NUTRITIONAL EVALUATION OF CANOLA MEAL PRODUCED FROM A NEW VARIETY OF CANOLA SEEDS IN BROILER CHICKENS AND LAYING HENS

BY

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THESIS

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ABSTRACT

Four precision-fed rooster assays, two broiler chicken experiments and one laying hen experiment were conducted. The four precision-fed rooster assays were used to determine the values of ME_n using conventional roosters and ileal digestible amino acid values using cecectomized roosters. The first experiment evaluated a conventional canola meal (Conv CM) in broiler chicken diets from 2 to 37 days of age. Treatments were replicated eight times using five chickens per replicate. Treatment diets were corn and soybean meal based and contained 0, 10, 20, 30 or 40% Conv CM from 2 to 21d of age and 0, 10, 20 or 30% Conv CM from 21 to 37d of age. In the starter phase (d 2 to 21), there was a significant negative effect ($P<0.05$) in weight gain and feed intake for CM levels in excess of 10% CM. The second broiler experiment evaluated both Conv CM and a new increased protein: reduced fiber Test CM. Seven treatments were replicated eight times using five chickens per replicate. For the starter phase (2 to 19d), the Treatment 1 diet contained no CM, Treatment 2-4 diets contained 8% Test CM and Treatment 5-7 diets contained 8% Conv CM. At day 20, chicks were switched to grower diets which contained either no CM or 8, 16, or 24% of test CM or Conv CM. These diets were fed until 44 d of age. There were no significant differences among dietary treatments in weight gain, feed intake, or feed efficiency for either phase of the experiment. The third experiment examined the effects of the new test CM and Conv CM in laying hen diets from 33 to 49 weeks of age. Seven treatments were replicated eight times using 14 caged hens per replicate. Corn-soybean meal diets again contained either no CM or 8, 16, or 24% Test CM or Conv CM. No significant differences were observed among treatments for feed intake, egg production, egg weight, egg mass, feed efficiency, or body weight change over the duration of the experiment. The results of these experiments indicate that a new increased protein; reduced fiber Test CM can be used

effectively in broiler chicken and laying hen diets when diets are formulated to be equal in ME and digestible amino acids.

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CHAPTER 1

INTRODUCTION

The term "canola" is used to reference a variety of rapeseed that is low in glucosinolate content (< 30 µmol/g) and erucic acid (< 2%); (Bell, 1993; Khajali and Slominski, 2012). Canola seeds vary in size and shape, but are often small and round. Canola is typically grown in northern areas where soybeans do not mature rapidly and are produced from a yellow-flowering plant. However, variations among varieties in climatic conditions and harvesting conditions may affect the concentration of fat, protein, amino acids, and carbohydrates in canola seeds and meals (Barthet and Duan, 2011; Newkirk, 2011). Canola is the second largest oilseed crop after soybeans (USDA, 2012) and contributes approximately 13% of the total oilseed meal production in the world (USDA, 2013). However, the oil content of canola is higher than in soybeans, as a percentage of the seed, and often considered healthier for human consumption, which makes it more desirable (Daun, 2011). After the oil has been extracted for the food industry, the resulting meal is used as a livestock feed ingredient. Traditionally, canola meal has been primarily fed to ruminant animals due to the high fiber content, which is poorly digested in poultry and swine, and anti-nutritional factors that can be "detoxified" in the rumen. These anti-nutritional factors, which include glucosinolates, erucic acid, sinapine, and tannins, make canola meal less desirable to poultry and swine because they may reduce feed intake and growth performance, as well as the digestibility of nutrients (Bell, 1993).

In order for canola meal to be utilized by all livestock species, breeding programs have been established to reduce the anti-nutritional factors, increase the protein content, and reduce the fiber content to be more competitive with soybean meal (Khajali and Slominski, 2012). For

animal diets, the nutritional value of feed ingredients is a function of nutrient composition, specifically digestible protein and amino acid levels, as well as energy and mineral concentrations (Arntfeld and Hickling, 2011). Therefore, new, yellow-seeded varieties of canola have a larger seed with a thinner hull compared to their black-seeded relatives (Thacker, 1990; Slominski et al., 1994; Khajali and Slominski, 2012). With a thinner hull, there is a reduction in fiber content and because of this, it is expected that the resulting meal has greater nutritional value than meal produced from traditional black-seeded varieties. Further research is needed to determine if new varieties of canola seeds that have reduced fiber and increased protein have improved nutritional value when fed to poultry compared with the traditional black-seeded conventional varieties.

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CHAPTER 2

THE NUTRITIONAL VALUE OF CONVENTIONAL AND HIGH-PROTEIN CANOLA MEAL FED TO POULTRY: A LITERATURE REVIEW

INTRODUCTION

Rapeseed is an oilseed from the *Brassica* species that has been produced for centuries all around the world. Over the years, plant breeding programs for rapeseed have been able to improve the nutritional quality and content to make it a higher valued feed ingredient for livestock. Much of this success has come from breeding programs to reduce the anti-nutritional properties that rapeseed contains. Traditionally, *Brassica rapa* (rapeseed) contained 25 to 45% erucic acid and 50 to 100 µmol/g glucosinolates (Bell, 1993). Rapeseed contains an enzyme called myrosinase that degrades the glucosinolates into toxic metabolites which makes it harmful to nonruminant species (Fenwick and Curtis, 1980). These toxic metabolites produced from the glucosinolates may be the cause of reduced feed intake, liver hemorrhages, fish-taint in brown eggs, and perosis in chicks (Fenwick and Curtis, 1980; Bell, 1993). Genetic breeding programs have decreased erucic acid levels to below 2% and glucosinolate levels to below 30 µmol/g resulting in what is referred to as "double-low" or "double zero" rapeseed. "Double-low" varieties are called "canola" in North America (Bell, 1993).

Phytic acid, fiber, sinapine and tannins are other anti-nutritional factors in canola (Bell, 1993; Khajali and Slominski, 2012). Phytic acid, or phytate, is the primary storage form of phosphorus (P), which reduces P absorption and utilization by monogastric animals (Nwokolo and Bragg, 1977; Khajali and Slominski, 2012). Phytate binds Ca, K, Mg, Fe, Mn, and Zn, which reduces the availability of these minerals (Nwokolo and Bragg, 1977). The addition of

phytase in the diets of poultry will hydrolyze part of the phytate binding complexes, resulting is more available P and Ca for the animal (Simons et al., 1990; Selle et al., 2009). Canola meal has relatively high levels of fiber because the hulls in the seeds stay with the meal during processing (Newkirk, 2009; Barthet and Duan, 2011). The new high-protein varieties of canola also contain less fiber due to the increased seed size which reduces the thickness of the hull. Therefore, the resulting canola meal from the new varieties contain less fiber compared to conventional canola and rapeseed products (Spragg and Mailer, 2007).

Tannins are phenolic compounds with varying molecular weights and complexities (Kozlowska et al., 1990; Jansman, 1993). They are present in the hull portion of canola and decrease energy and protein digestibility in the diet (Thacker and Petri, 1990; Khajali and Slominski, 2012). In one study it was observed increased endogenous losses of Met, Lys, and His when tannic acid was added to the diet (Mansoori and Acamovic, 2007). Met and Lys are usually the first limiting AA in commercial diets for poultry, the presence of tannins in canola meal prevents high inclusion of the ingredient. Tannins are removed in the oil extraction process (Kozlowska et al., 1990), and canola meal usually only contains 1.5% tannins (Mailer, 2004; Bonnardeaux, 2007). Another compound in canola meal, sinapine, the ester of sinapic acid, may contribute to the dark color and bitter taste in canola meal (Kozlowska et al., 1990). Sinapine is believed to be the cause of fishy-tainted eggs in brown egg layers (Perez-Maldonado, 2002). Sinapine can bind with choline which prevents choline absorption in the small intestine. Bacterial fermentation of choline in the lower gut causes the production of trimethylamine (TMA), which is then absorbed into the portal blood. Subsequently, this causes the TMA to be deposited into the egg yolk, which results in a fishy smell of the eggs (Ward et al., 2009). Despite the effectiveness of reducing the tainting potential of rapeseed meal by treatment with

lime, ammonia, or by micronisation, the effects were not sufficient to prevent inhibition of TMA oxidation and subsequent egg tainting (Fenwick et al. 1984)

Canola seeds contain 45 to 50% oil depending on the variety, of which about 98% is removed by the prepress solvent extraction process (Barthet and Duan, 2011). The resulting material leftover from the processs is canola meal. Canola oil is marketed for human consumption as the lowest saturated fat containing vegetable oil. It has roughly 50% less saturated fatty acids than corn and soybean oil (Aukema and Campbell, 2011). The meal fraction contains 36 to 44% crude protein (CP); (Barthet and Duan, 2011; Khajali and Slominski, 2012; Slominski et al., 2012). The neutral detergent fiber (NDF) values in canola meal range from 22 to 26% compared with 8 to 12% in soybean meal (Slominski et al., 1994; Khajali and Slominski, 2012; NRC, 2012).

New yellow-seeded varieties of canola that have been genetically modified through breeding programs are nutritionally superior to their conventional black-seeded relatives. The yellow seeds are larger and have a thinner hull, which results in increased crude protein and decreased fiber compared to darker seeds (Downey and Bell, 1990; Thacker and Petri, 1990; Khajali and Slominski, 2012). Since most of the protein is stored in the embryo of the seed, canola meal derived from the larger yellow seeds contains 46 to 50% CP (Simbaya et al., 1995; Slominski et al., 2012) and therefore contains higher AA concentrations than canola meal derived from black or dark seeded canola seeds (Slominski et al., 2012). Due to the decreased hull, dietary fiber concentrations of canola meal derived from yellow-seeded canola is 24 to 27% compared with 30 to 34% in canola meal from dark-seeded varieties (Slominski et al., 1994; Simbaya et al., 1995; Slominski et al., 2012). The differences in composition of canola meal

derived from yellow and black-seeded canola makes it necessary to conduct research on the nutritional value of each as a feed ingredient in poultry diets.

EFFECTS OF CANOLA MEAL FED TO BROILER CHICKENS

Slominski et al. (1999) conducted a two week feeding trial to compare yellow-and black-seeded varieties of *Brassica napus.* The treatment diets were fed to the chicks from 4 to 18 days of age. There was no difference in the CP content among the two meals but the yellow-seeded canola meal had significantly less fiber and fat than the black-seeded canola meal. The concentration of glucosinolates in the two meals were not different. The inclusion levels of the black and yellow-seeded canola meal in the experimental diets were 29.7 and 29.5%, respectively. There were no differences observed in body weight gain between the two canola meals; however, the chickens fed the diets containing the yellow-seeded canola meal had an improved feed to gain ratio compared to chickens fed the canola meal derived from black-seeded canola. Values for feed intake among dietary treatments were not reported, but presumably, feed intake was less for birds fed diets that consisted of yellow-seeded canola meal. The author concluded from this study that the yellow-seeded *B. napus* canola was superior to its black-seeded counterpart.

Newkirk and Classen (2002) conducted an experiment to determine if eliminating the use of sparge steam during canola meal processing would prevent toasting and to study the effects of toasting on broiler chicken performance. The authors hypothesized that the moisture incorporated into canola meal during desolventization, as sparge steam, promotes toasting and that nontoasted canola meal would result in higher digestible amino acids. Sparge steaming is used in canola meal processing to remove the residual hexane solvent from the meal. Dietary

treatments consisted of a conventional toasted canola meal or canola meal that had been desolventized without the use of sparge steam (nontoasted canola meal). The meals were fed to broiler chickens from 0 to 39 days of age and replaced 0, 20, 40, 60, 80, and 100% of the soybean meal in wheat-based diets. The authors observed that the elimination of toasting increased broiler weight when measured at day 19 and 39 as well as feed efficiency from 0 to 19 days of age but toasting had no effect on mortality. Newkirk and Classen (2002) concluded from this study that desolventization without sparge steam did produce a nontoasted canola meal that yielded improved broiler growth and feed efficiency in comparison to the chickens whose diets contained toasted canola meal.

Mushtaq et al. (2007) conducted a growth trial to test the effect of canola meal level on performance in the diets of broiler chickens from 1 to 42 days of age. The experiment was divided into a starter phase (2 to 21 d) and a grower phase (22 to 42 d). The dietary treatments consisted of either 20 or 30% canola meal derived from an unidentified canola species. The canola meal used was analyzed to contain 38.8, 7.17, 0.58, and 6.74% CP, CF, fat, and ash, respectively. Glucosinolate contents of the canola meal were not reported. Body weight gain was significantly reduced when 30% canola meal was added in the diets during the starter phase. The feed to gain ratio and mortality were also observed to be high at the higher level of canola meal. When data were combined for the starter and grower periods, no differences in weight gain and the feed to gain ratio were observed among treatments. Mushtaq et al. (2007) concluded that diets containing 30% canola meal were not recommended in broiler diets during the starter phase but could be used during the grower phase.

Min et al. (2011) conducted a similar experiment to evaluate canola meal from biodiesel production as a feed ingredient for broiler chickens. The experiment used canola meal at 0, 5,

10, 15, 20, or 25% of the diet from 1 to 28 days of age. No chemical composition of the canola meal was reported. No differences were observed among treatments for feed intake, body weight gain, feed conversion ratio, or mortality. The author concluded that canola meal can be included in the diets of broilers at 25% without observing any negative effects on growth performance when the diets are formulated to have equal levels of digestible amino acids.

Thacker and Petri (2011) conducted an experiment to evaluate the nutritional value of canola protein concentrate for broiler chickens and its effects on nutrient digestibility and growth performance. The control diet was based on corn and soybean meal and contained 15% canola meal. The experimental diets contained 3, 6, 9, 12, or 15% canola protein concentrate added at the expense of canola meal. The diets were formulated to be isocaloric (3,100 kcal/kg) and equal in digestible amino acids. The composition of the canola meal was 35.19, 3.80, and 25.84% CP, ether extract, and neutral detergent fiber (NDF), respectively. The canola protein concentrate had increased NDF (28.34 vs. 25.84) and increased CP (54.37 vs. 35.19) compared with the canola meal. The digestibility of dry matter, energy, and phosphorus increased linearly with increasing levels of canola protein concentrate. However, the higher nutrient digestibility of the diets containing the canola protein concentrate did not translate to improvements in broiler performance. Weight gain was unaffected by level of canola protein concentrate but feed intake was significantly increased, with the result that feed conversion tended to be poorer for birds fed diets containing canola protein concentrate. Thacker and Petri (2011) concluded that although the digestibility of dry matter, gross energy, and phosphorus were higher for birds fed canola protein concentrate compared with canola meal, these improvements did not equate to improvements in broiler performance. The authors offered no further explanation of why these results may have happened.

Jia et al. (2012) conducted an experiment to evaluate the nutritive value of canola meals derived from black- and yellow-seeded *Brassica napus* in broiler chickens. Growth performance was assessed from 3 to 17 days of age. The diets were corn-soybean meal based and contained either 30% canola meal derived from black- or yellow seeds. The yellow-seeded canola meal contained more crude protein and less fat, fiber, and glucosinolates than the black-seeded canola meal (Slominski et al., 2012). No differences among dietary treatments were observed for body weight gain, feed intake, or the feed-to-gain ratio. The greatest digestibility values for total and indispensable AA were for diets containing the yellow-seeded canola meal, indicating that protein from the yellow-seeded canola meal is more digestible than protein from the black-seeded meal. Additionally, the yellow-seeded canola meal contained the greatest amount of ME (2,190 vs. 1,904 kcal/kg of diet). Jia et al. (2012) concluded that the yellow-seeded *Brassica napus* had superior characteristics in regards to available energy and amino acid content; however, it is not clear why the broiler chickens fed the yellow-seeded canola meal did not have superior growth performance over the chickens fed the black-seeded canola meal.

Gopinger et al. (2014) conducted an experiment to compare the effect of different dietary levels of canola meal on growth performance and nutrient digestibility in broiler chickens from 8 to 35 days of age. Starter diets were used from 8 to 21 days of age followed by a grower diet from 22 to 35 days. Dietary treatments consisted of canola meal at 0, 10, 20, 30, or 40% as a substitute for soybean meal. Weight gain and average body weight showed a quadratic response, decreasing with the addition of 40% canola meal. Apparent nutrient digestibility of DM, CP, and nitrogen-free extract decreased linearly with increased levels of canola meal. Gopinger et al. (2014) concluded that canola meal can be fed up to 16.7% in diets for broilers without negatively

impacting growth performance, and canola meal can be included up to 20% without negative effects on the digestibility of CP.

McNaughton et al. (2014) conducted an experiment to compare the use of a genetically modified, a near-isogenic but not genetically modified, and commercial canola meals on broiler performance from 1 to 42 days of age. The different canola meals were included at 10% of the starter diet and at 20% in the grower diet. The CP values of the canola meals derived from genetically modified canola seeds averaged 48.6% while the CP of the canola meal derived from non-gentically modified, near-isogenic canola seeds averaged 44.3%. Also, crude fiber content of the meal from genetically modified canola seeds was lower than the meal derived from non-genetically modified canola seeds (10.1 vs. 12.0%). All of the dietary treatments were formulated to be isocaloric and were equal in digestible amino acids for both the starter and grower phases. No differences were observed among treatments for body weight gain, feed intake, or mortality for either phase of the experiment. The authors concluded that the meal derived from genetically modified canola seeds were nutritionally equivalent to meal produced from non-genetically modified canola seeds.

EFFECTS OF CANOLA MEAL FED TO LAYING HENS

Jackson (1969) studied the toxic effects of rapeseed meal derived from *Brassica napus* and its use as a protein supplement in the diets of laying hens. The experimental diets consisted of 0, 4, 8, 12, 16, or 20% rapeseed meal which was fed to 109 Hyline® light-weight laying hens for nine 28-day periods starting at 24 weeks of age. The light-weight hens exhibited a high mortality when fed rapeseed meal in excess of 4% of the diet mainly caused by hemorrhage of the liver. Mortality for the duration of the trial was 26, 44, 33, and 50% for the levels of 8, 12, 16, and 20% rapeseed meal, respectively. It was also observed that the thyroid weight and liver

weight increased linearly with the inclusion of rapeseed meal. Egg production also decreased when at least 8% rapeseed meal was included in the diet. The author concluded from this study that the initial effect of the rapeseed thyrotoxins on the thyroid gland are compensated for by thyroid enlargement and that those birds who survive the initial phase are then capable of normal physiological function with regard to egg production.

Summers et al. (1971) conducted a similar experiment to obtain information on the nutritive value of rapeseed meal for laying hens by studying the "toxic factors" at varying levels of rapeseed meal in the diet. The diets consisted of varying levels of protein obtained by blending protein sources. All diets contained 5% protein from corn with the remaining dietary protein coming from either soybean meal, rapeseed meal, or a combination of both. The diets were formulated so that differences in amino acid composition were due entirely to the two protein supplements. At the low level of protein (10%), there were no differences in response due to the type of protein supplement. The authors concluded from this observation that any toxic effect of rapeseed meal may have been masked due to amino acid deficiencies. It was also observed that the addition of rapeseed meal resulted in significantly lower egg production, feed intake, smaller egg size and loss of body weight. In general, the higher the level of rapeseed meal resulted in decreased egg production and egg weight which is believed to be caused by an amino acid imbalance because a decrease in production does not usually result in decreased egg size unless protein is limiting.

March et al. (1975) conduced an experiment to investigate the effects of feeding rapeseed meal during the growing and/or laying periods on mortality and egg production in laying hens. White Leghorn pullets were fed soybean or rapeseed meal during either or both the growing period and laying period in two experiments. In Experiment 1, pullets were reared in batteries

from day old to 16 weeks of age. Two starting diets and two growing diets were formulated to contain soybean meal or rapeseed meal as a supplementary protein source. The starter diets contained either 11% soybean meal or 17% rapeseed meal while the grower diets contained either 6% soybean meal or 9.5% rapeseed meal. At 16 weeks of age, the pullets were transferred to community cages at which point they received the laying diets that contained either 12.5% soybean meal or 19.6% rapeseed meal. Experiment 2 used the same design as Experiment 1 with the exception that the birds did not receive the laying diet until 23 weeks of age and treatments consisted of either 13% soybean meal or 19% rapeseed meal. Egg production was consistently higher in both experiments when the laying diet contained soybean meal rather than rapeseed meal and feed efficiency was correspondingly poorer. Hens that received soybean meal during the growing period and were shifted to laying diets that contained rapeseed meal had the lowest egg production and the poorest feed efficiency. Liver hemorrhage was the cause of death in 14 birds (5%), all of which were fed rapeseed meal laying diets. March et al. (1975) concluded that rapeseed meal may cause liver hemorrhage in laying hens; however, the effect was inconsistent and depended on the level of inclusion, the stage of life of the hen, and possibly the genotype of the birds.

Smith and Campbell (1976) conducted an experiment to study the effects of rapeseed meal glucosinolates on the performance of laying hens. Four dietary treatments were fed for three 28-day periods to Hyline White Leghorn hens. A standard barley-soybean meal diet served as the control diet. Three sources of rapeseed meal (Bronowski, 1788, and Target) were used in the experimental diets at an inclusion level of 50%. At the conclusion of the experiment, all surviving hens were killed and the livers were examined for the presence of non-fatal hemorrhage. The glucosinolate content of the rapeseed meals were 0.49, 0.34, and 3.62 mg/g for

Bronowski, 1788, and Target, respectively. No significant differences were observed among the treatments in average weight gain or feed consumption; however, hens fed Target rapeseed meal had lower egg production ($P<0.05$) than hens fed 1788 or Bronowski rapeseed meals. No differences in egg production were observed among the groups fed 1788 or Bronowski; however, the hens fed the control diet had higher egg production ($P<0.05$) than all other dietary treatments. There were also no significant differences observed among treatments in the frequency of fatal or non-fatal liver hemorrhaging.

Leeson et al. (1987) conducted an experiment to investigate the effects of replacing dietary soybean meal with canola meal in the diets of laying hens with emphasis on efficiency of mineral utilization. The dietary treatments consisted of 0, 25, 50, or 100% replacement of soybean meal with canola meal which equated to canola meal levels at 0, 6.32, 12.64, and 25.28% of the diet, respectively. Dietary treatment had no effect on feed intake ($P>0.05$) even though the birds fed diets with supplemental canola meal were numerically heavier than those fed the control diet. This study also observed no effect of the dietary treatments on egg production, egg weight, and eggshell deformation. Leeson et al. (1987) also observed no differences among dietary treatments for nutrient retention and bone mineralization and concluded that canola meal can totally replace soybean meal without any adverse effects on performance, nutrient retention or mineral metabolism in the diets of laying hens.

Campbell et al. (1999) conducted two experiments to evaluate the nutritional value of low-glucosinolate canola meal for laying hens. The first study compared a low-glucosinolate canola meal to a commercial canola meal and a control diet (no canola meal) for a 5 month period while the second experiment used diets that varied in glucosinolate concentrations among the canola meals. Production performance as well as organ weights, thyroid hormone levels, and

liver enzyme levels were measured to assess the treatment effects. Aside from the control diet, dietary treatments consisted of either 10 or 20% inclusion of either low-glucosinolate or commercial canola meal. The glucosinolate content of the low-glucosinolate canola meal was 1.80 F mol/g which is substantially lower than the commercial canola meal (10 – 15 F mol/g). No differences were observed among dietary treatments for egg production, feed efficiency, or mortality. The author also observed no differences among dietary treatments for thyroid weight, liver weight, thyroid hormone levels, or liver enzyme levels. Campbell et al. (1999) concluded that the low-glucosinolate canola meal may be used in laying hen diets based on its nutritive value in comparison to other protein sources with no need for an upper-limit constraint.

CONCLUSIONS

It has been shown that canola meals produced from some new varieties of canola seeds have greater crude protein and decreased fiber content and glucosinolates compared to conventional canola meal. These improvements through genetic breeding indicate that the feeding value of canola meal can potentially be improved for poultry and other nonruminant animals. For example, canola meal produced from yellow-seeded canola not only has increased protein and reduced fiber, it also has higher levels of methionine than soybean meal which further adds to its potential value in poultry diets since methionine is usually the first limiting amino acid. However, canola meal has lower concentrations of lysine than soybean meal which leads to the frequent necessity of more synthetic lysine being added to the diets for both broiler chickens and laying hens. The effects of rapeseed meal on the growth and performance of broiler chickens and laying hens has been well documented; however, more research is needed to investigate the effects of new high-protein canola meals. Research is also needed to evaluate the effect of feeding high-protein, reduced fiber canola meal compared with conventional canola

meal in poultry diets. Therefore, the objective of this thesis was to evaluate the feeding of several increasing levels of a new high protein, reduced fiber canola meal to broiler chickens and laying hens when all diets are formulated to be equal in ME and digestible amino acids.

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CHAPTER 3

NUTRITIONAL EVALUATION OF CONVENTIONAL AND HIGH-PROTEIN CANOLA MEAL FED TO BROILER CHICKENS

ABSTRACT

Four precision-fed rooster experiments and two broiler chicken experiments were conducted to evaluate the nutritional value and the feeding of increasing dietary levels of conventional canola meal (Conv CM) and a new increased protein: reduced fiber test CM. The test CM contained higher levels of ME_n and digestible amino acids than the Conv CM as determined in the rooster assays. All diets in the two broiler experiments were then formulated to be equal in ME_n and digestible amino acids based on the values from the precision-fed rooster assays. The first broiler experiment evaluated a Conv CM in broiler chicken diets from 2 to 37 days of age. Treatments were replicated eight times using five chickens per replicate. Treatment diets were corn and soybean meal based and contained 0, 10, 20, 30 or 40% Conv CM from 2 to 21 d of age and 0, 10, 20 or 30% Conv CM from 21-37 d of age. In the starter phase (d 2-21), there was a significant negative effect ($P<0.05$) on weight gain and feed intake for CM levels in excess of 10%. The second broiler experiment evaluated both Conv CM and the new increased protein: reduced fiber test CM. Seven treatments were replicated eight times using five chickens per replicate. For the starter phase (2 to 19 d), the Treatment 1 diet contained no CM, Treatment 2-4 diets contained 8% Test CM and Treatment 5-7 diets contained 8% Conv CM. At Day 20, the chicks were switched to grower diets which contained either no CM or 8, 16, or 24% of test CM (Diets 2 – 4) or the same levels of Conv CM (Diets 5 – 7). These diets were fed until 44 d of age. There were no significant differences among dietary treatments in weight gain, feed intake,

or feed efficiency for either phase of the experiment. The results of this study indicate that the new test CM has increased nutritional value compared to Conv CM and that up to 30% of either type of CM can be fed to broiler chickens during the grower phase if diets are formulated to be equal in ME_n and digestible amino acids.

Key words: Test CM, Conv CM, broiler chicken, precision-fed rooster assay, ME_n

INTRODUCTION

Inclusion levels of canola meal (CM) in diets for poultry have often been limited in the past. The major reason for the latter is the anti-nutritional factors in the CM. The main factors have been glucosinolates and fiber which reduce the value of the meal for nonruminant animals. The presence of glucosinolates has been shown to result in reduced growth performance, reduced feed intake, enlarged thyroids, and mortality in broilers (Khajali and Slominski, 2012; Fenwick and Curtis, 1980). Feed ingredients with high fiber content have been shown to have decreased energy value and may also decrease digestibility of various minerals for poultry (Nwokolo and Bragg, 1977; Bell, 1993). The agricultural industry has developed breeding programs for CM to reduce these anti-nutritional factors. New yellow-seeded (*Brassica napus)* varieties contain lower levels of glucosinolates and fiber as well as having higher levels of protein (Simbaya et al., 1995; Slominski et al., 1999; Slominski et al., 2012). The new yellow-seeded varieties have a larger seed and thinner hull, than their traditional black-seeded relatives *Brassica napus* (Khajali and Slominski, 2012). With a thinner hull, there is a reduction in fiber which may increase the digestibility for broiler chickens. The yellow-seeded varieties have not been used substantially in animal diets because of their inherent agronomic problems (Rakow et al., 2007). Recently, a new test high protein: low fiber canola seed has been developed. Therefore, the objective of this

study was to evaluate a new test higher-protein, reduced fiber CM produced from the newly developed canola seeds in the diets of broiler chicks.

MATERIALS AND METHODS

All animal procedures were approved by the University of Illinois Institutional Animal Care and Use Committee (IACUC).

Diets and Experimental Design

Four precision-fed rooster assays (Kim et al., 2010) were conducted to determine TME_n and digestible amino acid concentrations for the conventional CM, high protein test CM and the soybean meals used in the broiler experiments. The TME_n values were determined in conventional roosters and the digestible amino acid values were determined in cecectomized roosters. The composition of the CM and soybean meals are shown in Tables 3.1 and 3.2. Two additional experiments were conducted to evaluate the nutritional value of CM in broiler chicken diets. The first broiler experiment evaluated increasing levels of conventional CM to provide input for the treatments to evaluate in the second experiment. The first experiment used 200 Ross 308 males which were randomly assigned to one of five dietary treatments from 2 to 19 d of age in which chicks were fed diets containing 0, 10, 20, 30 or 40% conventional CM. The chickens were then fed diets containing 0, 10, 20 or 30% conventional CM during the grower phase (20 to 37 d). The dietary treatment that included 40% CM was not included during the grower phase due to limited grower battery space. The second experiment used 280 Ross 308 males which were randomly assigned to one of seven dietary treatments from 2 to 42 d of age. These treatments consisted of 0 or 8% test or conventional CM in the starter phase (2 to 19 d) and 0, 8, 16, or 24% test or conventional CM in the grower phase (20 to 44 d). At the initiation of each experiment, chicks were weighed, wing banded, and allotted to their dietary treatments

via a complete randomized design so that each pen had a similar mean initial body weight. There were 5 chicks per pen and 8 replicate pens per treatment. During the experiments, chicks were housed in thermostatically-controlled Petersime starter batteries with raised-wire flooring in an environmentally controlled room with continuous lighting. Experimental diets and water were available ad libitum for the duration of the experiments. Feed intake per pen was recorded and final body weight of each chick was recorded at the conclusion of the experiment. Data were then summarized to calculate weight gain, feed intake, and gain: feed ratio.

The composition of each diet for the first broiler experiment is provided in Table 3.3 for the starter phase and in Table 3.4 for the grower phase. The composition of the diets for Experiment 2 is provided in Table 3.5 for the starter phase and Table 3.6 for the grower phase. All diets were formulated to be equal in ME_n, digestible amino acids, Ca and available P using the ingredient compostion values shown in Table 3.1. The ME_n values were calculated based on the TME_n values determined in the precision-fed conventional rooster assays and the digestible amino acid values were determined in the precision-fed cecectomized rooster assays and table values for corn (National Research Council, 1994).

Nutrient Analysis

Ingredients were analyzed for GE using bomb calorimetry (Model 6300; Parr Instruments, Moline, IL), CP by combustion (Method 990.03; AOAC International, 2007) using a Rapid N Cube (Elementar Americas Inc, Mt. Laurel, NJ) with Asp as the standard, and ash (Method 942.05; AOAC International, 2007). Ingredients were also analyzed for ADF (Method 973.18, AOAC International, 2007), NDF (Holst, 1973), and amino acids (Method 982.30 E [a, b, and c]; AOAC International, 2007). Ingredient samples were also analyzed for DM by forced air oven drying for 2 h at 135°C (Method 930.15; AOAC International, 2007), Ca and P using

inductively coupled plasma spectroscopy (Method 985.01 A, B, and C; AOAC International, 2007) after wet ashing (Method 975.03 B[b]; AOAC International, 2007).

Statistical Analysis

All data were analyzed by analysis of variance procedures for a one-way completely randomized design using PROC GLM of SAS® (SAS Institute Inc., Cary, NC). Statistical significance was determined at $P<0.05$. When a statistical significance in the model was present, Fisher's Least Significant Difference means separation test was used.

RESULTS AND DISCUSSION

In Experiment 1, the growth performance results are shown in Table 3.7 for the starter phase and Table 3.8 for the grower phase. There was a significant reduction in weight gain and feed intake at CM levels greater than 10% inclusion in the diet in the starter phase (2 to 21 d). However, there were no significant differences among treatments for gain:feed ratio indicating that the primary cause of the reduced weight gain was reduced feed intake. In the grower phase (21 to 37 d), there were no significant differences at $P<0.05$ in weight gain, feed intake, or gain:feed among dietary treatments. However, the effect of CM level approached significance ($P= 0.066$) for weight gain, primarily due to the large reduction in weight gain at 30% CM.

The results of Experiment 1 led to the experimental design of Experiment 2. The significantly reduced growth performance of the chicks in Experiment 1 with CM exceeding 10% of the diet in the starter phase carried over into the grower phase. Due to the large growth depression at the higher levels of CM in the starter phase, the chickens had reduced performance throughout the remainder of the trial. Because of the adverse effects at high levels of CM in Experiment 1, it was decided to limit the inclusion of canola meal in the starter phase of Experiment 2 to 8%. When the CM inclusion in the starter phase was limited to 8%, no adverse

effects on performance were observed from either test or conventional CM (Table 3.9). In addition, no significant differences were observed from feeding, 8, 16, or 24% of test CM or conventional CM during the grower phase (Table 3.10) or for the entire experiment (2 – 44 d)(Table 3.11).

Batal and Parsons (2002) showed that ME_n and AA digestibility of corn-CM diets increase with age for young chicks between 0 and 14 d of age. This is one possible explanation of why the chicks fed the high levels of CM in Experiment 1 had reduced growth and feed intake when compared to the chicks in Experiment 2. Another study concluded that AME_n values vary significantly among expeller-extracted CM samples and that the fiber components may have a considerable effect on AME_n value (Toghyani et al., 2014). These findings could also be an explanation why the chickens in Experiment 1 had reduced growth and performance and the chickens in Experiment 2 did not.

The results of studies evaluating the feeding of increasing or high levels of CM have not been consistent. In the current study, CM levels of 20% or higher could not be fed during the starter phase without depressing growth. Mushtaq et al. (2007) found similarly reduced body weight gain, feed conversion, and increased mortality in broiler chicks when 30% CM was added to the diets during 1 to 21 days of age. Results of another study indicated that CM can be added up to 16.7% in the diet without affecting growth performance of broiler chickens from 0 to 35 d of age and up to 20% without any negative effect on the CP digestibility; however, a decrease in digestibility of DM and nitrogen-free extract at levels exceeding 20% inclusion was observed (Gopinger, 2014). Only a few studies have been conducted to evaluate the replacement value of CM for soybean meal in diets for broiler chickens. Newkirk and Classen (2002) studied the effects of traditional toasted CM versus nontoasted CM as a replacement for soybean meal at

varying levels in diets of broiler chickens. Results of their study indicated that nontoasted CM improved broiler growth and feed efficiency at levels of 0 to 24% from 0 to 39 d of age compared to toasted CM and further concluded that nontoasted CM could be effectively fed to broiler chickens. Similarly, Leeson et al. (1987) showed that CM can replace 100% of the soybean meal in broiler diets from 0 to 21 d of age without any significant effect on feed intake, weight gain or feed efficiency as well as protein, fat, calcium, phosphorus or magnesium retention and energy utilization. Jia et al. (2012) fed 30% CM that was derived from either yellow-seeded *Brassica napus* or black-seeded *Brassica napus* canola seeds to broiler chickens from 3 to 17 d of age. Although the broiler chickens that were fed canola meal derived from yellow-seeded *Brassica napus* had better energy utilization than the birds fed black-seeded CM, there were no observed differences in growth performance.

As can be seen in Table 3.2, the test CM had greater nutritional value than that of the conventional CM. The test CM had lower fiber values of 15.1 and 9.2% for neutral detergent fiber and acid detergent fiber, respectively, compared to 25.0 and 17.5% for the conventional CM used in Experiment 2. Additionally, the test CM had higher CP levels than the conventional CM (45 vs. 40%) as well as greater levels of digestible amino acids. Due to the superior quality of the test CM, less soybean meal can be used in the diets of broiler chickens while still maintaining growth performance which has economic benefits. Because soybean meal is typically a more expensive feed ingredient, using CM as its replacement can lower feed costs. Additionally, the use of synthetic methionine would decrease when replacing soybean meal with CM; however, synthetic lysine supplementation would increase but L-lysine HCl is typically less expensive than DL-methionine. In conclusion, the new high protein, reduced fiber canola meal can be included up to at least 8% in broiler starter diets and up to 24% in grower diets without

any adverse effects on body weight gain, feed intake, feed efficiency and mortality when the diets are formulated to be equal in ME and digestible amino acids.

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TABLE 3.1. Nutrient composition of ingredients used in Experiment 1 (as-fed basis)

Item	Conventional canola meal	Soybean meal
ME_n[3], kcal/kg	2,010	2,450
DM, %	89.9	88.2
CP, %	35.1	46.7
NDF[1], %	25.0	8.23
ADF[1], %	17.5	4.81
Ca, %	0.60	0.29
Total P[1], %	1.20	0.57
Available P[2], %	0.40	0.19
Total AA[1], %		
Arg	2.09	3.43
His	0.91	1.24
Ile	1.35	2.32
Leu	2.53	3.73
Lys	2.02	3.07
Met	0.68	0.69
Phe	1.38	2.45
Thr	1.49	1.82
Trp	0.46	0.68
Val	1.72	2.50
Cys	0.82	0.68
Ileal Digestible AA[13], %		
Arg	1.86	3.18
His	0.80	1.15
Ile	1.10	2.08
Leu	2.14	3.30
Lys	1.57	2.70
Met	0.59	0.62
Phe	1.17	2.21
Thr	1.20	1.59
Trp	0.37	0.60
Val	1.33	2.19
Cys	0.68	0.58

[1]NDF = neutral detergent fiber; ADF= acid detergent fiber; P = phosphorus; AA= amino acids.
[2]Calculated assuming that 30% of the total P was available.
[3]ME_n values determined using conventional roosters in precision-fed rooster assay. Ileal digestible AA values determined using cecectomized roosters in precision-fed rooster assay.

TABLE 3.2. Nutrient composition of ingredients used in Experiment 2 (as-fed basis)

Item	Test canola meal	Conventional canola meal	Soybean meal
ME_n[3], kcal/kg	2,200	2,010	2,450
DM, %	89.4	88.9	89.0
CP, %	45.40	40.25	49.00
NDF[1], %	15.10	18.88	6.74
ADF[1], %	9.22	14.32	3.83
Ca, %	0.60	0.60	0.29
Total P[1], %	1.20	1.20	0.62
Available P[2], %	0.40	0.40	0.19
Total AA[1], %			
Arg	2.79	1.66	3.54
His	1.12	1.01	1.24
Ile	1.78	1.57	2.24
Leu	2.84	2.67	3.65
Lys	2.48	2.17	2.99
Met	0.92	0.79	0.68
Phe	1.63	1.56	1.80
Thr	1.83	1.66	1.93
Trp	0.58	0.52	0.70
Val	2.32	2.02	2.35
Cys	1.28	1.04	0.69
Ileal Digestible AA[13], %			
Arg	2.59	2.34	3.32
His	1.12	0.80	1.15
Ile	1.55	1.34	2.03
Leu	2.78	2.14	3.30
Lys	2.06	1.75	2.56
Met	0.84	0.71	0.62
Phe	1.58	1.17	2.21
Thr	1.52	1.36	1.68
Trp	0.57	0.51	0.68
Val	1.94	1.65	2.02
Cys	1.11	0.89	0.58

[1]NDF = neutral detergent fiber; ADF= acid detergent fiber; P = phosphorus; AA= amino acids.
[2]Calculated assuming that 30% of the total P was available.
[3]ME_n values determined using conventional roosters in precision-fed rooster assay. Ileal digestible AA values determined using cecectomized roosters in precision-fed rooster assay.

TABLE 3.3. Ingredient and nutrient compositions of the experimental diets provided to chicks from 2 to 21 d of age for Experiment 1

	Dietary treatments[1]				
Ingredients	1	2	3	4	5
			(%)		
Corn	57.68	53.46	49.00	42.65	35.71
Soybean meal	36.01	29.11	22.38	17.45	13.03
Conventional canola meal	0.00	10.00	20.00	30.00	40.00
Soy oil	2.11	3.36	4.67	6.22	7.88
Limestone	1.46	1.43	1.40	1.36	1.32
Dicalcium phosphate	1.24	1.12	0.99	0.86	0.72
Salt	0.49	0.49	0.48	0.48	0.48
Vitamin mix	0.20	0.20	0.20	0.20	0.20
Trace mineral mix	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.25	0.22	0.19	0.14	0.09
L-lysine HCl	0.15	0.20	0.24	0.22	0.19
L-threonine	0.09	0.09	0.09	0.06	0.03
Choline chloride	0.07	0.07	0.07	0.07	0.07
Phytase[2]	0.05	0.05	0.05	0.05	0.05
Bacitracin[3]	0.05	0.05	0.05	0.05	0.05
Potassium carbonate	0.00	0.00	0.04	0.04	0.03
Calculated composition, as-fed basis					
ME, kcal/kg	3,040	3,040	3,040	3,040	3,040
CP, %	21.50	21.50	21.55	22.22	23.06
Ca, %	0.95	0.95	0.95	0.95	0.95
Available P, %	0.45	0.45	0.45	0.45	0.45
Ileal digestible Met + Cys, %	0.86	0.86	0.86	0.86	0.86
Ileal digestible Lys, %	1.20	1.20	1.20	1.20	1.20
Ileal digestible Thr, %	0.80	0.80	0.80	0.80	0.80
Ileal digestible Val, %	1.00	0.97	0.94	0.94	0.95

[1]Diet 1 contained no canola meal; Diet 2 contained 10% canola meal; Diet 3 contained 20% canola meal; Diet 4 contained 30% canola meal; Diet 5 contained 40% canola meal.
[2]Optiphos®, Huvepharma, Sofia, Bulgaria. Provided 500 FTU/kg of diet.
[3]Bacitracin methylene disalicylate. Provided 27.7 mg/kg. Obtained from Pfizer Animal Health, Madison, NJ.

TABLE 3.4. Ingredient and nutrient compositions of the experimental diets provided to chicks from 21 to 37 d of age for Experiment 1

	Dietary treatments[1]			
Ingredients	1	2	3	4
		(%)		
Corn	63.59	59.24	53.85	47.70
Soybean meal	30.79	23.91	18.06	12.90
Conventional canola meal	0.00	10.00	20.00	30.00
Soy Oil	1.68	2.98	4.42	5.97
Limestone	1.37	1.34	1.30	1.26
Dicalcium phosphate	1.10	0.98	0.85	0.72
Salt	0.49	0.49	0.48	0.48
Vitamin mix	0.20	0.20	0.20	0.20
Trace mineral mix	0.15	0.15	0.15	0.15
DL-methionine	0.23	0.20	0.16	0.11
L-lysine HCl	0.16	0.21	0.22	0.22
L-threonine	0.09	0.09	0.07	0.05
Choline chloride	0.05	0.05	0.05	0.05
Phytase[2]	0.05	0.05	0.05	0.05
Bacitracin[3]	0.05	0.05	0.05	0.05
Potassium carbonate	0.00	0.06	0.09	0.09
Composition, as-fed basis				
ME, kcal/kg	3,075	3,075	3,075	3,075
CP, %	19.50	19.50	19.85	20.44
Ca, %	0.87	0.87	0.87	0.87
Available P, %	0.42	0.42	0.42	0.42
Ileal digestible Met + Cys, %	0.80	0.80	0.80	0.80
Ileal digestible Lys, %	1.08	1.08	1.08	1.08
Ileal digestible Thr, %	0.73	0.73	0.73	0.73
Ileal digestible Val, %	0.91	0.88	0.86	0.86

[1]Diet 1 contained no canola meal; Diet 2 contained 10% canola meal; Diet 3 contained 20% canola meal; Diet 4 contained 30% canola meal.
[2]Optiphos®, Huvepharma, Sofia, Bulgaria. Provided 500 FTU/kg of diet.
[3] Bacitracin methylene disalicylate. Provided 27.7 mg/kg. Obtained from Pfizer Animal Health, Madison, NJ.

TABLE 3.5. Ingredient and nutrient compositions of the starter diets provided to chicks from 2 to 19 d of age for Experiment 2

Ingredients	Dietary treatments[1]		
	1	2-4	5-7
		(%)	
Corn	58.80	58.04	56.06
Soybean meal	34.97	27.43	28.94
Test canola meal	-	8.00	-
Conventional canola meal	-	-	8.00
Soy oil	1.93	2.33	2.84
Limestone	1.46	1.45	1.44
Dicalcium phosphate	1.25	1.15	1.15
Salt	0.49	0.46	0.46
Vitamin mix	0.20	0.20	0.20
Trace mineral mix	0.15	0.15	0.15
DL-methionine	0.26	0.20	0.21
L-lysine HCl	0.24	0.28	0.27
L-threonine	0.08	0.08	0.08
K_2CO_3	0.00	0.05	0.03
Choline chloride	0.07	0.07	0.07
Bacitracin[2]	0.05	0.05	0.05
Phytase[3]	0.05	0.05	0.05
Calculated composition, as-fed basis			
ME, kcal/kg	3,040	3,040	3,040
CP, %	21.99	21.87	22.04
Calcium, %	0.95	0.95	0.95
Available phosphorus, %	0.45	0.45	0.45
Ileal digestible Met + Cys, %	0.86	0.86	0.86
Ileal digestible Lys, %	1.20	1.20	1.20
Ileal digestible Thr, %	0.80	0.80	0.80
Ileal digestible Val, %	0.92	0.92	0.92

[1]Diet 1 contained no canola meal; Diets 2-4 contained 8% test canola meal; Diet 5-7 contained 8% conventional canola meal.
[2]Bacitracin methylene disalicylate. Provided 27.7 mg/kg. Obtained from Pfizer Animal Health, Madison, NJ.
[3]Optiphos®, Huvepharma, Sofia, Bulgaria. Provided 500 FTU/kg of diet.

TABLE 3.6. Ingredient and nutrient compositions of the experimental diets provided to chicks from 20 to 44 d of age for Experiment 2

	Dietary treatments[1]						
Ingredients	1	2	3	4	5	6	7
				(%)			
Corn	64.60	63.80	62.48	59.75	61.80	59.00	55.40
Soybean meal	29.85	22.32	15.25	9.49	23.83	17.81	12.53
Test canola meal	-	8.00	16.00	24.00	-	-	-
Conventional canola meal	-	-	-	-	8.00	16.00	24.00
Soy oil	1.52	1.94	2.44	3.13	2.46	3.40	4.45
Limestone	1.37	1.35	1.34	1.31	1.35	1.33	1.30
Dicalcium phosphate	1.11	1.02	0.92	0.82	1.01	0.91	0.81
Salt	0.49	0.46	0.44	0.41	0.46	0.43	0.40
Vitamin mix	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Trace mineral mix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.24	0.17	0.11	0.04	0.19	0.14	0.09
L-lysine HCl	0.25	0.28	0.28	0.29	0.27	0.29	0.30
L-threonine	0.07	0.08	0.08	0.06	0.07	0.07	0.06
K_2CO_3	0.00	0.08	0.16	0.20	0.06	0.12	0.16
Choline chloride	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Bacitracin[2]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Phytase[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Calculated composition, as-fed basis							
ME, kcal/kg	3,075	3,075	3,075	3,075	3,075	3,075	3,075
CP, %	19.90	19.78	19.84	20.38	19.95	20.01	20.33
Calcium, %	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Available phosphorus, %	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Ileal digestible Met + Cys, %	0.80	0.80	0.80	0.82	0.80	0.80	0.80
Ileal digestible Lys, %	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Ileal digestible Thr, %	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Ileal digestible Val, %	0.84	0.84	0.85	0.88	0.84	0.84	0.85

[1]Diet 1 contained no canola meal; Diet 2 contained 8% test canola meal; Diet 3 contained 16% test canola meal; Diet 4 contained 24% test canola meal; Diet 5 contained 8% conventional canola meal; Diet 6 contained 16% conventional canola meal; Diet 7 contained 24% conventional canola meal.
[2]Bacitracin methylene disalicylate. Provided 27.7 mg/kg. Obtained from Pfizer Animal Health, Madison, NJ.
[3]Optiphos®, Huvepharma, Sofia, Bulgaria. Provided 500 FTU/kg of diet.

TABLE 3.7. Body weight gain, feed intake and gain:feed for starter phase (2-21 d) for Experiment 1[1]

Dietary treatments	Weight gain (g/chick)	Feed intake (g/chick)	Gain: feed (g/kg)
0% Conventional canola meal	687.9[a]	874.3[a]	787
10% Conventional canola meal	684.3[a]	887.8[a]	772
20% Conventional canola meal	633.2[b]	823.1[b]	769
30% Conventional canola meal	617.3[bc]	793.8[bc]	769
40% Conventional canola meal	575.6[c]	748.4[c]	769
Pooled SEM	15.7	17.3	16.1
P-value	<0.0001	<0.0001	0.9170

[a-c]Means within a column with no common superscript are significantly different (P<0.05).
[1]Values represent means of 8 replicate cages containing 5 birds per cage.

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TABLE 3.8. Body weight gain, feed intake and gain:feed for grower phase (21-37 d) for Experiment 1[1]

Dietary treatments[2]	Weight gain (g/chick)	Feed intake (g/chick)	Gain: feed (g/kg)
0% Conventional canola meal	1477	2407	616
10% Conventional canola meal	1418	2528	560
20% Conventional canola meal	1432	2426	592
30% Conventional canola meal	1327	2283	583
Pooled SEM	32.4	56.9	15.0
P-value	0.0661	0.1028	0.1863

[1]Values represent means of 8 replicate cages containing 5 birds per cage.

TABLE 3.9. Body weight gain, feed intake and gain:feed for starter phase (2-19 d) in Experiment 2[1]

Dietary treatments[2]	Weight gain (g/chick)	Feed intake (g/chick)	Gain: feed (g/kg)
0% CM	613.4	803.5	763
8% Test CM	640.5	827.2	775
8% Test CM	614.4	816.6	753
8% Test CM	611.1	818.1	747
8% Conventional CM	612.8	807.7	760
8% Conventional CM	612.9	813.3	753
8% Conventional CM	610.1	811.4	752
Pooled SEM	8.5	11.5	10.9
P-value	0.1075	0.8406	0.6237

[1]Values represent means of 8 replicate cages containing 5 birds per cage.
[2]CM= canola meal.

TABLE 3.10. Body weight gain, feed intake and gain:feed for grower phase (20-44 d) in Experiment 2[1]

Dietary treatments[2]	Weight gain (g/chick)	Feed intake (g/chick)	Gain: feed (g/kg)
0% CM	2000	3530	567
8% Test CM	1977	3593	550
16% Test CM	2000	3547	564
24% Test CM	1921	3479	551
8% Conventional CM	1995	3432	581
16% Conventional CM	2011	3588	560
24% Conventional CM	2007	3573	561
Pooled SEM	44.1	50.5	10.0
P-value	0.8077	0.2330	0.4124

[1]Values represent means of 8 replicate cages containing 5 birds per cage.
[2]CM= canola meal.

TABLE 3.11. Body weight gain, feed intake and gain:feed for all phases (2-44 d) in Experiment 2[1]

Dietary treatments[2]	Weight gain (g/chick)	Feed intake (g/chick)	Gain: feed (g/kg)
0% CM	2614	4333	603
8% Test CM	2618	4421	592
8% Test CM/ 16% Test CM[3]	2614	4364	599
8% Test CM/ 24% Test CM[3]	2532	4297	589
8% Conventional CM	2607	4240	615
8% Conventional CM/ 16% Conventional CM[3]	2624	4401	596
8% Conventional CM/ 24% Conventional CM[3]	2617	4384	597
Pooled SEM	45.4	54.0	8.0
P-value	0.8089	0.2439	0.4179

[1]Values represent means of 8 replicate cages containing 5 birds per cage.
[2]CM= canola meal.
[3]Diets contained 8% of the Test or Conventional CM during the starter phase and either 16% or 24% of the test or conv. CM during the grower phase.

CHAPTER 4

NUTRITIONAL EVALUATION OF CONVENTIONAL AND HIGH-PROTEIN CANOLA MEAL FED TO LAYING HENS

ABSTRACT

An experiment was conducted to evaluate a new increased protein: reduced fiber test canola meal compared to conventional canola meal in laying hen diets from 33 to 49 weeks of age. Seven dietary treatments were replicated eight times using 14 caged hens per replicate. Corn-soybean meal diets contained either no canola meal or 8, 16, or 24% test canola meal or conventional canola meal. All diets were formulated to be equal in ME_n and digestible amino acids. No significant differences were observed ($P>0.05$) among treatments for body weight, egg production, egg weight, egg mass, feed intake, or feed efficiency when these parameters were evaluated over the duration of the experiment. These results indicate that diets containing up to 24% test or conventional canola meal can be fed to laying hens without having detrimental effects on hen performance or egg quality if diets are formulated to be equal in ME_n and digestible amino acids.

Key words: laying hen, test canola meal, conventional canola meal, egg production, egg mass

INTRODUCTION

Canola meal (CM) is a readily available feed ingredient for livestock feeding. However, in North America, the use of high levels of CM in poultry diets is not prevalent due to past problems associated with feeding rapeseed meal. Rapeseed meal reduces feed intake (Leslie and Summers 1972), weight gain (Pekerten and Ergul 1981) and egg production (Leslie and Summers 1972; Ergun 1983). Jackson (1969) determined that feeding rapeseed meal at levels of

up to 20% of the diet produced high mortality as a result of liver hemorrhaging. Summers et al. (1971) observed that inclusion of rapeseed meal at relatively high levels of 26% in laying hen diets may be detrimental to the normal physiological function of the hen. However, most of the work reported above used rapeseed varieties that were high in antinutritional factors such as erucic acid and goitrogens. The newer varieties of CM do not cause deleterious effects as the older rapeseed varieties although the ingredient is still rarely used in the diets of brown-shelled egg layers due to a recessively inherited mutation that causes fishy-egg tainting (Ward et al., 2009). However, the use of CM rather than rapeseed meal has reduced but not totally eliminated the liver hemorrhage problem in laying hens (Campbell and Slominski 1991). The results of one study indicate that there are no negative effects of replacing up to 30% of the dietary soybean meal with CM in laying hen diets (Albino et al. 1982). In another study that used very low glucosinolate CM (0.53 μmol/g) in laying hen diets as the sole protein supplement at 24 to 25% of the diet, a high level of egg production was maintained, which was similar to that obtained from feeding a soybean meal control diet. Additionally, liver and thyroid sizes remained normal and mortality due to liver hemorrhage was not observed (Campbell and Slominski, 1991). New yellow-seeded (*Brassica napus)* varieties contain lower levels of glucosinolates and fiber as well as having higher levels of protein (Simbaya et al., 1995; Slominski et al., 1999; Slominski et al., 2012). The new yellow-seeded varieties have a larger seed and thinner hull, than their traditional black-seeded relatives *Brassica napus* (Khajali and Slominski, 2012). The yellow-seeded CM varieties, however, have not been successful due to their agronomic problems (Rakow et al., 2007). The current study was undertaken to investigate the effects of a new high protein: reduced fiber test CM compared to conventional CM on performance and egg quality in laying hen diets from 33 to 49 weeks of age.

MATERIALS AND METHODS

All animal procedures were approved by the University of Illinois Institutional Animal Care and Use Committee (IACUC).

Diets and Experimental Design

Seven hundred eighty-four Hy-Line® W-36 White Leghorn laying hens were randomly assigned to one of seven dietary treatments from 33 to 49 weeks of age. The hens were housed in a completely enclosed, ventilated caged-layer building in which the daily photoperiod was 17 hours of light and 7 hours of dark. The experiment was initiated in December of 2013 and completed in March of 2014. Hens were assigned to dietary treatments so that mean body weights were not different for all treatments. Each experimental diet was fed to 8 replicate groups of 14 hens. A replicate consisted of two adjacent cages of seven hens per cage and each cage measured approximately 58 x 61 cm. Hens were provided ad libitum access to feed and water. The composition of each diet is provided in Table 4.1. The first treatment consisted of a control corn-soybean meal diet with no CM. Treatments 2-4 consisted of the test CM at 8%, 16%, or 24% inclusion in the diet, respectively. Diets 5-7 consisted of conventional CM at 8%, 16%, or 24% inclusion in the diet, respectively. The test CM and conventional CM were the same as those used in broiler Experiment 2 of Chapter 3. The test CM had a higher ME, increased crude protein, and reduced fiber compared to that of the conventional CM but both were lower in energy and crude protein and higher in fiber than soybean meal. The test CM was also higher in ileal digestible amino acids than the conventional CM. To keep the diets isocaloric and equal in digestible amino acids, soy oil and synthetic amino acids were used. Soy oil levels increased as the level of CM increased due to the fact that CM was primarily replacing

dietary soybean meal which is higher in energy and protein. In addition, inclusion of synthetic DL-methionine decreased as CM inclusion increased.

Body weights of the hens were measured at the beginning and end of the experiment. Egg production and mortality were recorded daily. Egg weight, egg mass (g egg/hen/day), feed consumption, and feed efficiency (g egg/g feed) were measured every two weeks. Egg specific gravity was measured using the flotation method every four weeks for all eggs produced by each replicate group of hens from the previous day. The eggs were submerged in a basket into varying salt solutions ranging from 1.068 to 1.091 specific gravity. At the end of the experiment, 5 hens from each dietary treatment were randomly selected and euthanized with CO_2 gas. The livers were removed and observed for fatty liver syndrome or liver hemorrhaging.

Statistical Analysis

All data were analyzed by analysis of variance procedures for a one-way completely randomized design using PROC GLM of SAS® (SAS Institute, 2010). Egg production during the first two weeks of the experiment for the control diet was found to be 4 percentage units higher ($P<0.05$) than that for hens on all other treatments. Therefore, all results were analyzed using analysis of covariance and all statistical analysis was done on the adjusted means. The egg production for the first two weeks of the trial was used as the covariate in the statistical model.

RESULTS AND DISCUSSION

Hen performance for the duration of the experiment is shown in Table 4.2. There were no differences ($P>0.05$) among treatments for hen-day egg production, egg mass, and feed efficiency. There were also no differences for feed intake or egg weight among dietary

treatments. No differences among treatments for final body weights were observed (Table 4.3). In addition, dietary treatments had no significant effects on the egg quality measures of Haugh units and egg specific gravity (Table 4.3).

The results of the this study demonstrated that the production performance of the laying hens fed diets containing up to 24% CM was not different from that of hens fed a diet containing no CM. Therefore, CM has the potential to replace soybean meal and corn, primarily soybean meal, in laying hen diets without the detrimental effects reported previously. For example, the decrease in feed intake associated with dietary rapeseed and CM (Leslie and Summers 1972; Clandinin and Robblee 1983) was not seen in this study. The results of the present study, however, confirm observations of Albino et al. (1982) and Leeson et al. (1987). Leeson et al. (1987) tested the replacement value of CM for soybean meal in the diets of laying hens. Dietary CM ranged from 6.32 to 25.28% inclusion in the diet which is similar to the present study. Leeson et al. (1987) observed no differences among treatments for egg production, egg weight, eggshell deformation, nutrient retention, or bone mineralization when CM inclusion ranged from 0 to 25% of the diet. Although nutrient retention and bone mineralization were not measured in the present study, similar results for egg production and egg weight were observed. Campbell et al. (1999) observed similar results when low-glucosinolate CM was included up to 20% in the diet for laying hens. No differences were observed among dietary treatments for egg production, feed efficiency, or mortality. Campbell et al. (1999) also observed no differences for thyroid weight, liver weight, thyroid hormone levels, or liver enzyme levels and concluded that low-glucosinolate CM may be used at levels up to 20% in laying hen diets. The results of that study concerning liver evaluation are quite similar to those observed in the present study. Although no data were presented in the current study, it should be noted that 5 hens from each dietary

treatment were euthanized and necropsied to check the condition of the liver at the end of the trial. All of the dietary treatments had some degree of fatty liver including the control diet but there was no observed increase in the severity of fatty liver for hens fed the diets containing either test or conventional CM. Therefore, it is not assumed the fatty liver was caused by the inclusion of CM in the present study.

No studies could be found that investigated the effects of feeding high protein: reduced fiber CM in laying hen diets. Additionally, no studies could be found that compared conventional CM to the new high-protein test CM. The results of the current study again document the increased nutritional and economic value of the new test CM compared to the conventional CM. Due to the higher ME_n and digestible amino acid levels in the test CM, diets containing the test CM had lower levels of supplemental oil and soybean meal than the same respective diets that contained conventional CM. It is concluded from this study that either test CM or conventional CM can be included in laying hen diets at levels of 24% or lower without any detrimental effects on performance, egg quality, or body weight if diets are formulated to be equal in ME_n and digestible amino acids.

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TABLE 4.1. Ingredient and nutrient compositions of the experimental diets provided to laying hens[1] for 16 weeks

	Dietary Treatments[2]						
Ingredients	1	2	3	4	5	6	7
				(%)			
Corn	62.94	61.78	59.05	56.34	60.25	56.13	51.97
Soybean meal	23.62	16.52	10.76	5.00	17.58	12.79	8.04
Test canola meal	-	8.00	16.00	24.00	-	-	-
Conventional canola meal	-	-	-	-	8.00	16.00	24.00
Soy oil	1.40	1.84	2.51	3.17	2.30	3.41	4.52
Limestone	9.52	9.50	9.48	9.46	9.50	9.47	9.44
Dicalcium phosphate	1.34	1.25	1.15	1.05	1.25	1.14	1.04
Salt	0.44	0.41	0.39	0.36	0.41	0.38	0.35
Vitamin mix	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Trace mineral mix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.18	0.12	0.10	0.07	0.13	0.11	0.09
L-lysine HCl	0.08	0.11	0.09	0.08	0.11	0.10	0.08
Choline chloride	0.08	0.07	0.07	0.07	0.07	0.07	0.07
Phytase[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Calculated composition, as-fed basis							
ME, kcal/kg	2845	2845	2845	2845	2845	2845	2845
Crude protein, %	16.48	16.54	17.11	17.68	16.53	17.07	17.63
Calcium, %	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Available phosphorus, %	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Ileal digestible Met + Cys, %	0.66	0.67	0.72	0.78	0.66	0.70	0.73
Ileal digestible Lys, %	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Ileal digestible Thr, %	0.55	0.55	0.57	0.58	0.55	0.57	0.59

[1]Hy-Line W-36 hens started at 33 weeks of age.

[2]Diet 1 contained no canola meal; Diet 2 contained 8% test canola meal; Diet 3 contained 16% test canola meal; Diet 4 contained 24% test canola meal; Diet 5 contained 8% conventional canola meal; Diet 6 contained 16% conventional canola meal; Diet 7 contained 24% conventional canola meal.

[3]Optiphos®, Huvepharma, Sofia, Bulgaria. Supplied 500 FTU/kg of diet.

TABLE 4.2. Effects of dietary canola meal on hen performance[1]

Dietary treatments[2]	Feed intake (g/hen/d)	Hen-day egg production (%)	Egg weight (g/egg)	Egg mass (g/egg/hen-day	Feed efficiency (g egg/g feed)
0% CM	98.0	87.3	60.1	52.5	0.535
8% Test CM	97.4	87.1	59.9	52.2	0.536
16% Test CM	97.1	86.4	59.5	51.4	0.529
24% Test CM	97.1	85.5	59.8	51.1	0.527
8% Conventional CM	97.6	86.9	59.7	51.9	0.531
16% Conventional CM	98.0	86.4	59.9	51.7	0.528
24% Conventional CM	97.0	87.5	59.9	52.5	0.541
Pooled SEM	1.16	0.65	0.35	0.48	0.0046
P-value	0.9896	0.3252	0.9222	0.1792	0.4601

[1]Dietary treatments were fed from 33-49 wk of age. Values represent least squares means of 8 replicates of 14 hens per treatment.
[2]CM = canola meal.

TABLE 4.3. Influence of dietary canola meal on hen body weights and egg quality measures[1]

	Hen weight (g/hen)			Haugh units	Egg specific gravity
Dietary treatments[2]	Initial	Final	Weight gain		(g/cm^3)
0% CM	1476	1558	82	76.9	1.0824
8% Test CM	1469	1526	57	75.9	1.0822
16% Test CM	1469	1588	119	76.2	1.0819
24% Test CM	1467	1569	102	74.3	1.0810
8% Conventional CM	1468	1543	75	76.2	1.0817
16% Conventional CM	1470	1597	127	77.3	1.0815
24% Conventional CM	1474	1579	105	75.1	1.0817
Pooled SEM	16.4	24.9	20.2	1.2	0.0005
P-value	0.9996	0.4207	0.1933	0.5797	0.5417

[1]Dietary treatments were fed from 33-49 wk of age. Values represent least squares means of 8 replicates of 14 hens per treatment.
[2]CM = canola meal.

CHAPTER 5

CONCLUSIONS

The experiments included in this thesis evaluated the nutritional value of a new high-protein: reduced fiber test canola meal compared with conventional canola meal or soybean meal in the diets of broiler chickens and laying hens. The test canola meal contained a higher level of crude protein and less fiber when compared with the conventional canola meal. However, both canola meals were lower in crude protein and higher in fiber when compared to soybean meal.

From the first experiment, conducted with broiler chickens, it is concluded that canola meal levels in excess of 10% in the starter diet had negative effects on growth performance. Due to the large growth depression at the higher levels of canola meal in the starter phase, the chickens had reduced performance throughout the remainder of the trial. The results of this experiment led to the experimental design of Experiment 2.

From the second experiment, conducted with broiler chickens, it is concluded that either the new test or conventional canola meal can be included at up to 8% in the starter diet and up to at least 24% in the grower diets without any adverse effects on body weight gain, feed intake, feed efficiency and mortality when the diets are formulated to be equal in ME_n and digestible amino acids. No differences were observed between the birds that received canola meal in the diet and the control corn-soybean meal diet.

From the third experiment, conducted with laying hens, it is concluded that either test canola meal or conventional canola meal can be included in laying hen diets at levels of at least 24% without detrimental effects on production, egg quality, or body weight when the diets are formulated to be equal in digestible amino acids and ME_n.

Results of these experiments indicate that the new high-protein: reduced fiber test canola meal has both nutritional and economic value. Equal growth performance in broiler chickens and production in laying hens can be achieved when using canola meal compared with using soybean meal. The canola meal can be used as a protein source in the diets of broiler chickens and laying hens when the diets are formulated to be equal in ME_n and digestible amino acids.