other settings as well, such as broiler and turkey feeding systems.

Pelleted feed is important as it has been found to be the preferred feed form for broilers. McKinney and Teeter (2004) found that when birds were offered feed with 80% pellets and 20% fines, the birds chose to consume 87% pellets and 13% fines. As the amounts of pelleted feed available fell below 40% pellets, it became increasingly difficult for birds to choose pellets, and the consumption ratio was equal to that of the feed portion. The difference between pellet consumption and fines consumption became significant after 60% pellets, however, indicating another reason to produce a high quality pellet. This study indicated that broilers selected larger pellets, thus providing evidence for improving pellet quality to avoid the destructive forces present within the automated feeding system.

Pellet quality is measured using Pellet Durability Index, or PDI. While there are many methods for testing PDI, the tumble box is considered standard for research (ASAE S269.4). The Lignotester method has become more prevalent in industry use, however, due to its shorter run time.

Spray-on additives are often used to add nutritive value to pelleted feeds, whether it be a liquid fat, liquid enzyme or drug. Thomas and Van Der Poel (1996) stated that fat is also sprayed on to aid in pellet quality as the addition of fat to a formula will decrease pellet quality. Edens *et al* (2002) found that using spray-on phytase was more cost effective, although it was less stable than the dry phytase added to the mixed feed. These are generally added immediately after pelleting, although some spray-ons, such as phytase, are heat sensitive. As the pellets are transported and damaging forces occur, the possibility of the spray-on additive being separated from the pellet becomes increasingly likely, as it is the first thing to contact these forces.

Fattori *et al.* (1992) stated that improper feed allocation will become evident in varied body weight goals. Auger feed lines that degrade pellets could result in fines distributed in certain parts of the system as well as allowing nutrients to segregate. An increase in fines could negatively impact uniformity. Some companies offer financial bonuses for uniform flocks, as it makes carcass processing easier. Nutrients being available consistently throughout a house will create better uniformity. These studies were conducted to find the impact of the destructive forces of an automated feed line on both pellet quality and nutrient distribution.

Materials and Methods

Experiment 1

Broiler feed was manufactured at a commercial feed mill (Key Feeds, Clay Center, KS) to meet or exceed the National Research Council recommendations for the broiler starter phase. Feed was bagged in 50 lb. paper sacks and transported via truck to the Tom Avery Poultry Unit (Manhattan, KS). The feed was stored in dry conditions at ambient temperature until use. The feed was then placed in a Chore-Time C2 plus Auger Feed Line with Brock Surge Bin (CTB Manufacturing, Milford, IN). All feed was placed directly in the surge bin, then allowed to be distributed through the 240 foot auger line with 93 pans, spanning 4 pans per 10 ft. segment.

For Experiment 1, pellets were placed in a Davis S-3 mixer (HC Davis, Bonner Springs, KS) directly from the bag so as to limit handling affects. They were then coated with 4.85% soybean oil by mixing for two min and applying the soybean oil manually. Pellets were removed from the mixer and placed into plastic tubs. Percent fines were determined after mixing occurred to account for any potential damage the mixer may have caused. Pellets were then carried by hand and placed in the surge bin and the remaining feedstuff was collected from pans 1, 2, 3, 14,

25, 36, 47, 58, 69, 80, 91 and 93. After collection, the feed was hand sifted using a #7 sifting screen placed at the bottom of a 2 ft. by 2 ft. wooden box with handles. Pellet weight was defined as all feedstuff remaining on the screen after sifting. Any feedstuff remaining in the holes of the screen was gently cleaned off and weighed with the pellets.

After weighing the test feed, pellets and fines were placed in sample collection bags for laboratory analysis of nutrients. Samples were stored for 2 days in a dry room at ambient temperature. All samples were analyzed to determine any potential variation from any other pan for crude fat (AOAC 930.39).

Experiment 2

Four pelleted broiler diets were manufactured at a commercial feed mill (Key Feeds, Clay Center, KS) to meet or exceed the National Research Council recommendations for the broiler starter phase. These diets were formulated and manufactured with varying degrees of whole sorghum utilized in the pellet (0%, 10%, 20% or 30%). These diets were stored at ambient temperature in a dry environment until placed in the automated feed line. Feed was collected and weighed as described in Experiment 1. Pellets and fines were then analyzed for Crude fat (AOAC 930.39), CP (AOAC 990.03), DM (AOAC 930.15), ash (AOAC 942.05) and Ca (AOAC 968.08). The pellets were also analyzed for pellet durability using the tumble box method. Feed was then placed in a Chore-time C2 Plus feeder via Brock Surge Bin as described in Experiment 1.

Experiment 3

Three pelleted diets were manufactured at the Kansas State University Grain Science Feed Mill (Manhattan, KS) and pelleted using a 1000 series “Master D” 30 horsepower CPM pellet mill. A 5/32 in. width die was used in manufacturing the pellets, which

were cut to 1.25 in. Feed was bagged in 50 lb. paper sacks and transported via truck to the Tom Avery Poultry Unit (Manhattan, KS) (Table 4). The first diet (diet A) was manufactured at ambient temperature with an 80% motor load and 30 sec. rotation, producing 3144 lb/hr. The second diet (diet B) was manufactured at 120 degrees F at 55% motor load with a 30 sec. rotation, producing 3372 lb/ hr. The third diet (diet C) was manufactured at 180 degrees F with 30% motor load and a 30 sec rotation, producing 2800 lb/hr. These three diets were then tested for PDI using the tumble box method (Kansas State University, Manhattan, KS) and the Lignotester (LignoTech, Omaha, NE). Three replications were done of each PDI test with both devices. The pellets were also tested prior to sifting and after sifting to determine any possible correlation to the auger feed line in field use.

The diets were then placed in 50 lb. bags and stored at ambient temperature in a dry area until use. When placed in the feed line for transport, the feedstuffs were added directly to the surge bin. Feed was collected at 5 locations along the feed line to represent each quartile; the first, 24th, 47th, 70th and 93rd pans. The feedstuff was then collected from the pan in a plastic tub until all samples were collected for analysis. Pellets and fines were then separately bagged for potential further analysis.

Statistics

Data was analyzed using a mixed procedure of SAS (release 9.1 for windows, SAS institute, Cary, NC). Experiments were analyzed with feed line replication as the experimental unit. A Scheffe adjustment as used to determine stronger significance. For all tests, $\alpha=.05$.

Results

Experiment 1

A difference of 1.53% to 2.49% fines was observed from the initial pan to the terminal pan, indicating that rations with high PDI are less affected by handling. A significant difference was observed in percent fat in each pan between pellets and fines (Table 6). The amount of fat found in pellets is also significantly higher in the final six pans compared to feed entering at the beginning of the automated broiler feeding system. Percent fat in fines was significantly higher than percent fat found in pellets or the control, indicating that the soybean oil on the exterior of the pellet was getting stripped off as pellets abraded. Fines were determined to have an average of 7.87% fat while pellets were observed to have an average of 7.16% fat.

Experiment 2

No significant ($P > .05$) effect was noted in percent pellets between the four diets. The results indicate that 0, 10, 20 or 30 whole sorghum had no effect on destructive forces administered from the automated feeding system during handling. The results also indicate no significant difference ($p > .05$) between pan pellet percent averages (Table 7). The difference in percent protein from the highest amount (pan 6) and the lowest amount (pan 2) was 1.51%, while the difference between the highest percentage of ash (pan 1) and lowest percentage of ash (pans 2 and 3) was .48%. The difference between the highest percentage of Ca (pan 1) and lowest percentage of calcium (pan 2) was .22%. These numbers were not found to be significantly ($p > .05$) different, thus indicating minimal effects of the feed line on nutrient distribution with these particular pellets.

Experiment 3

The three diets indicated a decrease in percent pellets from the initial pan to the terminal pan. Diet A resulted in a variation in percent fines of 24.5% from the initial pan to the terminal pan, while diet B resulted in a variation in percent fines of 13.4% and diet C resulted in a variation in percent fines of 7.0%. This indicates that a higher PDI diet is likely to create fewer fines. The differing pellet durability tests indicated a variation between the Lignotester and tumble box methods (Table 5). Diet A was found to have a PDI of 23 (5 adjusted PDI) when using the tumble box method when sifting prior to testing, compared to a PDI of 11.6 when utilizing the Lignotester. Diet B had a PDI of 66 (47 adjusted PDI) in the tumble box compared to a PDI of 9 in the Lignotester, while diet C had a PDI of 86 (81 adjusted PDI) in the tumble box compared to 62 PDI in the Lignotester. Results indicate the Lignotester is a more aggressive testing method and may struggle to differentiate between pellets of marginal quality.

Feed line results indicate disintegration of pellets occurred along the length of the automated feeding system, as well as a variation in the amounts of pellet disintegration between the different diets (Table 8). Diet 1 was resulted in an average of 49.5% pellets as directly measured from the bag, compared to 94.2% for diet 2, and 97.4% for diet 3. pellets.

Percent pellets in the terminal pan were 27.9% when examining diet A, 73.4% pellets when examining diet B and 78.1% pellets when examining Diet C. These numbers indicate destructive forces occur along the length of the automated feeding system, leading to degraded pellets. When compared to the tumble box and Lignotester testing numbers, there is less correlation. The tumble box resulted in a PDI of 22.9 for diet 1 and the Lignotester test for diet 1 resulted in 11.7. The PDI for diet 2 was 65.8 when using the tumble box method, while the data indicated that the feed in the Lignotester tester had a PDI of 9.2. Diet 3 had a result of 86.4 PDI

when examined via the tumble box method, while the data indicated that the feed in the Lignotester method had a PDI of 61.7. These results suggest that the Lignotester tester is more aggressive and gives a different scale of numbers, while the tumble box method estimate was within 8.5% in all cases.

Discussion

Nutrient analysis indicated that the only nutrients that weren't distributed uniformly due to the feed line were those coated on the exterior of the pellets. All other nutrients, under standard mixing conditions, did not show variation even as the pellet disintegrated. Pellets that were analyzed for nutrient distribution had a higher PDI, thus reducing the potential for pellet disintegration. A lower PDI diet may be more susceptible to degradation along a feed line and will need to be appropriately examined for nutrient distribution.

The whole grain diets did not result in a difference in percent fines using a #7 sifting screen, a larger screen may result in alternate data. The #7 screen was used to prevent particle sizes that may be considered pellets from passing through the screen, thus causing potentially inaccurate data due to the diameter of a pellet being similar to the diameter of larger pieces of whole sorghum. The pelleted whole grain also had a very high PDI, which could indicate a reduced degradation of the pellets and therefore limit the possibility of nutrients relocating or segregating.

The lack of variation between the Diet A and Diet B using the Lignotester in Experiment 3 indicates a deficiency in the tester's ability to define a high quality pellet from a low quality pellet as compared to the results derived from the tumble box method. The tumble box method did indicate a relationship with the destruction the feed line causes to the pellets when sifted and performed properly (ASAE S269.4), but results were not similar when comparing the adjusted

PDI or the feed that was not sifted prior to examination. While the five 13mm hex nuts are added to simulate excessive pellet disintegration, this did not occur in the feed line, suggesting the auger feed line is not a source of excessive damage.

While nutrient uniformity was not impacted by the destructive factors of the feed line, pellet quality was still affected. The lower pellet quality may cause variation in growth rates among birds in a house, especially a house with partitions. Partitions are used due to the instinct of broilers to move within a house, whether to huddle to the warmest part of the house during cold weather or to cooler parts of the house during extreme heat. This may cause a decrease in flock uniformity if the birds are confined to an area that has fines in the feed. Peak *et al* (2000) stated that the modern poultry industry has an interest in increased speed of the automated carcass processing line, which requires a high degree of flock uniformity. The impact of decreased uniformity may have financial ramifications as well, as some poultry producers provide a bonus to a contract grower for uniform flocks.

Pellet degradation along a feed line could benefit from further research, particularly to examine the cost of increased pellet quality in comparison to the financial ramifications of decreased growth rates and decreased flock uniformity. Cutlip *et al* (2008) stated feed costs are 60-65% of the total cost of a broiler operation, therefore creating a greater need to maintain feed form as it was manufactured. Automated feeding systems have negative effects on pellet quality and should be further examined for the impact they may potentially have on broilers.

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Table 4. Ingredients and Nutrient Composition of Broiler Starter Rations (Experiment 3).

Feed	Percent of Diet
Ground Corn	60.39%
Soybean Meal 48.5%	30.50%
Soybean Oil	3.40%
Limestone	1.18%
Monocalcium Phosphate 21%	0.99%
Salt	0.25%
DL-Methionine	0.24%
Porcine Meat and Bone Meal	2.50%
Feed Additives ^{1,2}	0.38%
Calculated Composition	
Metabolizable Energy (kcal/kg)	1429.3
Crude Protein (%)	21.0
Lysine (%)	1.4
Methionine (%)	.56
Methionine and Cysteine (%)	.89
Calcium (%)	.9
Available Phosphorus (%)	.44
Sodium	.16

¹Supplied at per kilogram of feed at .05% Coban (product of Elanco Animal Health, Greenfield, IN), .04% BMD-60 and .04% L-Lysine 98%, NB3000 supplied at per kg of feed of .02% manganese, .02% zinc, .01% iron, .0025% copper, .0003% iodine, .00003% selenium, .69 mg folic acid, 386 mg choline, 6.61 mg riboflavin, .03mg biotin, 1.38 mg vitamin B₆, 27.56mg niacin, 6.61 mg pantothenic acid, 2.20 mg thiamine, .83 mg menadione, .01 mg vitamin B₁₂, 16.53 IU vitamin E, 2133 IU vitamin D₃, 7716 IU vitamin A.

²NB3000 supplied by Nutrablend, Neosho, MO

Table 5. Pellet Durabilites of Broiler Pelleted Feed Utilizing Various Methods and Three Diets Differing in Pellet Quality.

Diet	BS ¹	BSA ²	BU ³	BUA ⁴	LS ⁵	LU ⁶
Diet 1	0.228	0.052	0.183	0.045	0.116	0.067
Diet 2	0.658	0.468	0.618	0.445	0.092	0.100
Diet 3	0.864	0.810	0.830	0.780	0.627	0.508

Diet	Pan1	Pan2	Pan3	Pan4	Pan5	Bag
Diet 1	52.5%	40.2%	42.0%	39.6%	27.9%	49.5%
Diet 2	87.0%	84.2%	83.8%	78.1%	73.4%	94.2%
Diet 3	85.8%	87.8%	88.0%	79.5%	78.1%	97.4%

¹ Tumble box Method with sifting prior to operation

² Tumble box method with five 13mm hex nuts to represent adjusted PDI

³ Tumble box without sifting prior to operation

⁴ Tumble box method without sifting prior to operation with five 13mm hex nuts

⁵ Lignotester with sifting prior to operation

⁶ Lignotester without sifting prior to operation

Table 6. Percent Fat in 12 collection sites of Automated Feed System after 4.85% Spray-on fat applied (Experiment 1).

Pan	Percent Fat in Pellets	Percent Fat in Fines
Control	6.81% ^a	6.81% ^a
1	6.96% ^a ±0.27 ^a	7.82% ^c ±0.32
2	7.12% ^a ±0.23 ^a	7.97% ^c ±0.34
3	6.94% ^a ±0.16 ^a	7.98% ^c ±0.60
4	7.01% ^a ±0.31 ^a	8.06% ^c ±0.39
5	6.97% ^a ±0.16 ^a	7.84% ^c ±0.41
6	7.15% ^b ±0.26 ^b	8.06% ^c ±0.34
7	7.26% ^b ±0.21 ^b	7.78% ^c ±0.39
8	7.25% ^b ±0.36 ^b	7.91% ^c ±0.52
9	7.28% ^b ±0.32 ^b	7.93% ^c ±0.37
10	7.38% ^b ±0.34 ^b	7.81% ^c ±0.31
11	7.27% ^b ±0.11 ^b	7.65% ^c ±0.51
12	7.31% ^b ±0.42 ^b	7.69% ^c ±0.46
Total Average	7.16% ^b	7.87% ^c

^{a-c} Different letters indicate significant differences (p>.05) between values

Table 7. Percent Nutrients at Each Collection Pan Along Automated Broiler Feeding System (Experiment 2).

Pan	Protein(%)	Fat(%)	Ash(%)	Ca(%)
Control	20.89 ^a ±0.81	4.69 ^b ±0.10	7.47 ^c ±0.16	1.18 ^d ±0.07
1	19.92 ^a ±1.33	4.60 ^b ±0.16	8.12 ^c ±0.40	1.38 ^d ±0.09
2	19.88 ^a ±0.67	4.57 ^b ±0.15	7.64 ^c ±0.39	1.16 ^d ±0.11
3	20.35 ^a ±0.63	4.66 ^b ±0.20	7.64 ^c ±0.07	1.18 ^d ±0.03
14	20.09 ^a ±1.08	4.67 ^b ±0.13	7.83 ^c ±0.37	1.28 ^d ±0.10
25	20.45 ^a ±0.76	4.67 ^b ±0.01	8.06 ^c ±0.27	1.38 ^d ±0.10
36	21.39 ^a ±1.22	4.68 ^b ±0.16	7.88 ^c ±0.15	1.29 ^d ±0.06
47	20.85 ^a ±0.49	4.69 ^b ±0.07	7.91 ^c ±0.24	1.28 ^d ±0.09
58	20.05 ^a ±0.89	4.68 ^b ±0.18	7.84 ^c ±0.30	1.30 ^d ±0.14
69	20.92 ^a ±0.62	4.74 ^b ±0.13	7.74 ^c ±0.37	1.21 ^d ±0.17
80	20.81 ^a ±1.13	4.82 ^b ±0.06	7.85 ^c ±0.39	1.22 ^d ±0.09
91	20.53 ^a ±0.82	4.71 ^b ±0.14	8.02 ^c ±0.33	1.32 ^d ±0.16

^{a-d} Indicate Significant ($p > .05$) difference between percentages

Table 8. Percent Pellets at Selected Pans Along an Automated Broiler Feeding System For Different PDI Values (Experiment 3).

Average Percent Pellets by Pan			
Pan	Diet A (23 PDI)	Diet B (68 PDI)	Diet C (88 PDI)
1	52.5 ^a ±13.4%	87.0 ^d ±5.1%	85.8 ^d ±4.7%
24	40.2 ^b ±4.4%	84.2 ^d ±2.6%	87.8 ^d ±1.4%
47	42.0 ^b ±5.3%	83.8 ^d ±1.5%	88.0 ^d ±2.0%
70	39.6 ^b ±7.0%	78.1 ^d ±5.2%	79.5 ^d ±11.3%
93	27.9 ^c ±10.9	73.4 ^e ±13.9%	78.1 ^d ±5.8%
Control	49.5% ^{ab}	94.2% ^f	97.4% ^f

^{a-f} Indicate Significant (p>.05) difference between percentages

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