SELF-SELECTION OF ANIMAL BY-PRODUCT BY POULTRY THROUGH UTILIZATION OF CHOICE FEEDING

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled:

Self-Selection of Animal By-Product by Poultry Through Utilization of Choice Feeding

presented by Liam Carlson, a candidate for the degree of Master of Science, and hereby certify that, in their opinion, it is worthy of acceptance.

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INTRODUCTION

The emergence of animal welfare provisions by humane societies has limited management practices. One of these provisions is the animal's freedom to express normal behavior. Animal by-product feeding to livestock and poultry is a common management practice and it is stigmatized in the public eye and some animal welfare activists. Certification processes by organizations like the Humane Farm Animal Care association are trying to remove the use of animal by-products from animal feed and move to more "vegetarian diets" due to the belief that the consumption of animal by-product is not part of the animal's normal behavior.

In the United States, animal by-product is everything produced by the animal except for the dressed meat which is used for human consumption (Jayathilakan, 2011). Animal by-products have a variety of uses, in both edible and inedible forms. In the agriculture industry, all the animal is utilized to maximize profits and minimize waste.

We've seen many food related scares over the last few decades, and today, the public generally views animal by-product feeding as unnatural and don't approve of livestock and companion animals being fed rendered animal by-products. We see this with consumer pressure to shift humane standards in how animals are raised, and the increase in labels like “vegetarian fed” diets in which animal derived products are not used in the production of livestock/poultry. Animal by-product utilization is financially and environmentally important to several industries (Jayathilakan, 2011). The two most common methods of waste utilization have been to use the waste as either animal feed or fertilizer (Jayathilakan, 2011). Focusing on animal product utilization, In the United States alone, we produce 11.2 billion lbs of animal by-products and 10.9 billion lbs of rendered fats annually. Around 85% of these produced by-products are used for feed in the animal industry (Meeker, 2006). Using both animal by-products and fat deposits are important to many other industries, the majority is used in the animal industry with tallow and animal by-products used in creating both commercial livestock feed and pet food. Waste disposal and by-product management in the food processing industry pose problems in the areas of environmental protection and sustainability (Russ and Pittroff, 2004).

Choice feeding allows for animals to express normal behavior, which is important in today’s societal climate where pressure to change animal welfare standards is prevalent. The freedom to express normal behavior falls under one of the Five Freedoms of Animal Welfare (Farm Animal Welfare Council).

With increasing competitiveness of the poultry industry, the need to cut costs while maximizing feed efficiency and growth of the animals is a recurring theme. Use of animal by-products allows for efficient production of poultry. Use of animal by-products is a cheap and effective alternative to plant-based protein sources in the feed industry. Additionally, the importance of utilizing animal by-products is undervalued as it impacts several industries outside animal feed. Allowing poultry to choose between various feed ingredients including animal by-products should be considered an expression of normal behavior.

ANIMAL WELFARE

Animal welfare is broken into three major parts: their overall health, their affective status, and their environment. A healthy animal and promoting good animal welfare depend on meeting the needs of the animal (Appleby et al., 2018). These broad concepts encompassing animal welfare can be further broken down and over the years, have developed into the Five Freedoms of Animal Welfare.

The Five Freedoms of Animal Welfare contain a long history and they have been around since around 1965. Brambell, in Dec. 1965, created a report in which he underlined the behaviors of animals and claimed what they should have the freedom to do, which became "Brambell's Five Freedoms." This was later adopted by and revised by the Farm Animal Welfare Committee and became the now known "Five Freedoms of Animal Welfare" which is widely adopted through organizations like the American Humane Association and is considered the gold standard for animal care.

This currently used model of the Five Freedoms is as follows:

1. Freedom from thirst, hunger, and malnutrition – having access to fresh water and a full nutritional diet.

2. Freedom from discomfort and exposure – having a suitable, comfortable shelter and environment
3. Freedom from pain, injury, and disease - preventing or rapid diagnosis or treatment.
4. Freedom from fear and distress – having conditions that aid in avoiding mental suffering.
5. Freedom to express normal behavior – providing space, proper facilities, and social company with animals of its own kind.

A newer model has been introduced over the last several years called the "Five Provisions of Welfare" which intertwines with "Animal Welfare Aims" are an alternative to the Five Freedoms (Mellor, 2016). The Five Freedoms is still currently the adopted standard for many livestock and companion animal organizations/producers. The Animal Welfare Act of 1966 which is the only Federal regulatory piece of animal treatment aids in the proper handling of both livestock and companion animals (*Animal Welfare Act*, 1966).

CHOICE FEEDING

With the rise of animal welfare activism and public pushback in the agriculture and animal production world, there is a demand shift from large-scale production back to small, family farms due to the stigma of "factory" farming. Giving animals the opportunity to choose between different feedstuffs allow them the freedom to express normal behavior according to animal welfare concepts.

Given a selection of nutritionally different ingredients, animals should inherently be able to naturally formulate its own balanced diet. Choice feeding is the natural selection of feeds by an animal to meet its nutrient requirements (Overmann, 1976; Cumming, 1992). Emmans in 1991 describes the 3 key parameters in feed are protein, energy, and minerals.

While goals of choice feeding research vary, a lot of traditional choice feeding research aims to show potential benefits for choice feeding poultry in a production setting. Munt and colleagues in 1995 observed that while body weights of birds offered either a pelleted diet or choice fed diet differed – with birds consuming pelleted diets weighing more - choice feeding had an overall cost savings of 15% over complete diets. Fanatico and colleagues in 2013 observed that free-choice feeding is effective for outdoor production systems because poultry can forage for nutrients on top of supplemented feed. Free-range, free-choice fed chickens had similar weight gain and a lower breast yield compared to chicken fed a formulated diet. In this study, the cost was cheaper for the choice fed group vs the formulated diet group. As described in Karunajeewa’s review (n.d.) of choice feeding in poultry, there are downsides and benefits to choice feeding. Biologically, poultry have been variable in their ability to adapt to choice feeding and shown different results in growth itself while on that system. Typically, poor performance with choice feeding systems is due to birds failing to consume enough energy, as they usually over-consume protein.

We can get a general sense of nutrient requirements for the animals through choice-feeding, as they'll adjust what they eat based on their physiological requirements. This idea of animals formulating their own diet is supported by the aminostatic theory. However, there are behavioral aspects that exist as well. Forbes and Shariatmadari (1994) observed that birds will sample other feedstuffs/diets even after they have learned if a diet is nutritionally adequate.

Choice feeding broilers

Work done by a Mastika (1981, 1987) showed free-choice feeding in broiler chickens and how they get acclimated to naturally selecting a diet and how important it is to them. Broilers take about 10 days to learn to accurately balance their protein concentrate and whole-grain intakes. Beyond that, they need to be in groups of at least 8 birds and offered protein and whole-grain in identical troughs (either the same one or adjacent troughs).

Broilers will select foods with nutritional purpose, and flavor doesn't influence their intake in the long-term (Balog and Millard, 1989). While flavor doesn't influence intake, they do show preferences to diets (Henuk and Dingle, 2002). Work has been done on choice feeding some individual AAs and minerals throughout the years. When using a choice feeding system, the choice of feed should not be nutritionally close. Ingredients should be distinctly different nutritionally so birds can make an appropriate judgment on what best fits their needs. For feeding vitamins and minerals, they should be mixed into grain or another ingredient because a vitamin/mineral premix alone might have poor palatability and taste to the birds and they won't consume it (Bennet, 2003). Research by Gous and Swatson in 2000 showed broilers would attempt to maximize their performance by choosing the best possible combination of protein sources given to them. Choice-fed broilers choose an average protein content of 189 g/kg, giving them a similar growth and body composition compared to those fed a single feed containing 225 g/kg of protein (Forbes and Shariatmadari, 1994). This shows that broilers will tend to eat less/close to the same amount of protein as those fed a formulated diet and grow similarly. However, Gabriel and collleagues in 2003 observed no effect of whole wheat on performance of broilers given free choice. Amerah and Ravindran (2008) found lower body weight of broiler chickens when whole wheat was offered in a free-choice setting.

Protein concentrates and energy source (whether it was pelleted, whole, or mash) has no significant effect on body weight, feed intake, or feed efficiency of male broilers at 42 and 56 days of age (Olver and Jonker, 1997). Joshua and Mueller in 1979 showed that broilers fed a calcium-deficient diet consumed more of a separate calcium source than the control set of birds that were fed adequate amounts. The birds that were choice feeding also ate less calcium by day than the control birds who consumed a complete diet, showing a possibility that current calcium requirements are too high by industry standards. Driver and colleagues in 2005 found that the NRC requirements might also be too high for growing broilers as excessive calcium began to linearly decrease feed efficiency. Selle and colleagues (2009) found that overfeeding calcium hinders phytase activity as calcium binds to phytate in the GI tract, hindering phosphorus absorption in broilers.

Choice feeding layers

Cumming (1992) observed differences in strains, layers adjusted faster to a choice feeding setting than broilers, and brown egg layers faster than white egg layers. Though this faster adjustment might be hindered as evidence shows layers seem to be less able to balance their protein intake than broilers (Forbes and Shariatmadari, 1994). Further, Bradbury and colleagues (2014) found that layers were unable to consistently choose calcium at a sufficient level for production when given the choice between diets with varying levels of calcium. Layers given the choice between 170 or 230 g CP/kg showed no differences in egg mass between the choice groups, and they show no significant differences in body weight gain. Though they could select protein intake corresponding to their requirements for egg production, their ability was not very accurate (Steinruck and Kirchgessner, 1992). It takes hens less than 12 hours to recognize change in the protein content of feed (Chah and Moran, 1985), Implying they have some inherent/natural ability to understand when they are missing nutrients to meet their physiological requirement. It's suggested that mature birds learn slower than younger, quickly growing birds (Pousga et al., 2005). In a paper regarding the practical use of choice feeding by Cumming and colleagues (1987), they suggest introducing layers to choice feeding as soon as possible (before sexual maturity) if using it as a production method to maximize their ability to adapt to it.

Layers on a choice feeding system consume 167 g/kg of protein on average, giving them a similar growth and body compositions compared to those on a complete diet containing 165 g/kg of protein. (Forbes and Shariatmadari, 1994). This shows that layers on choice feeding systems will consume similar amounts and perform the same as those fed a complete diet. Layers should be offered a calcium source separately when using a choice-feeding system as it can minimize feed intake variation (Sauveur and Mongin, 1974).

Choice feeding turkeys

Emmerson and colleagues (1990) observed natural diet management in turkey hens and put them on either a choice fed system or complete diet system and found that turkeys on choice-feeding had 10% less feed intake, 44% less protein intake, and consumed similar levels of energy as the complete diet group, but still produced a similar number of eggs as the complete diet group. In a production setting where turkeys receive choices between whole wheat, maize, or barley as an energy source, they tend to grow better given the choice than being fed a complete diet (Cowan and Michie, 1997).

Turkeys allowed the choice of feedstuffs usually select a diet that ensures rapid growth but occasionally overconsume more expensive feedstuffs than wheat, causing higher feed costs (Rose et al., 1995). This is supported by Cowan and Michie (1978) where they observed that turkeys typically overconsume protein. Mikulski and colleagues (2015) observed that turkeys consumed too little protein which resulted in poor growth performance compared to a complete diet. Mikulski and colleagues (2015) suggest turkeys aged 5-8 weeks either need a longer time to fully adapt to a free-choice feeding system or may not be able to adapt to a free choice-feeding system at all. Other poultry appear more adept at using a choice feeding system.

ANIMAL BY-PRODUCTS

An important function of choice feeding is allowing the animal to choose from ingredients they need to meet their nutritional requirements, and animal by-products are generally cost-effective, high-quality ingredients that can help supplement an animal's diet. By-products are the secondary products of the production process of the main product (AAFCO, 2012). Animal by-products are the leftover portions from processing that humans do not consume and are rendered into both edible and inedible products. Parts that are rendered include, but are not limited to blood, bone, feathers, offal, viscera, fat, and dead animals. (Jayathilakan, 2011). Animal by-product is typically processed through grinding the material, heating it to evaporate moisture and kill bacteria, and centrifuging to separate the fat from the ground, cooked protein meal (Woodard and Curran, 2006).

Animal by-products are variable in their nutrient compositions, with many factors like growing conditions for the animal and/or plant, and even the processing method used to create the by-product. The variation in feedstuffs makes formulating diets precisely difficult for producers, and therefore it's important to analyze the composition of the ingredients. This is not always an efficient, nor practical way to manage large scale operations, so producers often provide an excess of the requirement to make sure they're meeting the nutritional needs of the animals.

When processing livestock and poultry, there is only so much that is available for human consumption, with around 35% for turkeys, 37% for broilers, 44% for pigs, 49% of cattle, and 57% of most fish carcasses are not utilized for humans (Meeker, 2006). Utilizing and disposing of the whole carcass is important both financially and environmentally (Jayathilakan, 2011). Animal by-products are produced via the rendering process, which converts by-products from the meat and livestock industry into non-hazardous, safe/usable material (EFPRA, n.d.).

Feed is the most expensive part of poultry and livestock production, and protein is one of the major elements of this cost, with common high protein ingredients like soybean meal. Animal by-products are important, cost-effective proteins used in feeding livestock and other domesticated animals that provide specific nutrients. (Meeker et al., 2006). Animal by-products also help supplement important essential AAs like methionine. Most poultry diets are soybean meal based as the protein source, and soybean meal's first limiting AA is methionine. Typically, most poultry diets first limiting amino acid is methionine, then lysine (Baker, 2006; Schutte and Jong, 1999). Threonine is broiler's third limiting amino acid, followed by valine. However, valine and isoleucine are both limiting when the diet being fed includes poultry by-product meal (Dozier et al., 2011). Essential amino acids must be met in the diet or performance will suffer (NRC, 1994).

With 11.2 billion pounds of rendered animal by-products created a year, utilizing them effectively saves the poultry industry up to $10 per ton of feed in the United States alone. (Meeker et al., 2006). Caires et. al (2010) did a similar experiment with several different by-products being included in the poultry diets and they saw that a 5% inclusion rate did not harm live performance or carcass yield, and there was an average of 9% cost reduction when substituting animal by-product for a plant-based protein source.

Worldwide pet food sales in 2018 were $91.1 billion dollars, compared to $59.3 billion in 2010 (Statista, 2020). With the growth of marketing and consumer concern over animal by-products in pet food, the sales of organic/natural have seen a steady increase from $3 billion to $6.8 billion from 2009 to 2019 in the United States alone (Statista, 2020). All ingredients that go into pet food are through safety standards including being generally recognized as safe (GRAS), approved through a food additive petition, and through an informal sanctioned review by the Association of American Feed Control Officials (AAFCO, 2012). Dogs are omnivores, and cats obligate carnivores – So adding animal protein to their diets is viable for dogs, and necessary for cats nutritionally and behaviorally. Nutrients like vitamin B12 and taurine are typically found in insufficient quantities in plant-based feedstuffs and must be supplemented either through animal-derived protein or synthetic means. Vegetarian diets typically are high in carbohydrates but lack proteins, vitamins A, B12, D3, zinc, iron, and calcium. (Watanabe et al., 2014). McCusker and colleagues in 2014 found that some species of insects like ants and flesh flies, and algae species like *Mazaella* spp. may provide an alternative taurine source for pet food diets outside traditional animal products.

The most common poultry product added in pet foods is poultry by-product meal. About 25% of rendered poultry by-products end up in commercial pet food. (Watson, 2006). Pet food grade by-products are typically seen as higher quality than livestock grade feed. Dozier and Dale (2003) looked at the AA compositions of feed grade and pet food-grade poultry by-product meal and saw pet food-grade meal had more lysine and methionine, two of the first limiting AAs in poultry muscle development. Later, Dozier and Dale (2005) also looked at the nutritional composition between feed-grade and pet food-grade poultry by-product samples. They observed that the pet food-grade did have a higher CP than feed-grade and a numerically lower ash amount. They also observed that the pet food-grade poultry by-product meal had less variation than the feed-grade, suggesting more quality control takes place when producing pet food-grade ingredients.

There are many animal by-products that come from processing. Common ones are:

Poultry by-product; it is a high-quality feed ingredient that is important in both the livestock and pet food industries due to it containing essential AAs, vitamins, minerals, and fatty acids (Dale et al., 1993). Poultry by-product meal is made from combining all the by-products coming from poultry production, being those parts that are not used for commercial human consumption. These parts as defined by the AAFCO are "the dry rendered product from a combination of clean flesh and skin with or without accompanying bone, derived from the parts of whole carcasses of poultry or combination thereof, exclusive of feathers, heads, feet, and entrails." Silva and colleagues (2014) showed benefits to live performance when adding poultry by-product meal to poultry diets at different amounts, in which there was observed increase in weight gain, lower FCR, and lower feed intake up until a certain inclusion rate. Poultry by-product could be included at least up to 6% of the diet without negatively impacting body weight, feed efficiency, or overall consumption (Azman and Dalkilic, 2006). Kirkpinar and colleagues (2004) did similar work and saw results where the inclusion of poultry by-product meal did not hinder animal performance compared to a control of a corn-soybean meal diet. Inclusion of poultry by-product meal was observed to not hinder performance or quality of eggs in layers up to a 7.5% inclusion rate (Hosseinzadeh, 2010). Further support of this with poultry by-product meal substituting up to 5% in a practical corn and soybean meal-based diet will not harm growth or performance, but will hinder growth when added in at 10% of the diet (Escalona and Pesti, 1987). In lactating dairy cows, the inclusion of poultry by-product meal increased overall milk yield and dry matter intake per day (Gonzalez et al., 2007). When included in a poultry diet at 60 g kg^{-1}, broilers had better weight gain and a lower FCR than those that were fed just a corn-soybean meal based diet. (Silva et al., 2014).

Poultry by-product meal has a variable range of crude protein (CP) and amino acids (AA) but generally has a range of 58-70% CP (Donadelli et al., 2019; Li et al., 2010; Pesti et al., 1986; NRC, 1994). This number also depends on if it's being used for pet food or livestock feed, as pet food by-products typically have higher amounts of CP and AA (Dozier and Dale, 2005). Dozier and Dale looked at the nutrient composition of feed grade poultry by-product meal, which has an average of 58% CP, 14.4% ether extract, 4.2% moisture, and 17.1% ash. Pet food-grade poultry by-product meal has an average of 66% CP, 12.6% ether extract, 4.1% moisture, and 15.1% ash. Feed grade poultry by-product meal had lower amounts of lysine and methionine (2.75% and .77%) than pet food grade (2.92% and .84%). Pet food-grade had overall higher levels of CP and limiting amino acids.

Meat and bone meal is not specific to any species unless specified. This product comes from dead animals and the excess material from slaughterhouse processing. Feeding meat and bone meal is banned from ruminant feeding in the US and many other places as it typically contains ruminant protein and is associated with Bovine Spongiform Encephalopathy (BSE). Since the BSE outbreak in the 1990s, the UK has banned the use of the spinal cord and brain (Schreiber and Seybold, 1993). In Elferink's Ph.D. dissertation (2009), he covers the relationship between the BSE scare removing meat and bone meal from livestock feed and its effect on the amazon rainforest due to a large increase in soybean meal production. Elferink claims the large rise in overall soybean production from 1980 to 2004 can be largely attributed to the meat and bone meal ban – where Europe was replacing 16 million tons of meat and bone meal with 23 million tons of soybeans every year. This high production of soybean meal has led to deforestation in Brazil to meet the demand of soybean exports over the last several decades. Meat and bone meal feeding to poultry is also banned in some areas like the EU and Thailand because of the fear of it "carrying viruses, bacteria, and other ingredients harmful for human and animal health." (Daily Star, 2019). Like poultry by-product meal, meat and bone meal is a good source of protein. Meat and bone meal is typically limited depending on the amount of phosphorus that's needed for the animal, and generally restricted between 5-10% if used. Drewyor and Waldroup (2000) observed up to 13% of high ash, and up to 17.76% of low ash meat and bone meal used without any hindering effects on growth and efficiency. However, including meat and bone meal at high levels of the diet of broilers hinder performance. Additionally, phytase increases weight gain in diets without meat and bone meal but appears to not affect weight gain on those diets containing meat and bone meal (Liu et al., 2016).

Ravindran and colleagues (2002) showed the variability of meat and bone meal through 19 samples collected from different rendering plants and observed CP levels ranging from 49-67%, proximate analysis for other constituents and AA availability also showed much variation. This also matches the NRC composition of meat and bone meal. Meat and bone meal is a good calcium and phosphorus source, though the bioavailability of both of these is typically variable. In one instance, phosphorus in high protein and low ash meat and bone meal of swine was less available than low protein, high ash of bovine-derived meat and bone meal. They also found that excessive processing of meat and bone meal did not harm phosphorus bioavailability (Traylor et al., 2005). Meat and bone meal has an average of 51.6% CP, 7.7% moisture, 12.3% ether extract, and 22.8% ash (Parsons et. al, 1997). This is consistent with the 1994 NRC numbers of meat and bone meal. AA compositions of meat and bone meal vary depending on the amount of ash. The more bone in the meal, the more ash, which will lower CP and AA concentrations (NRC, 1994; Ravindran et al., 2002; Li et al., 2011).

Feather meal is another by-product of poultry processing. 5-7% of commercial poultry today are feathers (Zhang et al., 2014). While there are many varying numbers from different sources, the world produces tens of millions of tons of feathers annually (Ullah et al., 2011; Poole et al., 2008; Zhang et al., 2014). AAFCO defines feather meal as "hydrolyzed Poultry Feathers as the product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry, free of additives and or accelerators. Not less than 75% of its CP content must be digestible by the pepsin digestibility method." Feather meal is another source high in protein but typically is not very digestible due to high amounts of keratin, 85-90% (Chandler, n.d.). With such high keratin amounts, processing methods need to break the disulfide bonds to form smaller, more digestible proteins/AAs. There are many modern methods of processing that have increased protein digestibility of feather meal. Belewu and colleagues (2008) utilized *Rhizopus oligosporous* fungus in solid-state fermentation. Steam hydrolysis is a common method in which high pressure and temperature cooks and breaks down the disulfide bonds of feathers. A review article by Shih (1993) covers some of the processing methods in feather utilization such as anaerobic digestion, using bacteria that degrade feathers into a semi-hydrolyzed feather-lysate and using keratinase, an enzyme that hydrolyzes many proteins such as collagen, elastin, and collagen. Feather meal is relatively high in cysteine (4.26 %), which is consistent with the NRC (4.34%) making it a potential suitable sulfur source. However, the digestibility of amino acids in feather meal is relatively low and variable (Waldroup and Yan, n.d.). Feather meal's nutrient composition is 87.8% protein, 6.7% moisture, 10% ether extract, and 1.9% ash (Contach et al., 2006).

Blood meal is the collected blood from slaughter of various species. It has many methods of drying such as oven drying, flash drying, and spray drying. Blood can also be separated into its components of albumin and plasma and processed to create plasma meal. Like most by-products, blood is a potentially hazardous material and must be processed properly to avoid transmission of any potential diseases. It's not a very palatable product, so it should not be included in high amounts of a diet. Blood meal can begin to negatively impact growth and feed efficiency on finishing birds when included around 4% (Jagannatha et al., 2008). Using blood meal in a small amount of the diet can help be a replacement for a more expensive protein source. A study by Tyus and colleagues (2008) observed replacing up to 50% of their soybean meal with blood meal and supplementing isoleucine had no adverse effects on broiler performance up to 10 weeks of age. They did, however, observe replacing soybean meal completely with blood meal and supplemental isoleucine in broilers significantly reduced growth and feed consumption. Blood meal contains a relatively high amount of lysine. It can be paired with ingredients low in lysine like corn to balance the AA profile out (Piepenbrink, 1998). Ewa and colleagues (2017) observed that fortifying blood meal with methionine would not hinder broiler performance when 0.3% methionine was supporting 3% blood meal included in the diet. This was utilized to reduce diet costs when compared to a similar diet including fish meal. Blood meal is often used in aqua species as it's a good quality ingredient, cheaper than fish meal, and can used as a binding agent for aqua feed (Medale and Kaushik, 2009). Li and colleagues in 2014 found blood meal is high in protein (89.6%), this is similar to the NRC value of 88.9%. The NRC values of blood meal are 7% moisture and 1% ether extract.

Ermer and colleagues (1994) offered pigs diets with porcine plasma or dried skim milk to determine diet preference. Diets containing plasma meal were consumed more, this is possibly due to palatability, though the reason is not fully understood. Spray-dried plasma meals aid in stimulating feed intake and growth for early-weaned pigs (Pierce et al., 2005).

Fish meal is different from other by-products as it can be fish trimmings, or it can be whole fish that are harvested specifically to go into fish meal. It is a highly digestible ingredient that has a favorable AA profile and is a good source of fats, minerals, and vitamins (Miles and Chapman, 2006). Fish meal is an expensive by-product due to it being a concentrated source of nutrients. Because of the cost of this ingredient, producers may include it in small amounts – Other by-products may replace or help supplement the use of fish meal in an animal's diet. Fishmeal did not show a significant improvement in weight gain or FCR in broilers but does improve feed intake, which is likely due to fishmeal being a more palatable ingredient (Karimi, 2006). Fish meal is normally limited to a maximum of 5% in a diet (Cho and Kim, 2010). Fish meal has 63.4% CP (Li et al., 2014) and while it varies on species used and rendering process, it ranges from 63.6-72.3% CP from the NRC values. Fish meal is highly digestible and has a well-balanced amino acid profile which is what makes it a valuable protein source (Miles and Chapman, 2018).

There are also mixtures of by-products like poultry by-product and feather meal, which utilizes combined by-products to help AA balancing. This combo product shows adverse effects on growth and feed efficiency when added in between 15-20%, but no change when added in at 10% (Bhargava, 1975).

FEED INTAKE REGULATION

Through decades of domestication many species we utilize in agriculture have changed genetically, reproductively, and behaviorally (Hemmer, 1990). There are many reasons why animals choose to eat the way they do. Appleby and colleagues (2018) look at preference and motivation of animals. They observe that animals in environments that allow free choice to demonstrate individual behavioral differences and note that differences in species and breeds can lead to different actions and preferences. Poultry's diet decisions can be impacted by many potential variables like sensory cues or physiological feedback mechanisms. Gomez and Celli (2008) cover bird's olfactory system and determine birds use their sense of smell for feeding and interacting with other birds. Chicken's sense of taste is minimal compared to most mammals, having up to 500 taste buds and lacking the "sweet" taste receptor T1R2 (Liu et al., 2018). Humans have up to 10,000 taste buds (Breslin, 2013), and cows between 15,000-20,000 (Davies et al., 1979).

The aminostatic theory, along with many others (glucostatic, hepatostatic, and thermostatic) are potential explanations behind why animals consume certain feedstuffs. The aminostatic theory revolves around the idea that AA metabolism can regulate appetite (Mellinkoff et al., 1956). This theory shows that animals will adapt their diet to consume a feedstuff that meets their nutritional needs, i.e. deficient in an AA. AAs are detected in the central nervous system by the anterior piriform cortex

(Geitzen, 2000). This theory shows animal's ability to choose feedstuffs that meet their nutritional needs given a period of time to adjust and allowing their bodies' physiological feedback loop to recognize which diet or ingredient meets their requirements. In rats, lesions to this piriform cortex hindered the rat's ability to differentiate between essential AA balanced, or essential AA deficient diets (Rogers and Leung, 1971). Work by Geitzen (2000) show that the piriform cortex in the CNS is important for animals' ability to recognize AA differences. AA imbalance (both excess and deficiency) can cause a suppression of feed intake and weight gain. Chicks given the choice between purified diets that either met NRC requirements or were deficient in an essential AA would be able to differentiate between the two within an hour and consume the complete NRC requirement diet (Firman, 1986). Han and Baker in 1993 observed a continuous decrease in feed intake and weight gain when you added DL-methionine in excess to their normal requirements. When given the choice between diets that had no lysine, low amount of lysine, and sufficient lysine, chicks would choose the diets with more lysine included – but the smaller the difference in lysine levels, the less they could discern which was more deficient (Newman and Sands, 1983). Poultry can determine what they should eat to meet their nutrient requirements, but not always to the most optimal level. Rats can recognize essential AA deficiencies when the differences are larger, similar to Newman and Sands study in poultry using lysine levels (Koehnle, 2003). Koehnle looked at an essential AA threonine and determined rats with more threonine deficient meals ate less than those diets with a sufficient amount of threonine. Koehnle also did a second experiment to observe if taste was effecting the rats choice, where two nonessential AAs serine and Isoleucine were added into two basal diets, then fed serine and Isoleucine devoid diets during the experimental period and observed no difference in feed intake, while the group fed the threonine basal diet decreased feed intake when fed the threonine devoid diet. Rats would consume more bitter, balanced AA diets than they would sweetened, unbalanced AA diets (Rogers and Leung, 1977). Poultry would likely show similar results as they lack “sweet” taste receptors T1R2 (Cheled-Shoval, 2015). Kare and Maller (1967) found that feeding a low energy diet to broilers would increase their preference to water with sucrose added. Harper (19700 observed that intragastric and intravenous infusions of AAs caused food intake to decrease, these last few studies show that sensory cues like taste are not essential for detecting AA deficiencies. Rats (and perhaps other animals) can also quickly find AA devoid or balanced diets within 12-16 minutes (Fromentin, 1998).

SUMMARY

One of the many growing pressures by consumers and animal welfare activists for the animal production industry is the removal of animal by-products from poultry/livestock and pet feed. This pressure exists due to a push for vegetarian style diets and views on animal welfare. The gold standard for animal welfare is the Five Freedoms of Animal Welfare, with the last being the freedom to express normal behavior. Normal behavior would include behavior in which the animal can express itself in a similar way as it would in a more natural, wild setting. Choice feeding presents the opportunity for animals to pick and choose between different ingredients, allowing them to express more normal behavior – aligning with the 5th freedom. There is little literature on choice feeding animal by-products to monogastric species. they will generally consume ingredients that meet their physiological requirements given the choice between different feedstuffs and this process can help be explained through the aminostatic theory. Animal by-products are, while variable, generally high-quality protein sources that can be utilized in small amounts of a diet to make it more cost-effective. By-products improve both the diversity of the diet and performance to the animal. The continued use of animal by-products is important environmentally and financially (Jayathilakan, 2011).

CHAPTER 2

SELF-SELECTION OF ANIMAL BY-PRODUCT BY BROILERS THROUGH UTILIZATION OF CHOICE FEEDING

ABSTRACT

Utilizing by-products of animals has been around for centuries in various ways. Today, we utilize by-products for many commodities, including animal feed. The rendering industry produces an annual volume of 11.2 billion pounds of animal-derived proteins and 10.9 billion pounds of rendered fat in the United States. The growing concern of animal welfare has led some animal rights groups to claim it's not in some species natural behavior to eat animal protein and are pushing for the animals to be produced on vegetarian diets. The purpose of this study was to allow broilers to choose feed from both individual plant-based protein sources and animal-based protein sources to determine what they would consume if left to naturally manage their diet. Broilers were housed in 6 pens individually, and in 8 groups of 20. Each pen was given water and feed ad-libitum and given an energy source, vitamin/mineral premix, and several protein sources. The ingredients were corn, vitamin/mineral premix, soybean meal, poultry meat and bone meal, bovine meat and bone meal, and bovine blood meal – all of which

were put in individual feeders and randomized in each pen. Birds were given 16 hours of light and temperature was recorded daily. Feed intake was recorded twice a day, at morning and night, and feeders were randomized each recording period over a 10-day experimental period. Results showed that broilers housed in groups ate up to 11% of their total diet in animal by-products on average. Individual pens varied and would up consume to 6% of their total diet in animal by-products. These results show that even when given the choice between a plant-based protein source or an animal by-product protein source, broilers species will consume animal by-products as a part of their diet.

INTRODUCTION

Consumer pressure and animal welfare activists have been advocating for livestock to be allowed expression of natural behavior such as feeding in production settings. Moreover, this pressure includes the removal of animal by-products from livestock feed. Animal by-products make up 11.2 billion lbs. of waste a year (Meeker, 2006). Utilization and disposal of product-specific waste is difficult (Jayathilakan et al., 2011), that's why it's important to properly utilize it where possible. Feeding byproduct to animals is an effective way to recycle waste and drive feed cost down, which drives product cost down. Knowing consumers want livestock to be able to express natural behavior as according to the 5 freedoms of animal welfare (Farm Animal Welfare Council), this research can show that they will naturally eat/include animal byproduct as a part of their diet so the industry can continue the feeding by-product to broilers and other species. Previous research shows poultry will make sensible diet choices when given varying the option of choosing between protein sources of varying quality (Cowan and Michie, 1978; Balag and Millard, 1989; Gous and Swatson, 2000).

The objective of this study was to determine if broilers would consume animal by-products willfully when given the choice between both plant and animal-derived feed ingredients.

MATERIALS AND METHODS

166 Ross 708 commercial broiler chickens were used in this study. Broilers were raised from hatch to 17 days old on standard starter diet at the University of Missouri's Rocheford Farm. At 17 days of age, broilers were weighed and separated at random into either groups of 20 or individually, then placed randomly among 14 pens. Broilers were adapted to the new layout as presented in Figure 2.0 for 5 days. Broilers began the 10-day experimental period at 22 days old. Water was given *ad libitum* from a single bell waterer per pen. Feed ingredients were placed in individual feeders and given *ad libitum*. Birds were given 16 hours of light. Temperature was recorded daily and stayed around 79^{o} F. All procedures were in accordance with the University of Missouri's Animal Care and Use Committee (ACUC) protocols.

Feed ingredients utilized in this experiment were corn, soybean meal, and a vitamin/mineral premix (NB-3000) were sourced from the University of Missouri feed mill. Animal by-products utilized in this experiment were poultry by-product, bovine meat and bone meal, and ruminant blood meal which were sourced from a local Kansas City-based feed ingredient company.

Broilers were given the choice between corn, soybean meal, vitamin/mineral premix, poultry by-product, bovine meat and bone meal, and ruminant blood meal. Each of these single feed ingredients were placed in separate feeders. All feed ingredients were randomly distributed in each pen after being weighed. In the 10-day experimental period, broilers could choose between each of the 6 different feed ingredients. Plastic, 1-quart jar feeders were weighed and refilled twice a day before being randomly placed back in the pens. Feed intake was recorded twice a day via bench scale. Broilers were weighed immediately before and after the experimental period.

Feed Analysis

Analysis of feeds was performed by the University of Missouri – Columbia Experiment Station Chemical Laboratories. Analysis was run on corn, soybean meal, poultry by-product, bovine meat and bone meal, and ruminant blood meal. Proximate analysis of feedstuffs and amino acid values of animal by-products are presented in Tables 2.3 and 2.4. Guaranteed analysis of vitamin and mineral premix is presented in Table 2.5.

Statistical Analysis

A randomized complete block design (RCBD) was used to control variation and allow replication. Non-parametric statistical analysis was performed on rank transformed data using SAS PROC GLM to meet ANOVA assumptions.

RESULTS

Group-Housed

Grouped housed broilers showed the ability to formulate their diets similar to a commercially formulated diet. Intake composition of choice fed, group-housed birds are presented in Figure 2.1. Broilers consumed both plant and animal proteins, consuming corn and soybean meal in the highest amounts. Group-housed broilers consumed all three animal by-products in varying amounts ($p<.0001$). Group-housed broilers consumed Poultry by-product meal in the highest amount, followed by bovine meat and bone meal as presented in Table 2.0. Ruminant blood meal was not considered consumed in an amount that would be sufficient evidence of purposeful intake (<1% of total intake). Normal behavior such as pecking out of curiosity or scratching litter could account for a small amount of feed removal. Broilers gained an average of .038 kg/day as presented in Table 2.1. Feed conversion ratio (FCR) of choice fed, group-housed broilers was comparable to commercial stands for Ross 708 broilers (1.26 vs 1.47) at 32 days old and is presented in Table 2.2.

Individual

Individually housed broilers showed high variation in diet composition as presented in Figure 2.2. Individually housed broilers gained an average of .016 kg/day as presented in Table 2.1.

DISCUSSION

Table 2.0 shows broilers in group pens consumed poultry by-product meal the most followed by bovine meat and bone meal. Ruminant blood meal was not eaten on average by the grouped pens and this could be due to palatability or poor amino acid balance. Blood meal should only be included up to 5% of the diet to avoid harming performance. Blood meal should also be supplemented with complementary feedstuffs or synthetic amino acids to best meet nutritional requirements (Tyus, 2008). Broilers consumed most of poultry by-product meal likely due to it being highly digestible and having an ideal balance of amino acids to meet their requirements (International Feed, n.d). 1-quart colored plastic feeders were used for broilers, while each pen had all feeders of the same color. Potentially, color could have affected birds' preferences. Khosravinia (2006) found that broilers prefer green lighting colors and green feed over colors like white, yellow, orange, and red. Feeders were randomly placed after each weigh to minimize selection bias and to avoid any feeding habits from forming. Individually housed broilers grew less than group-housed broilers. Poor performance of individuals could be due to worse ability to adapt to choice feeding since they lacked the social setting of group-housed birds. This could also be due to preferences or simply because it's looking at one bird instead of an averaged group.

CONCLUSION

Individually housed broilers showed a high amount of variability in their ingredient selection. Broilers in group housing chose animal by-products more consistently than individual broilers. Group-housed broilers also chose ingredients that would compare to a commercially formulated diet. Broilers given the choice between feeds will tend to consume to meet their physiological needs (Gous and Swatson, 2000). This experiment showed broiler's ability to effectively manage their diet in a group setting given the choice between different ingredients and show that broilers willfully choose animal by-products as a part of their diet when presented with both plant and animal-derived feedstuffs.

CHAPTER 3

SELF-SELECTION OF ANIMAL BY-PRODUCT BY LAYERS THROUGH UTILIZATION OF CHOICE FEEDING

ABSTRACT

Utilizing by-products of animals has been around for centuries in various ways. Today, we utilize by-products for many commodities, including animal feed. The rendering industry produces an annual volume of 11.2 billion pounds of animal-derived proteins and 10.9 billion pounds of rendered fat in the United States. The growing concern of animal welfare has led some animal rights groups to claim it's not in some species natural behavior to eat animal protein and are pushing for the animals to be produced on vegetarian diets. The purpose of this study was to allow layers to choose feed from both individual plant-based protein sources and animal-based protein sources to determine what they would consume if left to naturally manage their diet. Layers were housed in 6 pens individually, and in 8 groups of 20. Each pen was given water and feed ad-libitum and given an energy source, vitamin/mineral premix, and several protein sources. The ingredients were corn, vitamin/mineral premix, soybean meal, poultry meat and bone meal, bovine meat and bone meal, and bovine blood meal – all of which were put in individual feeders and randomized in each pen. Birds were given 16 hours of

light and temperature was recorded daily. Feed intake was recorded twice a day, at morning and night, and feeders were randomized each recording period over a 10-day experimental period. Results showed that layers housed in groups ate up to 13% of their total diet in animal by-products on average. Individual pens varied and consumed up to 40% of their total diet in animal by-products. These results show that even when given the choice between a plant-based protein source or an animal by-product protein source, layers will consume animal by-products as a part of their diet.

INTRODUCTION

Consumer pressure and animal welfare activists have been advocating for livestock to be allowed expression of natural behavior such as feeding in production settings. Moreover, this pressure includes the removal of animal by-products from livestock feed. Animal by-products make up 11.2 billion lbs. of waste a year (Meeker, 2006). Utilization and disposal of product-specific waste is difficult (Jayathilakan et al., 2011), that’s why it’s important to properly utilize it where possible. Feeding byproduct to animals is an effective way to recycle waste and drive feed cost down, which drives product cost down. Knowing consumers want livestock to be able to express natural behavior as according to the 5 freedoms of animal welfare (Farm Animal Welfare Council), this research can show that they will naturally eat/include animal byproduct as a part of their diet so the industry can continue the feeding by-product to layers and other species. Previous research shows poultry will make sensible diet choices when given varying the option of choosing between protein sources of varying quality (Cowan and Michie, 1978; Balag and Millard, 1989; Gous and Swatson, 2000).

The objective of this study was to determine if layers would consume animal by-products willfully when given the choice between both plant and animal-derived feed ingredients.

MATERIALS AND METHODS

166 Bovans Brown layers were used in this experiment. Layers were 52 weeks old from a local laying operation. Layers were housed either in either groups of 20 or individually placed randomly between 14 pens at the University of Missouri's Rocheford Farm. Layers were given 5 days to adapt to their new layout and environment. Water was given *ad libitum* from a single bell style waterer. Feed ingredients were housed in individual feeders and fed *ad libitum*. Layers were given 16 hours of light. Temperature was recorded daily and stayed around 74^{o} F. All procedures were in accordance with the University of Missouri’s Animal Care and Use Committee (ACUC) protocols.

Feed ingredients utilized in this experiment were corn, soybean meal, and vitamin/mineral premix were sourced from the University of Missouri feed mill. Animal by-products utilized in this experiment were poultry by-product, bovine meat and bone meal, and ruminant blood meal which were sourced from a local Kansas City-based feed ingredient company.

Layers underwent a 10-day experimental period. Layers were given the choice between corn, soybean meal, vitamin/mineral premix, poultry by-product, bovine meat and bone meal, and ruminant blood meal. Each of these ingredients was placed in separate 30 lb. galvanized metal feeders. Feeders were randomly distributed in each pen after being weighed. Feeders were weighed and refilled twice a day and randomly placed back in the pens. Feed intake was recorded twice a day via bench scale. Layers were weighed immediately before and after the experimental period.

Feed Analysis

Analysis of feeds was performed by the University of Missouri – Columbia Experiment Station Chemical Laboratories. Analysis was run on corn, soybean meal, poultry by-product, bovine meat and bone meal, and ruminant blood meal. Proximate analysis of feedstuffs and amino acid values of animal by-products are presented in Tables 2.3 and 2.4. Guaranteed analysis of vitamin and mineral premix is presented in Table 2.5.

Statistical Analysis

A randomized complete block design (RCBD) was used to control variation and allow replication. Non-parametric statistical analysis was performed on rank transformed data using SAS PROC GLM to meet ANOVA assumptions.

RESULTS

Grouped

Grouped layers consumed corn in the highest amount, followed by soybean meal, poultry by-product and bovine meat and bone meal. Layers consumed both animal by-products and plant feed ingredients when given the choice. Layers consumed poultry by-product meal and bovine meat and bone meal in similar amounts ($p>.05$). They consumed poultry by-product meal and bovine meat and bone meal more than ruminant blood meal ($p<.0001$). Layer's intake of protein is presented in Table 3.0. Layer's choice fed diet composition is presented in Figure 3.0. Weight of layers over the experiment is presented in Table 3.1.

Individual

Individually housed layers showed high variation in ingredients consumed as presented in Figure 3.1. Individually housed layer weight is presented in Table 3.1.

DISCUSSION

Layers consumed numerically more bovine meat and bone meal than poultry by-product. Compared to broilers and turkeys, layers consumed the most of bovine meat and bone meal. This intake is likely due to layers high calcium requirement, 3.25% in layers compared to 1% in young growing broilers (NRC, 1994). Bovine meat and bone meal contains a high amount of calcium compared to the other animal by-product as presented in Table 2.9. While this aids in meeting calcium requirements, it should not be the only source of calcium. Cumming and colleagues (1987) cover observations that ground limestone has more available calcium than meat and bone meal. Poultry better adapts to choice feeding systems at a younger age, this could have affected the layer's ability to adapt given they were sexually mature before introducing a new feeding system (Forbes and Shariatmadari, 1994). As layers were mature, weight was recorded but growth was not observed.

CONCLUSION

Individually housed layers showed high variability with ingredient selection. Layers in groups chose animal by-products more consistently than individual layers. This experiment showed layer's ability to manage their own diet and meet nutritional requirements when given the choice between different feed ingredients. Layers willfully choose animal by-products as part of their diet when given the choice between both plant and animal-derived feedstuffs.

CHAPTER 4

SELF-SELECTION OF ANIMAL BY-PRODUCT BY TURKEYS THROUGH UTILIZATION OF CHOICE FEEDING

ABSTRACT

Utilizing by-products of animals has been around for centuries in various ways. Today, we utilize by-products for many commodities, including animal feed. The rendering industry produces an annual volume of 11.2 billion pounds of animal-derived proteins and 10.9 billion pounds of rendered fat in the United States. The growing concern of animal welfare has led some animal rights groups to claim it's not in some species natural behavior to eat animal protein and are pushing for the animals to be produced on vegetarian diets. The purpose of this study was to allow turkeys to choose feed from both individual plant-based protein sources and animal-based protein sources to determine what they would consume if left to naturally manage their diet. Turkeys were housed in 6 pens individually, and in 8 groups of 20. Each pen was given water and feed ad-libitum and given an energy source, vitamin/mineral premix, and several protein sources. The ingredients were corn, vitamin/mineral premix, soybean meal, poultry meat and bone meal, bovine meat and bone meal, and bovine blood meal – all of which were put in individual feeders and randomized in each pen. Birds were given 16 hours of light and temperature was recorded daily. Feed intake was recorded twice a day, at morning and night, and feeders were randomized each recording period over a 10-day experimental period. Results showed that turkeys housed in groups ate up to 13% of their total diet in animal by-products on average. Individual pens varied and consumed up to 40% of their total diet in animal by-products. These results show that even when given the choice between a plant-based protein source or an animal by-product protein source, turkeys will consume animal by-products as a part of their diet.

INTRODUCTION

Consumer pressure and animal welfare activists have been advocating for livestock to be allowed expression of natural behavior such as feeding in production settings. Moreover, this pressure includes the removal of animal by-products from livestock feed. Animal by-products make up 11.2 billion lbs. of waste a year (Meeker, 2006). Utilization and disposal of product-specific waste is difficult (Jayathilakan et al., 2011), that's why it's important to properly utilize it where possible. Feeding byproduct to animals is an effective way to recycle waste and drive feed cost down, which drives product cost down. Knowing consumers want livestock to be able to express natural behavior as according to the 5 freedoms of animal welfare (Farm Animal Welfare Council), this research can show that they will naturally eat/include animal byproduct as a part of their diet so the industry can continue the feeding by-product to turkeys and other species. Previous research shows poultry will make sensible diet choices when given varying the option of choosing between protein sources of varying quality (Cowan and Michie, 1978; Balag and Millard, 1989; Gous and Swatson, 2000).

The objective of this study was to determine if turkeys would consume animal by-products willfully when given the choice between both plant and animal-derived feed ingredients.

MATERIALS AND METHODS

166 female Hybrid Converter turkeys were used in this experiment. Turkeys were raised from hatch to 9 days on a standard starter diet at the University of Missouri's Rocheford Farm. At 9 days of age, turkeys were weighed and separated at random into groups of 20 or individually, then placed randomly among 14 pens. Turkeys were adapted to the new layout for 5 days. Water was given *ad libitum* from a single bell waterer per pen. Feed ingredients were placed in individual feeders and given *ad*

libitum. Birds were given 16 hours of light. Temperature was recorded daily and remained around 75° F. All procedures were in accordance with the University of Missouri's Animal Care and Use Committee (ACUC) protocols.

Feed ingredients utilized in this experiment were corn, soybean meal, and vitamin/mineral premix were sourced from the University of Missouri feed mill. Animal by-products utilized in this experiment were poultry by-product, bovine meat and bone meal, and ruminant blood meal which were sourced from a local Kansas City-based feed ingredient company.

Turkeys were given the choice between corn, soybean meal, vitamin/mineral premix, poultry by-product, bovine meat and bone meal, and ruminant blood meal. Turkeys started the experiment at 14 days old. In the 12-day experimental period, turkeys could choose between each of the 6 different, individually housed feed ingredients. 30 lb. galvanized metal feeders were weighed and refilled twice a day and randomly placed back in the pens. Feed intake was recorded twice a day via bench scale. Turkeys were weighed immediately before and after the experimental period.

Statistical Analysis

A randomized complete block design (RCBD) was used to control variation and allow replication. Non-parametric statistical analysis was performed on rank transformed data using SAS PROC GLM to meet ANOVA assumptions.

Feed Analysis

Analysis of feeds was performed by the University of Missouri – Columbia Experiment Station Chemical Laboratories. Analysis was run on corn, soybean meal, poultry by-product, bovine meat and bone meal, and ruminant blood meal. Proximate analysis and amino acid values of feedstuffs are presented in Table 2.3 and 2.4. Guaranteed analysis of vitamin and mineral premix is presented in Table 2.5.

RESULTS

Grouped

Turkeys in group housing over consumed protein compared to NRC recommendations. Turkeys consumed both plant and animal proteins, consuming animal by-products in varying amounts ($p<.0001$) as presented in Table 4.0. Intake composition of choice fed, group-housed turkeys are presented in Figure 4.0. Turkeys consumed poultry by-product meal the most followed by bovine meat and bone meal. Blood meal was not consumed in a sufficient amount to consider purposeful consumption (<1% of the total intake). Turkeys grew an average of .011 kg/day over the 12-day experimental period as presented in Table 4.1. FCR of choice fed, group-housed turkeys compared to commercial standards were poor (3.91 vs 1.16) as presented in Table 4.2.

Individual

Individually housed turkeys showed high variation in diet composition as presented in Figure 4.1. Individually housed turkeys gained an average of .015 kg/day as presented in Table 4.1.

DISCUSSION

Turkeys are found to take longer to adapt to diets (Mikulski, 2015) and have less ability than broilers to balance their diets (Cowan and Michie, 1978). Turkeys consumed more soybean meal than corn overall. This is likely due to turkey's high demand for protein (NRC, 1994). Turkeys tend to overconsume protein when given the choice between ingredients (Cowan and Michie, 1978). Mortality was high with 18 turkeys dying in the experiment, this could be due to several reasons. Potentially poor adaptation to a choice feeding system, nutrition before the experimental period, or environment such as weather. Several turkeys noticeably showed early signs of perosis, hindering movement and potentially affecting results. These reasons can also impact FCR, as we observed poor efficiency relative to commercial standards for Hybrid Converter turkeys.

CONCLUSION

Group-housed turkeys showed the ability to formulate their own diet given the choice between different feed ingredients. However, to a lesser extent than broilers and with greater waste. Individually housed turkeys showed a high amount of variability in their ingredient selection. This experiment shows that turkeys willfully choose animal by-products as a part of their diet when presented with both plant and animal-derived feedstuffs.

SUMMARY

With pressure on the industry to decrease feed costs and reduce environmental waste, the utilization of animal by-products is important. Domesticated poultry will consume animal by-products when given the choice between both plant and animal-based feed ingredients. With this implication of normal behavior, animal welfare provisions should include animal by-product feeding as an alternative management practice in the poultry production process. Further research could be conducted with other domesticated or wild species to provide sufficient evidence of animal by-product intake with their respective species.

Table 2.0: Protein Intake per Broiler (Group-Housed)			
	Poultry By-Product	**Ruminant Blood Meal**	**Bovine Meat and Bone Meal**
Daily Intake (g)	169.68[a]	4.59[b]	88.90[c]
Total Portion of Diet (%)	7.24 ± 1.53[a]	.20 ± 0.01[b]	3.29 ± 0.41[c]

[a-c] numbers with different superscripts differed ($p<.0001$)

Table 2.1: Gain of Broilers		
	Group-Housed (20/pen)	**Individually Housed**
Average Start Wt. (kg)	.55	.60
Average End Wt. (kg)	.93	.76
Total gain – 10 day period (kg)	.38	0.16
Average Daily Gain (kg)	.038	.016

Table 2.2: FCR of Choice Fed Broilers Housed in Groups (20/pen) Compared to Commercial Standards		
	Choice Fed	**Commercial**
Broilers	1.26	1.47

Table 3.0: Protein Intake per Layer (Group-Housed)			
	Poultry By-Product	**Ruminant Blood Meal**	**Bovine Meat and Bone Meal**
Daily Intake (g)	139.63[a]	25.5[b]	153.63[a]
Total Portion of Diet (%)	5.611 ± .006[a]	1.03 ± .003[b]	6.17 ± .007[a]

[a-b] numbers with different superscripts differed ($p<.0001$)

Table 3.1: Average Weights of Layers		
	Group-Housed (20/pen)	**Individually Housed**
Average Start Wt.	1.83	1.83
Average End Wt.	1.86	1.71

Table 4.0: Protein Intake per Turkey (Group-Housed)			
	Poultry By-Product	**Ruminant Blood Meal**	**Bovine Meat and Bone Meal**
Daily Intake (g)	61.25[a]	2.00[b]	15.38[c]
Portion of Total Diet (%)	7.11 ± .02[a]	.23 ± .00[b]	1.79 ± .01[c]

[a-c] numbers with different superscripts differed (p<.0001)

Table 4.1: Gain of Turkeys		
	Group-Housed (20)	**Individually Housed**
Average Start Wt. (kg)	.34	.36
Average End Wt. (kg)	.42	.51
Total Gain (kg)	.11	.15
Average Daily Gain (kg)	.011	.015

Table 4.2: FCR of Choice Fed Turkeys Housed in Groups (20/pen) Compared to Commercial Standards		
	Choice Fed	**Commercial**
Turkeys	3.91	1.16

Table 2.3: Nutrient Composition of Corn and Soybean Meal		
	Ground Corn	**Soybean Meal**
Moisture	11.74	9.87
Crude Protein	10.07	48.32
Crude Fat	3.35	1.99
Crude Fiber	1.76	3.58
Ash	1.34	6.45
Calcium	0.011	0.339
Sodium	0.002	0.021
Chloride	<0.1	<0.1
Phosphorus	0.242	0.584

Numbers expressed on grams per 100 grams of sample
Results are expressed on as fed basis

Table 2.4: Nutrient Composition of Animal By-Product Meals			
	Poultry By-Product Meal	**Ruminant Blood Meal**	**Bovine Meat and Bone Meal**
Moisture	5.67	7.53	5.03
Crude Protein	67.06	91.85	49.58
Crude Fat	12.63	0	8.38
Crude Fiber	1.26	0.09	2.75
Ash	12.19	2.47	32.19
Calcium	3.12	0.068	12.06
Sodium	0.46	0.323	0.812
Chloride	0.5	0.5	0.7
Phosphorus	1.84	0.42	4.75
Taurine	0.4	0.11	0.08
Hydroxyproline	2.13	0.13	2.85
Aspartic Acid	5.18	7.99	3.32
Threonine	2.43	4.17	1.4
Serine	2.33	3.35	1.55
Glutamic Acid	8.36	8.79	5.6
Proline	4.04	3.48	3.86
Lanthionine	0.16	0.07	0.1
Glycine	6.42	3.36	6.52
Alanine	4.28	6.57	3.47
Cystine	0.7	1.41	0.36
Valine	3.04	5.98	1.89
Methionine	1.32	1.13	0.6
Isoleucine	2.53	3.66	1.33
Leucine	4.36	9.51	2.69
Tyrosine	1.97	3.04	1.08
Phenylalanine	2.47	5.53	1.52
Hydroxylysine	0.3	0.02	0.28
Ornithine	0.1	0.1	0.07
Lysine	4.05	7.64	2.32
Histidine	1.39	4.93	0.8
Arginine	4.44	4.76	3.24
Tryptophan	0.6	1.02	0.32

Numbers expressed on grams per 100 grams of sample.
Results are expressed on as fed basis.

Table 2.5: Guaranteed Analysis of Vitamin and Mineral Premix (NB-3000)			
Mn	4%	Menadione	150 mg/lb
Zn	4%	Riboflavin	1,200 mg/lb
Fe	2%	Thiamine	200 mg/lb
Cu	4,500 ppm	D-Pantothenic Acid	1,200 mg/lb
I	600 ppm	Niacin	5,000 mg/lb
Se	60 ppm	Vit. B6	250 mg/lb
Vit. A	1,400,000 IU/lb	Folic acid	125 lb/lb
Vit. D3	500,000 ICU/lb	Choline	70,000 mg/lb
Vit. E	3,000 IU/lb	Biotin	6 mg/lb
Vit. B12	2 mg/lb		

Figure 2.0 – Pen Layout

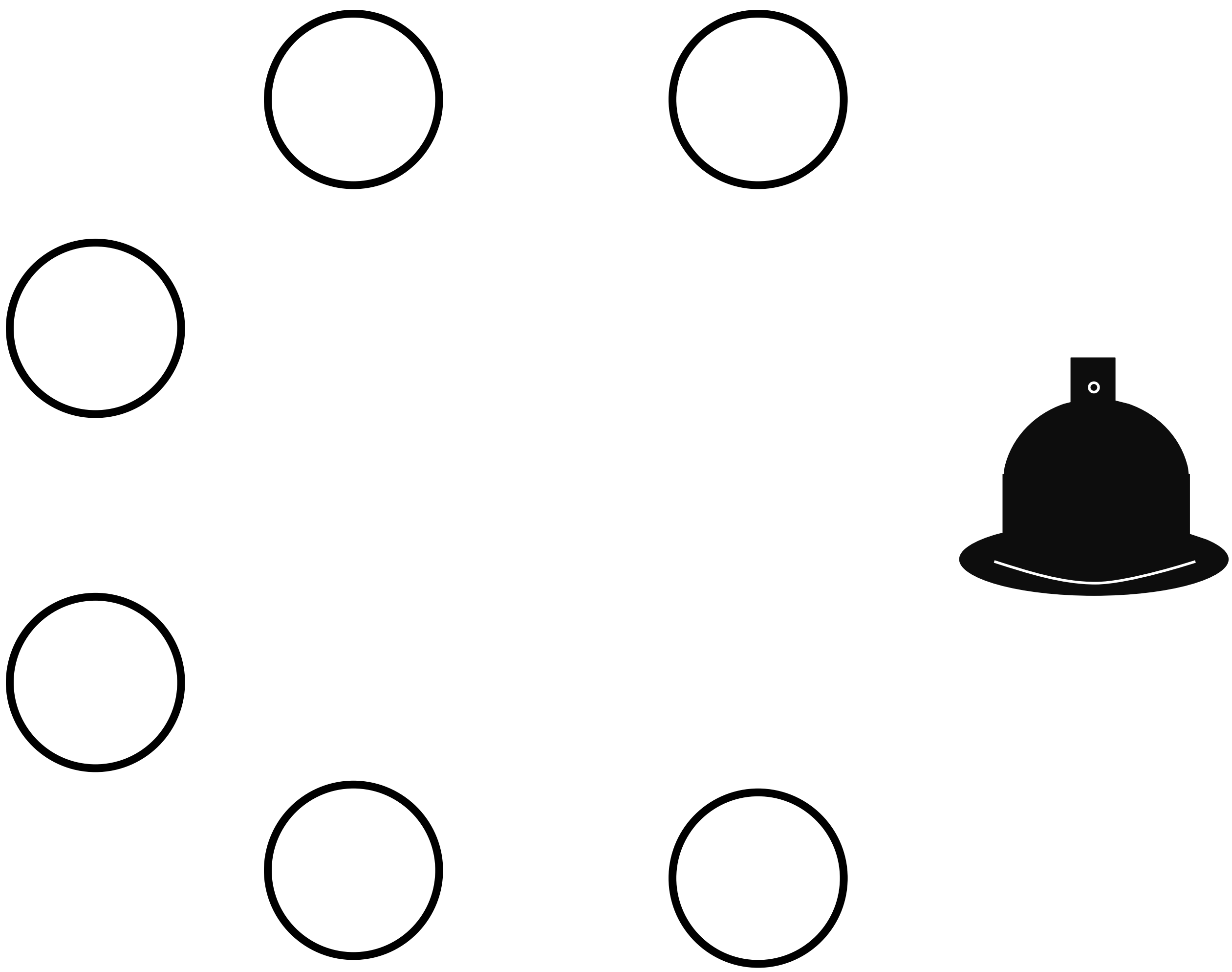


Figure 2.1 – Average % of Diet Intake for Group-Housed Broilers

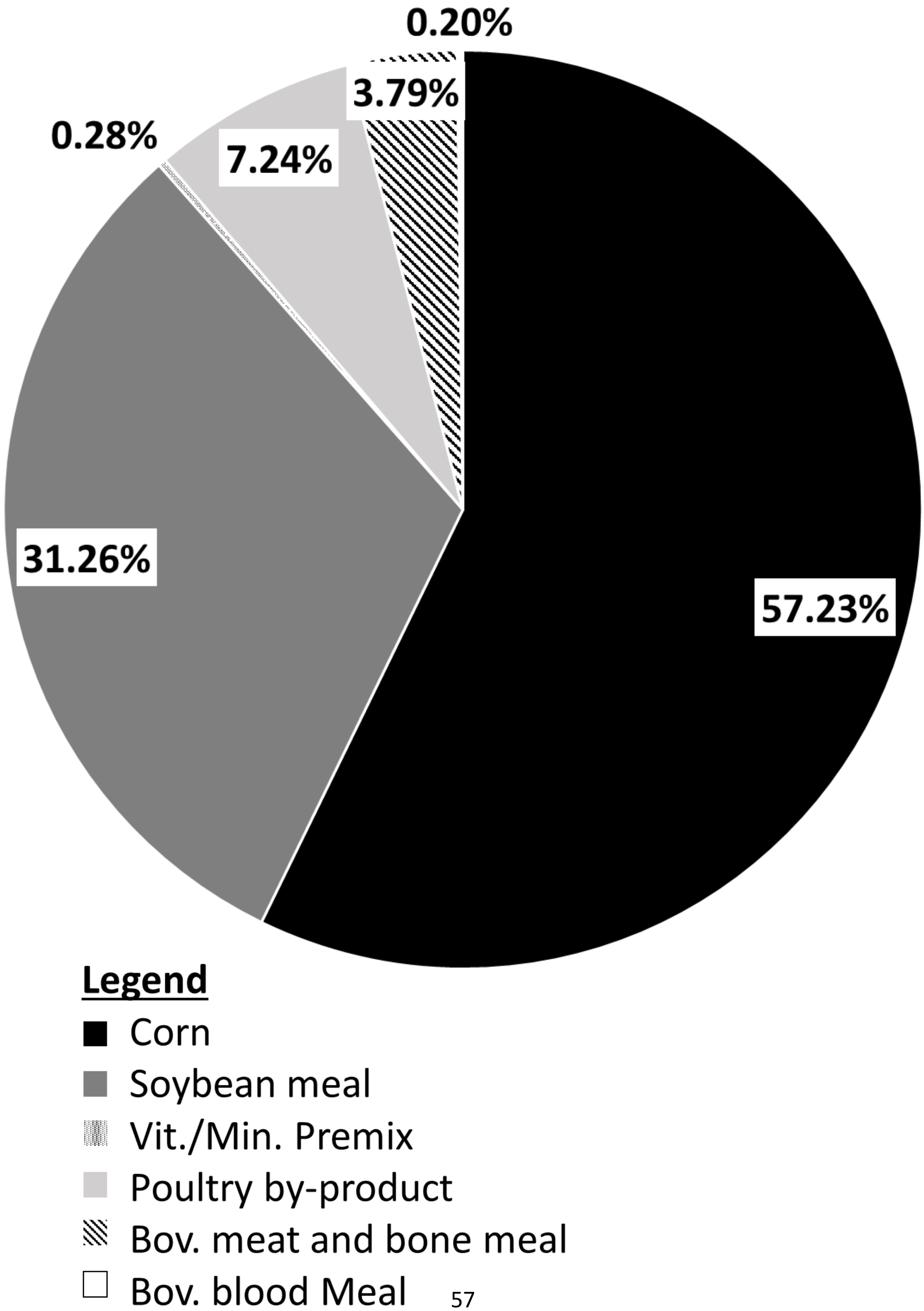


Figure 2.2 - % of Diet Intake Among Individually Housed Broilers

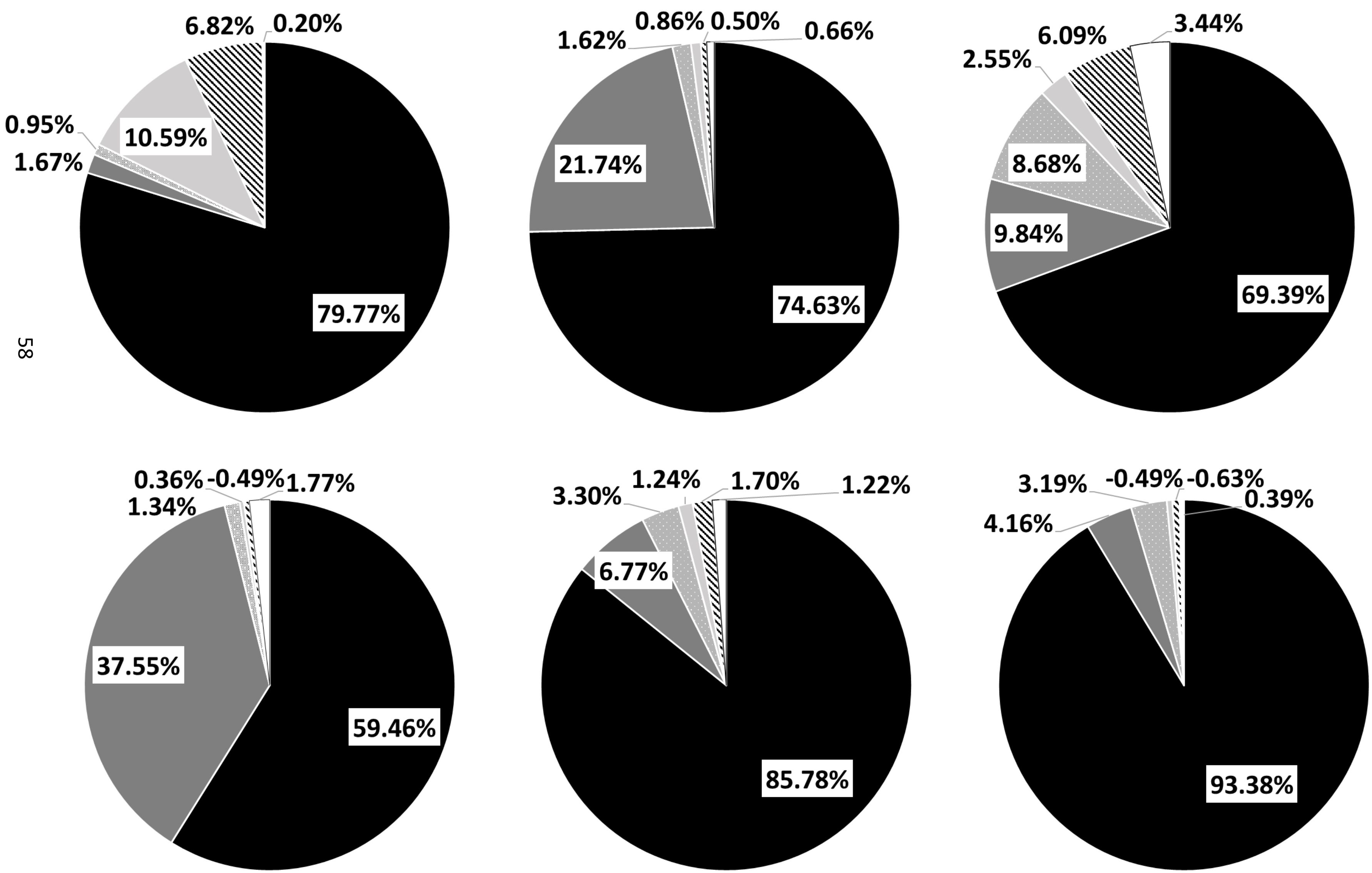


Figure 3.0 - Average % of Diet Intake of Group-Housed Layers

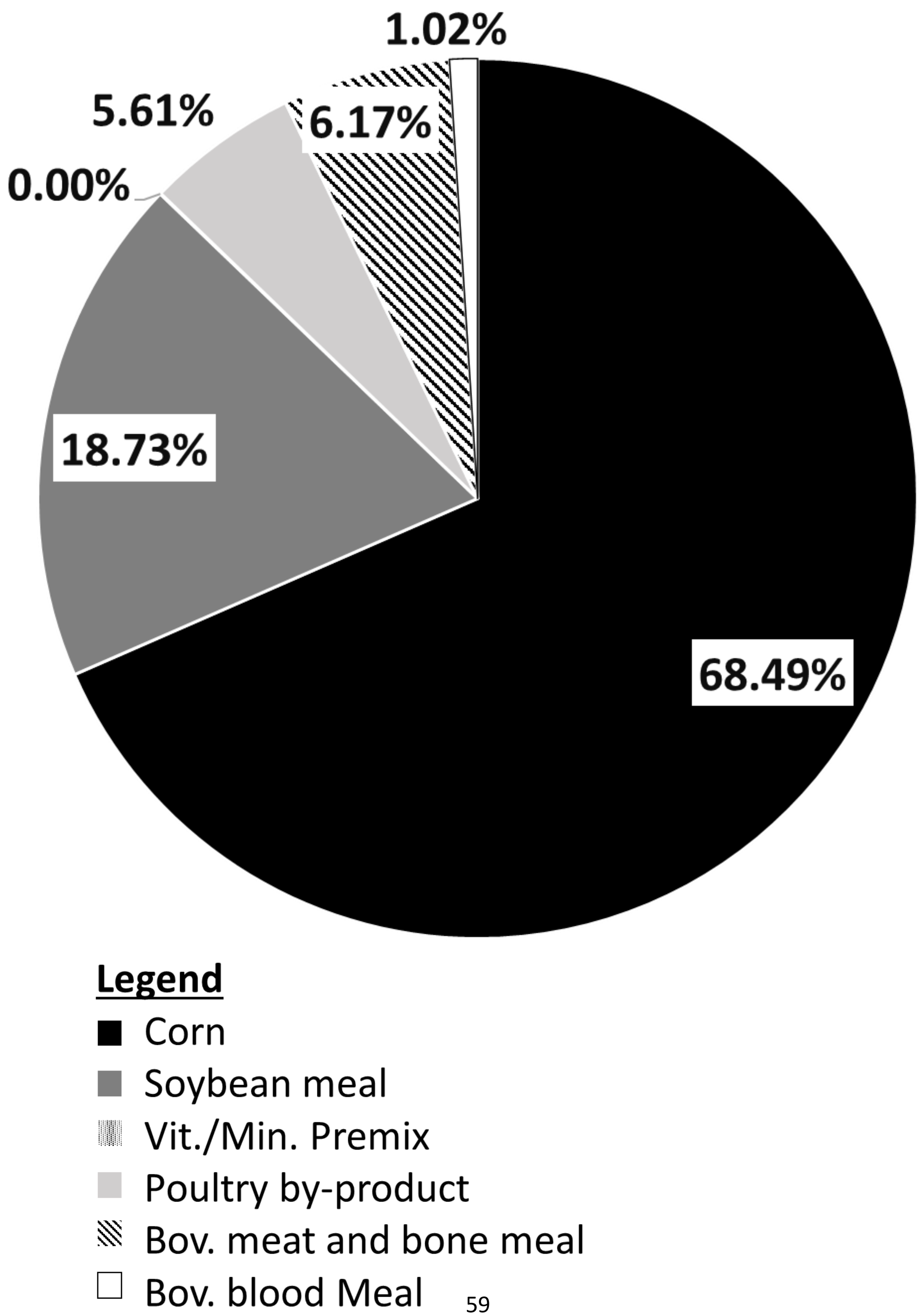


Figure 3.1 - % of Diet intake Among Individually Housed Layers

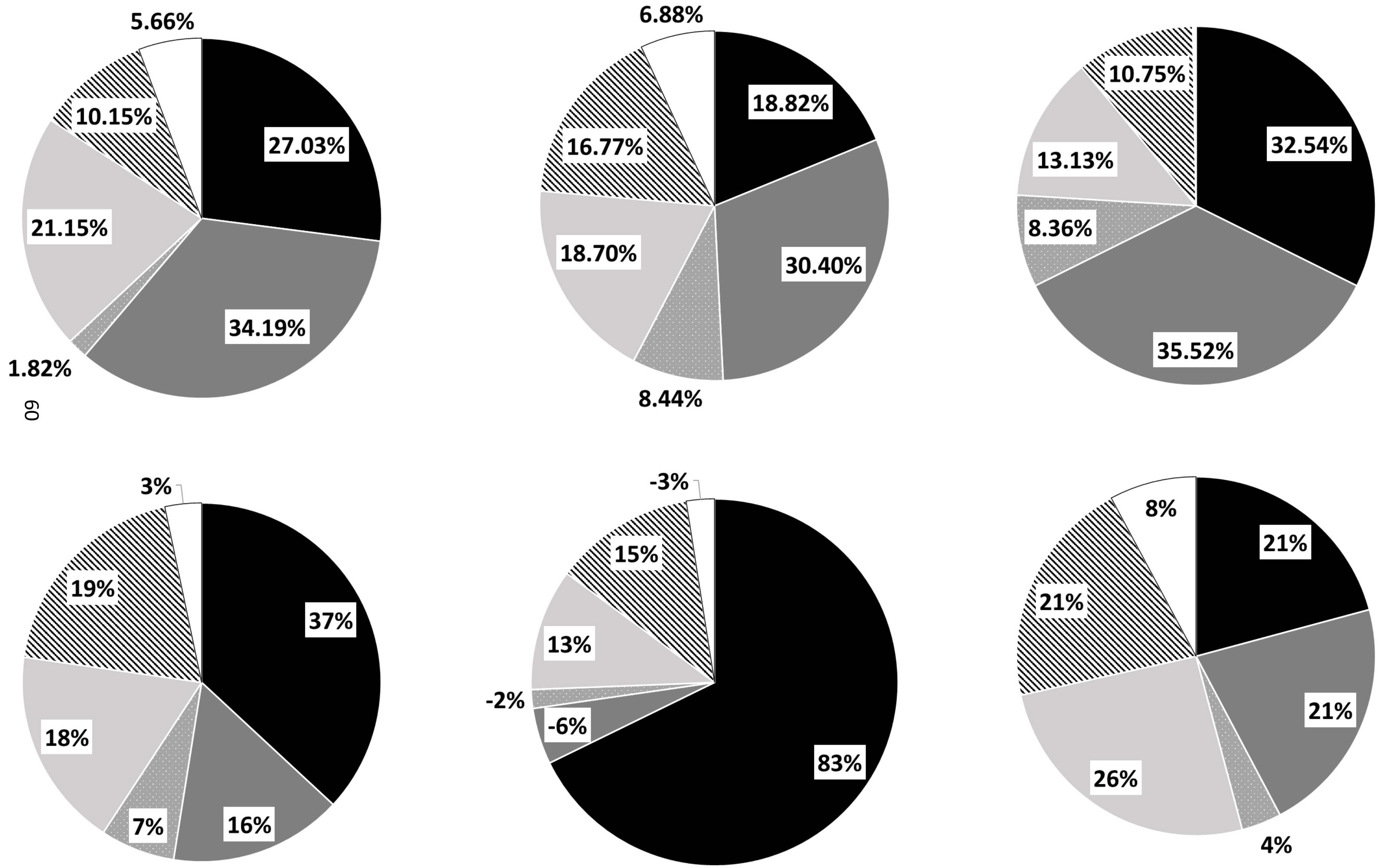


Figure 4.0 – Average % of Diet Intake of Group-Housed Turkeys

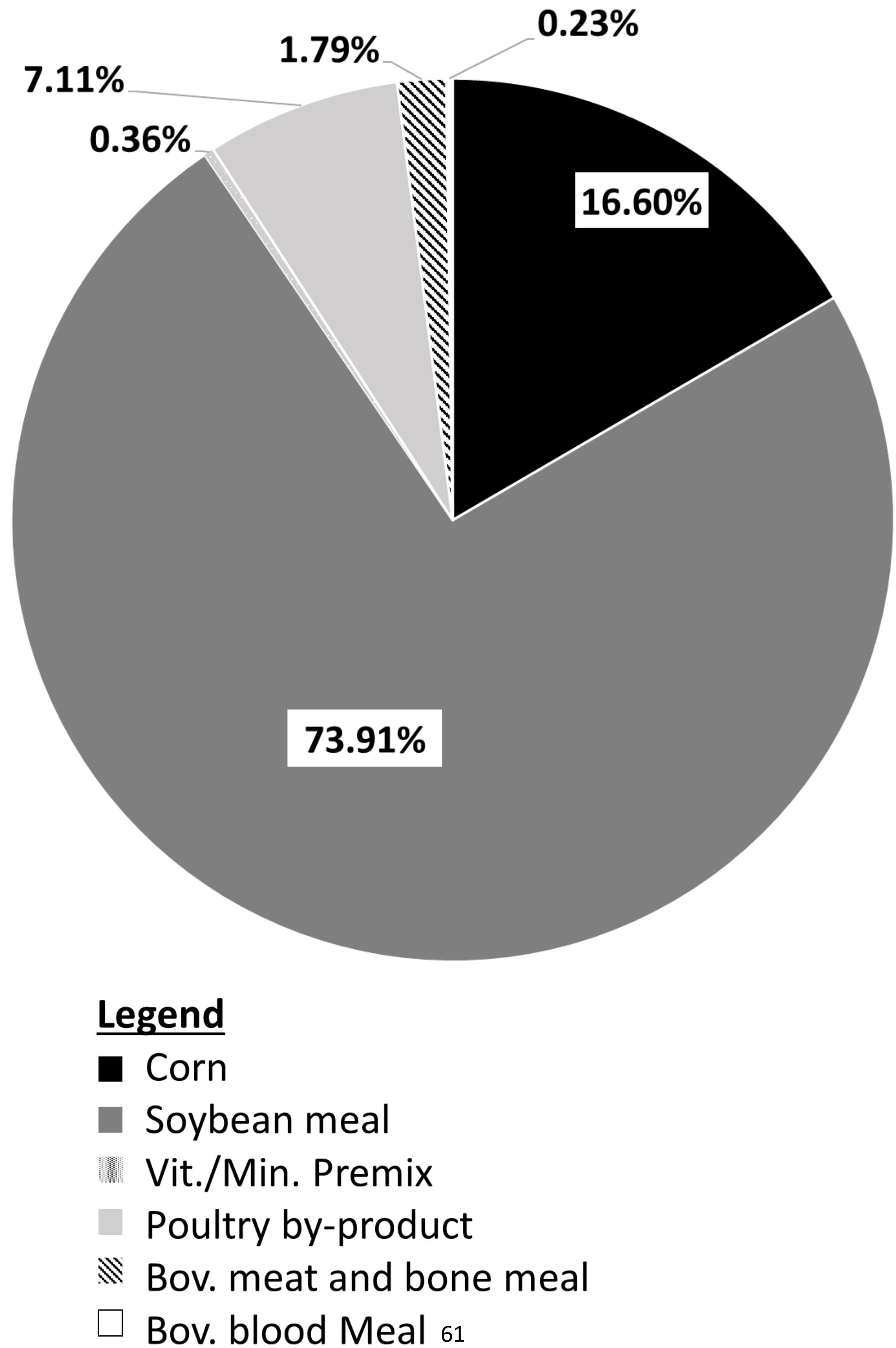
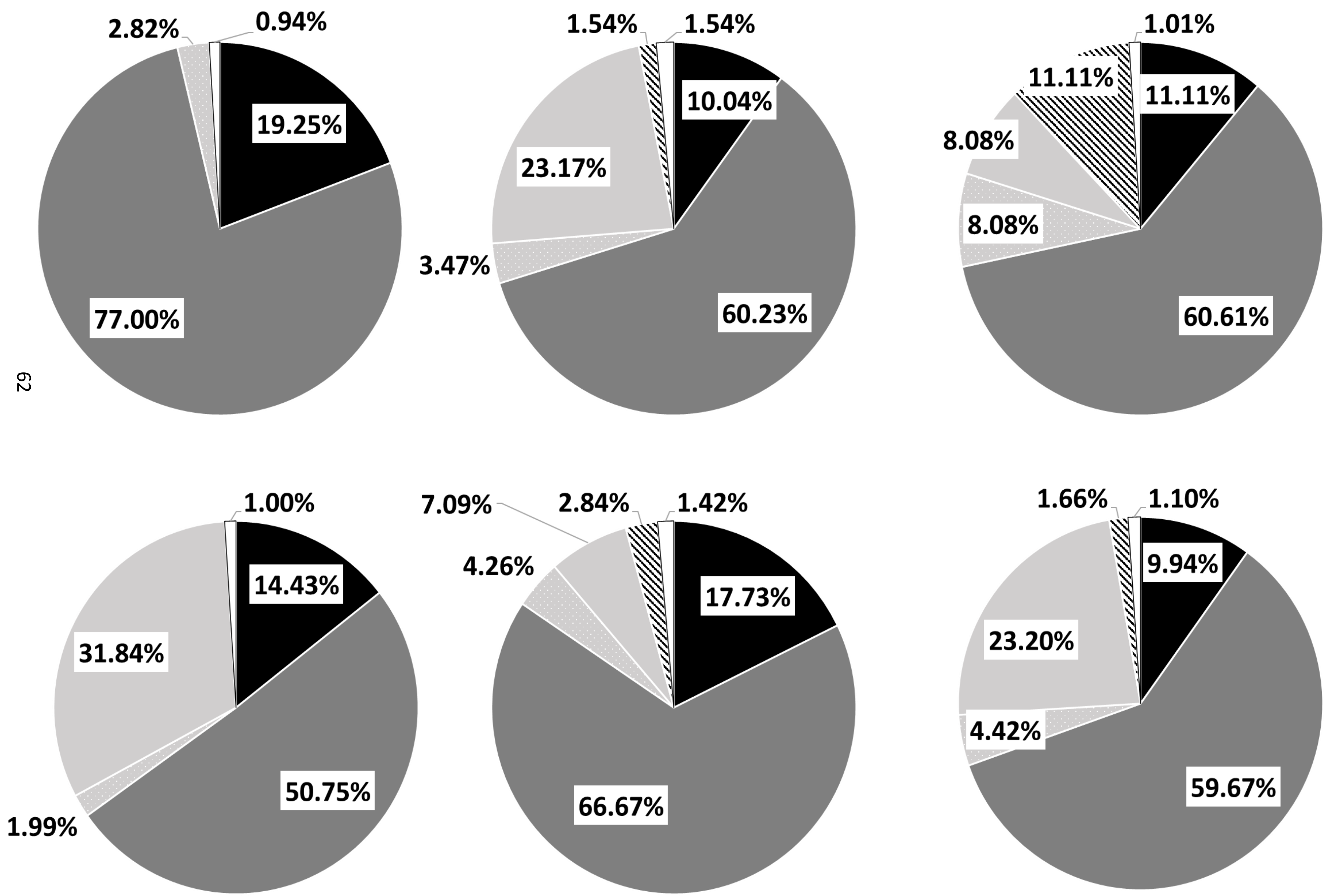


Figure 4.1 - % of Diet Intake Among Individually Housed Turkeys



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